AECOM

Business Case for Resilience in Southeast Florida

August 2020

Final Draft for Release

Prepared for:

Urban Land Institute
Southeast Florida Regional Climate Change Compact
Florida Department of Environmental Protection

Prepared by:

AECOM
Sustainable Economics Practice
Buildings + Places, Design and Consulting Services
300 California Street
San Francisco, CA, 94104 USA
aecom.com

This report was funded in part, through a grant agreement from the Florida Department of Environmental Protection, Florida Resilient Coastlines Program, by a grant provided by the Florida Coastal Office, as well as contributions by Southeast Florida Regional Climate Change Compact partners, including Broward County, Miami-Dade County, and Palm Beach County. The views, statements, findings, conclusions and recommendations expressed herein are those of the author(s) and do not necessarily reflect the views of the State of Florida or any of its subagencies, or the counties mentioned above.

August 2020

Table of Contents

Figures

Tables

General Limiting Conditions

AECOM devoted effort consistent with (i) the level of diligence ordinarily exercised by competent professionals practicing in the area under the same or similar circumstances, and (ii) the time and budget available for its work, to have the data contained in this report be accurate as of the date of its preparation. This study is based on estimates, assumptions and other information developed by AECOM from its independent research effort, general knowledge of the industry, and information provided by consultations with the client and the client's representatives. No responsibility is assumed for inaccuracies in reporting by the Client, the Client's agents and representatives, or any third-party data source used in preparing or presenting this study. AECOM assumes no duty to update the information contained herein unless it is separately retained to do so pursuant to a written agreement signed by AECOM and the Client.

AECOM's findings represent its professional judgment. Neither AECOM nor its parent corporation, nor their respective affiliates, makes any warranty, expressed or implied, with respect to any information or methods disclosed in this document. Any recipient of this document other than the Client, by their acceptance or use of this document, releases AECOM, its parent corporation, and its and their affiliates from any liability for direct, indirect, consequential or special loss or damage whether arising in contract, warranty (express or implied), tort or otherwise, and irrespective of fault, negligence and strict liability.

This report may not to be used in conjunction with any public or private offering of securities, debt, equity, or other similar purpose where it may be relied upon to any degree by any person other than the Client. This study may not be used for purposes other than those for which it was prepared or for which prior written consent has been obtained from AECOM subject to the grant conditions as noted below.

Possession of this study does not carry with it the right of publication beyond those allowed by the grant conditions noted below or the right to use the name of "AECOM" in any manner without the prior written consent of AECOM. No party may abstract, excerpt or summarize this report without the prior written consent of AECOM. AECOM has served solely in the capacity of consultant and has not rendered any expert opinions in connection with the subject matter hereof. Any changes made to the study, or any use of the study not specifically identified in the agreement between the Client and AECOM or otherwise expressly approved in writing by AECOM, shall be at the sole risk of the party making such changes or adopting such use.

AECOM acknowledges the State's rights to use and reproduce this report and the public records duties as outlined per Attachment 4 and Attachment 6, Section 4 of Florida Department of Environmental Protection grant agreement R1918. The Florida Department of Environmental Protection reserves a royalty-free, nonexclusive, and irrevocable license to reproduce, publish or otherwise use, and to authorize others to use, for federal and state government purposes: the copyright in any work developed under a grant or contract under a grant, and any rights or copyright to which a grantee or a contractor purchases ownership with grant support and all patent rights, copyrights and data rights must be in accordance with 2 CFR §200.315 and 37 CFR Part 401, as applicable.

This document was prepared solely for the use by the Client. No party may rely on this report except the Client or a party so authorized by AECOM in writing (including, without limitation, in the form of a reliance letter). Any party who is entitled to rely on this document may do so only on the document in its entirety and not on any excerpt or summary. Entitlement to rely upon this document is conditioned upon the entitled party accepting full responsibility and not holding AECOM liable in any way for any impacts on the forecasts or the earnings from (project name) resulting from changes in "external" factors such as changes in government policy, in the pricing of commodities and materials, price levels generally, competitive alternatives to the project, the behaviour of consumers or competitors and changes in the owners' policies affecting the operation of their projects.

This document may include "forward-looking statements". These statements relate to AECOM's expectations, beliefs, intentions or strategies regarding the future. These statements may be identified by the use of words like "anticipate," "believe," "estimate," "expect," "intend," "may," "plan," "project," "will," "should," "seek," and similar expressions. The forward-looking statements reflect AECOM's views and assumptions with respect to future events as of the date of this study and are subject to future economic conditions, and other risks and uncertainties. Actual and future results and trends could differ materially from those set forth in such statements due to various factors, including, without limitation, those discussed in this study. These factors are beyond AECOM's ability to control or predict. Accordingly, AECOM makes no warranty or representation that any of the projected values or results contained in this study will actually be achieved.

This study is qualified in its entirety by, and should be considered in light of, these limitations, conditions and considerations.

Executive Summary

Developing an understanding of the economic consequences from current and future coastal hazards is critical to informing decisions about how to protect the communities, businesses, and natural resources that make coastal communities in Southeast Florida a world-class destination for life, work, and leisure. This information is especially relevant to communities whose economies are heavily dependent on beach tourism and marine-service industries and associated property and sales tax revenues. Florida faces the highest cost in the nation to adapt infrastructure to protect coastal communities from rising seas, estimated by a recent study at $76 billion statewide by 2040 (The Center for Climate Integrity Resilient Analytics, 2019).

This report presents estimates of the economic consequences to coastal communities in Southeast Florida from failing to take action to mitigate the impacts from high-frequency coastal storms and sea level rise, as well as the economic benefits from adaptation actions designed to mitigate these coastal hazard risks. The research presented in this study builds on past work completed in the region by leveraging a robust economic modeling tool (i.e., REMI) to estimate cascading economic impacts at multiple geographic scales. As illustrated in this report, coastal storms and sea level rise can have wide-ranging direct, indirect and induced effects that extend beyond the borders of any one community.

In addition to considering the costs and benefits of adaptation strategies intended to reduce coastal hazard risks, it is also important to more broadly consider the opportunities for advancing economic resilience in the Southeast Florida communities that are subject to these risks. In the context of this study, economic resilience accounts for the ability of communities and the region to: (1) prepare for and withstand coastal hazard risks, and (2) respond and recover when these risks manifest. This study illustrates that advancing economic resilience requires action by both the public and private sector at various geographic scales, and that there is a shared interest for both communities to partner on this front.

Each coastal community in Southeast Florida has its own unique set of challenges to confront (not limited to coastal hazards) and varying amounts of resources to address these challenges. At the same time, coastal communities in the region share many similar characteristics, especially with respect to their primary industries and revenue sources. To advance economic resilience at the regional scale, it will be important to avoid a Balkanization approach to adaptation that fails to account for the complex interdependencies between local and regional economies, and the critical role that regional infrastructure plays in promoting robust and resilient economies.

Summary Findings

This study attempts to answer a number of questions related to the economic risks posed by high-frequency coastal storms and sea level rise as well as the potential benefits to be gained by investing in adaptation. A multi-step modeling approach was undertaken to estimate results. The first stage of the analysis involved an assessment of *primary consequences*, which accounts for direct impacts to property and assets that are exposed to the modeled coastal hazard conditions. The second stage of the analysis involved an assessment of *secondary consequences*, which accounts for economy-wide direct as well as indirect (e.g., supply chains) and induced (e.g., worker and household spending) economic impacts. As discussed later in this report, there is some level of overlap between the primary and secondary consequence analyses, with the secondary analysis incorporating outputs from the primary analysis. For example, lost output associated with a business that is subject to storm damage and has to temporarily close to undergo repairs is a primary consequence metric. This metric is then incorporated into the REMI model to estimate lost gross domestic product (GDP), which accounts for both output and intermediate inputs in a defined economic geography.

A variety of impact metrics or indicators have been evaluated in this study, including real and personal property impacts (e.g., structures, contents) as well as economic impacts (e.g., business output, jobs) and fiscal impacts (e.g., property taxes, sales taxes). A common mistake when conducting a comparative analysis of the benefits and costs for a policy, program or project is to conflate social welfare impacts, economic impacts, and fiscal impacts. Benefit-cost analysis (BCA) is focused on accounting for the primary effects to society at large. Economic impact analysis is focused on evaluating changes in economic activity in a defined region, including secondary direct, indirect and induced effects. Fiscal impact analysis is focused on assessing financial effects to governments in a defined region. Each of these analysis types provide meaningful information to decision-makers, but they fundamentally address different questions. *As such, the results for each impact assessment should not be added together.*

To develop an understanding of the costs and benefits of adaptation, impact metrics commonly incorporated in federal agency BCAs (e.g., USACE, FEMA) were evaluated. In particular, primary consequences associated with real and personal property under a no action scenario were estimated and compared to the costs and benefits of systemic (e.g., seawall, dunes) and building-level (e.g., elevate structure, floodproof structure) adaptation strategies. Table 1 and Table 2 show estimates for the cumulative impacts avoided and cumulative cost of adaptation, net impacts and resulting benefit-cost ratios for the systemic (e.g., seawalls, dunes) and building-level (e.g., elevate structure, floodproof structure) adaptation strategies.

Table 1. Systemic Adaptation Strategy Return on Investment for Direct Property Primary Consequences (Net Present Value, $Millions)

County	Cumulative Impacts Avoided	Cumulative Adaptation Costs	Net Impacts	Benefit-Cost Ratio
Broward	$9,601	$4,128	$5,473	2.33
Miami-Dade	$19,461	$2,101	$17,360	9.26
Monroe	$3,182	$7,669	-$4,487	0.41
Palm Beach	$5,613	$4,325	$1,288	1.30
Total	**$37,857**	**$18,223**	**$19,634**	**2.08**

Notes:

Results account for structure, content, land and relocation impacts.

Results are presented in net present value terms using a 5 percent discount rate over the period of the analysis from 2020 to 2070.

Table 2. Building-Level Adaptation Strategy Return on Investment for Direct Property Primary Consequences (Net Present Value, $Millions)

County	Cumulative Impacts Avoided	Cumulative Adaptation Costs	Net Benefits	Benefit-Cost Ratio
Broward	$4,541	$1,495	$3,046	3.04
Miami-Dade	$9,255	$1,786	$7,469	5.18
Monroe	$459	$598	-$139	0.77
Palm Beach	$3,312	$545	$2,767	6.08
Total	**$17,567**	**$4,424**	**$13,143**	**3.97**

Notes:

Results account for structure, content, land and relocation impacts.

Results are presented in net present value terms using a 5 percent discount rate over the period of the analysis from 2020 to 2070.

For both the systemic and building-level adaptation strategies, the benefits outweigh the costs for all counties except Monroe. This does not necessarily imply that adaptation is not a cost-effective investment for Monroe County. Rather, based on the high-level model assumptions, non-exhaustive impact categories evaluated, and financial discount rate incorporated, the outcomes were not proven to be economically justified for Monroe. To this end, future analysis should be conducted on a project-by-project basis, in Monroe County as well as in the other Southeast Florida counties, to better design and optimize the benefits that can result from investment in adaptation.

It is important to note that the systemic and building-level strategies are intended to be evaluated separately, with a few caveats. The systemic strategies would provide broader economic benefits than the building-level strategies as they would help reduce impacts to both property and infrastructure that are critical for economic activity (e.g., transportation networks), and would also help to maintain the profiles of beaches that support a vibrant tourism-related economy. The building-level strategies are focused on providing protection to individual structures. This protection is limited to coastal storms and does not provide protection against permanent sea level rise. These strategies would not convey benefits to transportation corridors, nor would they help to maintain the counties' coastal resources that provide significant recreational and aesthetic benefits and economic value.

While not quantified in this report due to a variety of uncertainties, both the systemic and building-level adaptation strategies could help to minimize the devaluation of real estate in the future. This would help to mitigate a variety of cascading effects such as foregone property taxes, increased cost and/or barriers to access insurance coverage and mortgage financing, loss of wealth and/or income for property and business owners, and downgrades to municipal bond ratings (MGI 2020). These effects from real estate devaluation could fundamentally alter the desirability of living and working in coastal communities, which in turn could result in the redistribution of populations and public and private investment, and long-term impacts to local, regional and state economies.

Another key benefit of the systemic adaptation strategy is that it will protect property from the modeled gradual sea level rise conditions. This study assumes property that is exposed to daily high tides in the future would no longer be considered a functional asset and would lose the entirety of its market value. As a result, failure to safeguard property from rising seas could result in significant property tax revenue losses. These monies are critical to local governments and any reductions to this revenue stream could hinder the ability of the public sector to fund its operations and invest in core community services and infrastructure, including adaptation. Table 3 shows the estimated property tax revenues that could be lost over the next half century, based off property identified to be vulnerable to the modeled daily high tide conditions. The reported investment costs for systemic adaptation in Table 1 would help to safeguard these revenues.

Table 3. Cumulative Property Tax Impacts from Permanent Sea Level Rise (MHHW) (2019 Dollars, $Millions)

County	Property Tax Impacts by Decade					
	2020 - 2030	2030 - 2040	2040 - 2050	2050 - 2060	2060 - 2070	Total
Broward	$12	$20	$34	$138	$620	$825
Miami-Dade	$114	$215	$249	$466	$1,345	$2,388
Monroe	$9	$22	$41	$142	$460	$674
Palm Beach	$9	$11	$24	$87	$418	$548
Total	**$144**	**$268**	**$348**	**$833**	**$2,843**	**$4,435**

Notes:

Results are not adjusted to account for financial discounting.

Investments in adaptation can provide benefits beyond the avoided impacts shown in Table 1 and Table 2. For example, monies used to construct a seawall will result in direct job gains for the construction industry, as well as downstream indirect (e.g., supply chain) and induced (e.g., worker and household spending) job gains. These cascading economic impacts, shown in Table 4, were modeled using REMI PI+, accounting for adaptation cost estimates and public and private spending assumptions.

Table 4. Economic Benefits from Investment in Adaptation (2019 Dollars, $Millions)

Economic Indicators	Systemic Adaptation	Building-Level Adaptation
	Combined Difference from Baseline	*Combined Difference from Baseline*
Broward County		
Job Years	12,060	17,540
GDP	$1,440	$2,210
Miami-Dade County		
Job Years	24,750	21,660
GDP	$2,980	$3,020
Monroe County		
Job Years	28,600	8,160
GDP	$2,070	$710
Palm Beach County		

Economic Indicators	Systemic Adaptation	Building-Level Adaptation
	Combined Difference from Baseline	*Combined Difference from Baseline*
Job Years	19,380	8,290
GDP	$1,900	$1,000

Notes:

Jobs rounded to nearest 10.

GDP rounded to nearest $10 million.

Job years is equivalent to one year of work for one person – for example: a new construction job that lasts two years will equate to two job years.

Results are not adjusted to account for financial discounting.

Advancing Economic Resilience

Investment in actions that can reduce coastal hazard risk and support adaptation to changing conditions can help to protect people, property, businesses, and infrastructure, and reduce the amount of resources and investment needed to respond to and recover from coastal hazard events over the long term. Overall, investing in adaptation now can result in a positive economic return for the region.

A primary goal of investing in economic resilience is to ensure that when coastal hazard events do occur, the shocks are manageable and not disruptive. However, while protective investments can help to minimize the shocks from coastal hazards, they will not address underlying chronic stresses present in local and regional economies (e.g., social equity, poverty, unemployment, lack of industry diversification) that will affect the capacity of communities to respond to and recover from immediate and more distant coastal hazard risks. Therefore, communities should attempt to identify the structural factors that will affect their ability to be resilient to changing conditions. This includes developing an understanding of the strengths and weaknesses of local and regional economies, and the opportunities for improving business-as-usual practices so communities do not just survive but are best positioned to thrive.

Strategies that communities in the Southeast Florida region can take to evaluate and advance their capacity for economic resilience are summarized below.

Increase Climate Risk Awareness: Fundamental to resilience is increasing climate risk awareness. Information about climate change risks and their knock-on effects is not incorporated into most policies that govern public and private institutions. As a result, risky behavior is often incentivized and/or subsidized. Both the public and private sector have a role to play in risk disclosure, through policies such as mandatory seller disclosure forms, loan terms, and technical assistance programs.

Invest in Key Vulnerable and Emerging Industries: Efforts should be made to protect vulnerable industries and promote economic diversification and innovation in the region. Underlying industry vulnerabilities can stem from operating in close proximity to the coast and from the interdependencies between industries. It is of critical importance that businesses are in a position to continue their operations in as close to a business-as-usual environment when coastal hazards occur. To do this, businesses should act now to develop business continuity plans that account for potential physical and economic impacts as well as responses and recovery mechanisms. Southeast Florida contains clusters of related businesses and industries that make the region competitive for jobs and private investment. Investing in adaptation that provides a direct benefit to ocean or coastal-related economic clusters present will have cascading positive impacts for regional resilience. Emerging economic clusters should also be identified and invested in, including industries in cleantech, life sciences, and information technology. Early investments in research and development can help with long-term economic opportunity for adaptation innovation-related industries, where a number of the solutions and problems to be solved remain unknown.

Develop an Occupational Roadmap to Resilience: Certain workers may be more vulnerable to coastal hazards, such as workers in vulnerable industries, workers with less adaptable skillsets, lower wage workers, and workers who travel far to get to work. At the same time, recovery efforts and adaptation investments will favor certain occupations over others, such as emergency responders and construction workers. Communities should develop coordinated workforce and economic development initiatives to grow the local labor pool capable of providing the services needed to prepare for and recover from coastal hazard events to keep more recovery funds in impacted communities, decrease the burden on supportive infrastructure, expand job skills training and potential future income earning potential, and provide faster recovery after an event.

Engage with and Provide Support to the Small Business Community: Small businesses generally have fewer resources to develop an understanding of coastal hazard risks and to make detailed plans to assist in response and recovery when coastal hazards occur. When small businesses are subject to the impacts of coastal hazards, they often lack the capital reserves, access to financing, or insurance coverage necessary to absorb a loss of income and the additional expenses that come with rebuilding. Streamlined access to capital and financing is critical to ensuring continued operations and related financial outcomes. Engaging with small businesses may be difficult given competing demands but improved communications through digital platforms can help to exchange information both within business communities and between the public and private sector.

Strategically Prioritize Projects and Monitor Efficacy: Given the finite financial resources available for adaptation, communities and regions will be faced with difficult decisions on where investment should be directed, what types of adaptation projects should be pursued, when these investments should be made, and how much money should be borrowed to accelerate investments in resilience in a way that is commensurate with expected risks. Projects should be prioritized through transparent evaluation frameworks that address existing societal vulnerabilities and that maximize project benefits. The project planning approach should be holistic - plans for economic development, workforce development, land-use, capital improvements and hazard mitigation should be aligned where feasible. Community lifelines, such as energy, water, transportation, and communications infrastructure, should be protected to avoid far-reaching direct and indirect consequences. To ensure that future adaptation projects provide their intended return on investment, the effectiveness of implemented adaptation strategies should be evaluated where feasible.

Develop Actionable Funding and Financing Plans to Pay for Resilience: The risks posed by a changing climate are too great for any one sector to take on alone, and the benefits provided by making investments in climate resilience are shared across sectors. As such, considerations on how to fund and finance adaptation and resilience should be made with an eye towards all of the entities that would benefit from such investments, from both public and private sector actors, as well as the capacity for specific individuals and populations to bear the burden of these costs.

Other Key Considerations & Recommendations

Social Vulnerability: This study has focused on producing monetary results that can lend to the interpretation of the costs and benefits conveyed by adaptation compared to inaction. While these reporting metrics are indicators of economic vulnerability, they do not explicitly account for community characteristics that can be indicative of social vulnerability. For example, economic disruption for certain workers may have outsized cascading impacts such as lost wages due to a storm resulting in an inability to pay rent. In addition, there are potential far-reaching health consequences that could be caused by disruption of public services (e.g. water or wastewater) that may impact certain populations more than others.

Decision-making around what investments are needed to shore up the risks posed by coastal hazards should not be limited to the potential economic return on investment, or they could lead to increasing inequality and de-prioritizing critical investments in the most vulnerable parts of our community. To broaden decision-making considerations as they relate to investments in adaptation and resilience, communities should consider the use of social vulnerability indices and related tools that can illustrate, in a standardized manner, the relative vulnerability of different populations to a range of shocks and stressors, both human and natural caused. These resources incorporate a number of indicators (e.g., age, poverty, vehicle access) that can help to illuminate the social vulnerability of a community and its potential to be resilient in the face of disaster. The most widely used social vulnerability index was developed for the Centers for Disease Control and Prevention (CDC[1]) to assist planners and public health officials in readying themselves for natural disasters, disease outbreaks and exposure to toxic chemicals, though a number of domain-focused social vulnerability indices have been developed by federal, state, academic and non-profit entities.

Opportunity Costs: This study models a suite of adaptation strategies and includes assumptions about how these investments are funded. Systemic adaptation strategies, like building a seawall, are assumed to be funded with both public and private dollars. Whether the source be grant funds from the state or local property and sales taxes, it is important to acknowledge that there is an opportunity cost to using these monies to pay for adaptation.

[1] https://svi.cdc.gov/

Regardless of who pays for adaptation, there is a tradeoff to using these funds for this purpose versus other community or personal needs. Local and regional governments as well as property and business owners face challenges in paying for existing needs such as housing, public health, or insurance. To this end, monies used to pay for adaptation can result in a decline in investment resources that could be directed to other goods or services. This consideration makes it critical that investments in adaptation provide co-benefits to people, the economy, and the environment.

Reputational Risks and Associated Impacts: Vulnerability to coastal hazards now and in the future can result in reputational risks and associated impacts such as: property devaluation, insurance premium increases, bond rating downgrades / increased borrowing costs, decreased tourism and associated spending, decreased public support (which can hinder future efforts to raise funds in support of mitigation), and risk from increased liability. Quantifying reputational damages relies on understanding the financial fundamentals of risk as well as the less studied and harder to quantify behavioral *perceptions* of risk which reflect considerations of the performance of policies, systems, and infrastructure. Modeling reputational impacts, such as perceptions of future climate change risk, was beyond the scope of this analysis. Yet these are important and relevant considerations when interpreting the potential outcomes of the modeled project alternatives. Future research and analysis may provide additional quantitative insights into variations to this approach, and if this occurs, these findings should be updated.

1. Introduction

1.1 Study Overview

The Southeast Florida community, under the auspices of the Southeast Florida Regional Climate Change Compact, undertook this study to answer key questions and close identified gaps in the regional economic evaluation of flood risk and exposure, with the specific inclusion of sea level rise. The Urban Land Institute was selected to guide the development of this study, with on-the-ground project management support by Brizaga and technical economic modeling assistance from AECOM.

The economics of sea level rise, flooding, and resilience are an essential component of encouraging continued action to address the challenges facing communities in Southeast Florida. Beyond the physical implications of rising seas, the economic implications of these impacts are an essential component of making informed decisions on how to invest in adaptation and resilience.

To further understand the business case for resilience, this study explores the following:

- the economic risks of flooding and the augmentation of that risk due to rising sea levels;
- the economic benefit of resilience action as a function of risk reduction and avoided economic losses;
- the economic opportunities associated with resilience investments; and
- recommended strategies to advance community resilience.

Given the large and varied geography of Southeast Florida, replicable analysis techniques and generalized assumptions were incorporated into the analysis, accounting for readily available and regionally standardized physical and economic data. As such, this study represents a high-level evaluation of economic consequences that could occur if no action is taken mitigate coastal hazard risks, as well as the costs and benefits that could result from investment in a subset of adaptation and resilience strategies. The findings are intended to show the importance, both locally and regionally, of continuing efforts to build broad public and private sector support for investment in strategies to confront the economic risks posed by current and future coastal hazards.

1.2 Key Study Concepts & Global Assumptions

Key concepts and global assumptions that support interpretation of the analysis and results detailed in this report are described below.

Impact Geography: This analysis is focused on evaluating economic outcomes to communities in Southeast Florida and the State of Florida. Broward County, Miami-Dade County, Monroe County and Palm Beach County make up the Primary Impact Area, while the State of Florida represents the Secondary Impact Area. Primary economic consequences are modeled for the Southeast Florida counties, the results of which are introduced to the REMI model platform to produce separate secondary economic consequence results for each Southeast Florida county and the State of Florida.

Static Built Environment: This analysis superimposes potential current and future coastal conditions on the existing built environment in Southeast Florida. While it is likely that the built environment in this region of Florida will undergo changes between the present year and the end year of analysis in 2070, it is challenging to accurately model those changes without detailed information on future development plans at the building scale. Incorporating this information into the analysis was not feasible due to data and resource limitations.

Effectiveness and Useful Life of Adaptation Strategies: Each of the adaptation strategies were modeled to provide some level of protection from expected coastal conditions in 2020, 2040 and 2070. These systemic and building-level strategies were modeled using a phased approach whereby the design features meet the specified modeled conditions in future years. For example, constructing a seawall in 2020 that will provide benefits through 2040 that can be further elevated in 2040 to provide protection through 2070. In this example, the benefits provided by the seawall are assumed to begin accruing in the base year of the analysis (i.e., 2020) and continue to accrue until the end year of the analysis (i.e., 2070). It is possible that adaptation strategies could provide some level of benefits after 2070 but this would require additional analysis to quantify. The type of adaptation strategies evaluated provide different levels of proportion from the modeled current and future coastal conditions. For example, systemic strategies (e.g., seawalls) are expected to neutralize nearly all of the modeled impacts, while the building-level strategies (e.g., floodproofing) only results in partial protection. The effectiveness of each strategy modeled is accounted for in the cumulative assessment of costs and benefits of adaptation. Note that it is assumed that best infrastructure management practices are implemented, thereby limiting deferred maintenance and the increased costs that are associated with infrastructure that does not function up to design standards.

Adaptation Strategy Costs: Only the capital investment costs to implement each adaptation strategy are incorporated into this analysis. Additional life cycle costs for maintenance are not included.

Prior Damage: The analysis assumes no cumulative damage from prior storms.

Risk Model Types: There are two primary model types for evaluating hazard risk: *deterministic* models and *probabilistic* models. Deterministic risk models generally account for the effects of a single or event-based scenario; for example, a 10-year storm event in a defined year, such as 2050. Probabilistic risk models account for uncertainty in physical and economic inputs, and include a wide range of scenarios, their likelihood, and the related effects. A deterministic model was primarily used to generate results for this report in part because of the limited number of scenarios and supporting data as well as the structure of the REMI economic impact modeling platform that was used.

Primary Consequence vs Secondary Consequence Modeling: A multi-step modeling process was undertaken to estimate results. To distinguish between these two modeling phases, this study refers to direct impacts to property and assets that are exposed to the modeled coastal hazards as *primary consequences*, while *secondary consequences* is used to account for economy-wide direct, indirect and induced economic impacts. Primary and secondary consequences in some cases can overlap to a degree and should not be added together. For example, lost output associated with a business that is subject to storm damage and has to temporarily close to undergo repairs is a primary consequence metric that is incorporated into the REMI model to estimate lost GDP, which accounts for both output and intermediate inputs in a defined economic geography.

Business Recapture: This study incorporates the assumption that a portion of the business-related sales and wage losses resulting from the modeled coastal hazards can be recaptured. Industry-specific recapture factors developed by FEMA for use in natural hazard assessments were used, accounting for the ability of businesses to shift their operations offsite and/or find ways to increase productivity at a later date. Additionally, there is the potential for other businesses within the same industry that are not directly exposed to the modeled hazards to increase their output to offset losses experienced by impacted firms that are not able to adjust their operations.

Assignment of Temporary vs Permanent Impacts: Results are organized in this report to avoid double counting of impacts. To do this, property and assets exposed to tidal inundation from sea level rise are considered to be permanently impacted and taken out of the assessment of temporary event-based storm impacts, even if the same property and asset may be exposed to storm conditions simultaneously. Permanent impacts captured in this report can include both one-time and recurring annual impacts. For example, a home vulnerable to daily high tides is assumed to have a one-time loss equivalent to the market value of the property, and recurring annual property tax losses.

Results Reporting: Multiple reporting metrics are used to present the findings of the analysis, including:

- *Event-Based Impacts:* This metric reflects the amount of impacts that could be expected if the modeled hazard events were to occur in the Study Area today. Essentially these results reflect the superimposition of future physical conditions on the existing built environment and economy. These results are not adjusted to account for the probability of such an event occurring in the discrete time horizon years.

- *Cumulative Impacts:* The estimated impacts for each year in the period of analysis, which account for the likelihood of the modeled hazards occurring, are summed to develop an estimate of cumulative impacts.
- *Avoided Impacts:* This value represents the difference between the estimated impacts under the No Action scenario to the estimated impacts for the modeled adaptation scenarios. Essentially this metric reflects the amount of impact mitigated as a result of investment in adaptation.

Net Impacts: The net impacts are calculated by subtracting the cumulative present value costs of adaptation from the cumulative present value of benefits (or impacts avoided) conveyed by investing in adaptation. Financial discounting is used to estimate the expected present value costs and benefits.

- *Benefit-Cost Ratio*: The economic justification for the modeled scenarios is presented in the form of a benefit-cost ratio (BCR) whereby the total present value of benefits conveyed by adaptation are divided by the total present value costs of adaptation. When the ratio of benefits to costs is greater than one, an investment can be considered economically justified. For instance, a project would be considered economically justified if the present value benefits are $100,000 and the present value costs are $90,000. The BCR in this context would be 1.1 ($100,000/$90,000).

Discount Rates: Federal guidance generally prescribes that a discount rate ranging from 3 percent to 7 percent can be used in an economic impact analysis of this type. The specific determination of what discount rate to use requires consideration of the nature of the project and how it affects private investment and consumption. For this analysis, a 5 percent discount rate is used to calculate present value of the costs and benefits associated with modeled scenarios unless noted otherwise.

Price Level: All costs and benefits have been normalized and are presented in 2019 dollars, unless noted otherwise.

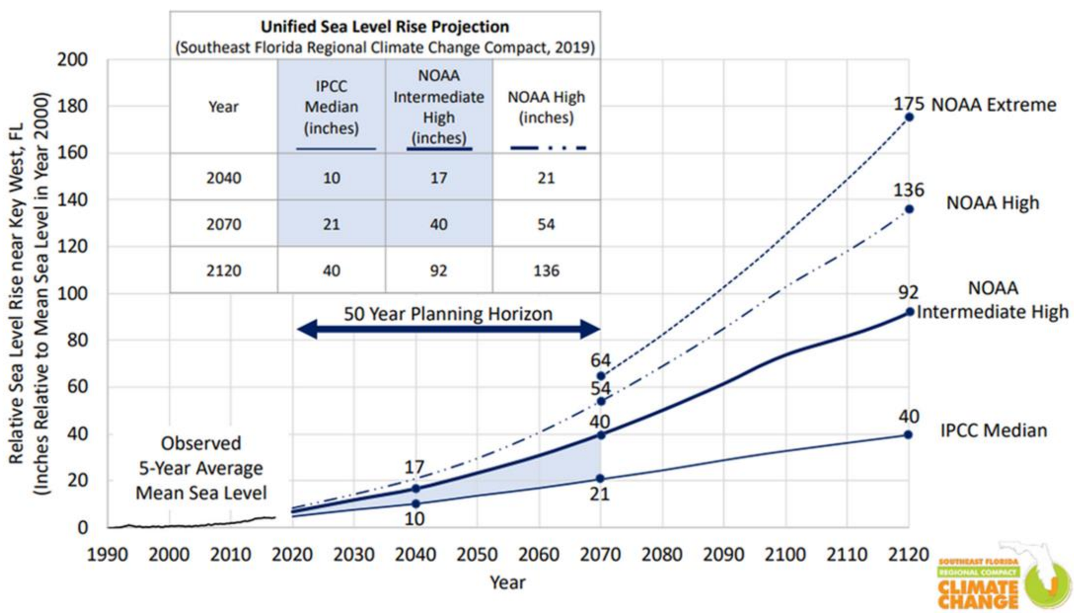
2. Hazard Scenario Selection and Exposure Analysis

This section of the report describes the approach taken to select existing and future coastal water level conditions and related mapping products, which were then used to assess the exposure of property and assets in the region.

2.1 Hazard Scenarios

The Project Team and Compact Partners selected a series of high-frequency coastal conditions, accounting for water levels in 2020, 2040 and 2070. Coastal conditions modeled include the average daily high tide or mean higher high water (MHHW), the 1-year tide or king tide, and the 10-year storm tide. The additive effect of sea level rise in the years of 2040 and 2070 was informed by projections recently developed for the Southeast Florida Climate Change Compact (2019). Specifically, the NOAA Intermediate High scenario was used, as shown in Figure 1. Water levels for these high-frequency coastal conditions were estimated for each Southeast Florida Compact county using the closest NOAA tide station. Additional details on the process undertaken for selecting sea level rise and water level conditions can be found in Appendix A.

Figure 1. Updated Southeast Florida Regional Climate Change Compact Recommended Sea Level Rise Projections



2.2 Exposure Modeling

Exposure mapping was conducted across parcels and core community infrastructure assets that are necessary for life safety or public and private service continuity, or that could pose a significant social consequence if damaged. Selected asset types evaluated generally mirror those that were included in the Southeast Florida Compact Vulnerability Study (2012). Asset exposure was evaluated using readily available mapping layers from the University of Florida's

Sea Level Scenario Sketch Planning Tool. Leveraged mapping layers represent an extension of water surface at the shoreline over inland topography, accounting for a variety of high-frequency storm conditions and sea level rise. The maps are not intended to provide the precise extent and depth of inundation across all the Compact Counties—a more sophisticated hydrodynamic modeling assessment would be required to do this. Rather, the maps provide a means to perform a high-level screening assessment of the timing and extent of potential shoreline overtopping and asset exposure due to rising sea levels.

Table 5 through Table 8 show the results of the GIS exposure analysis by county, accounting for all identified assets that intersect with the coastal condition mapping layers published in the University of Florida's Sea Level Scenario Sketch Planning Tool database. Additional detail on the data sources and methodology used to create the mapping layers, assumptions and caveats important for interpreting the maps, as well as steps taken to conduct the exposure analysis are described in Appendix B.

Table 5. Broward County Exposure Outputs

Feature Type	Time Horizon	MHHW	1-Year Tide	10-Year Tide
Parcels	2020	499	1,799	7,165
	2040	1,131	4,291	27,112
	2070	13,970	33,146	117,657
Ports and Airports	2020	1	2	2
	2040	2	2	2
	2070	2	2	3
Railroads[1] (miles)	2020	0	0	3
	2040	0	3	3
	2070	3	4	9
Major Roadways[2] (miles)	2020	0	1	8
	2040	0	4	37
	2070	18	45	149
Treatment Plants (water, wastewater)	2020	0	0	0
	2040	0	0	0
	2070	0	0	2
Pump Stations (water, wastewater, stormwater)	2020	No Data	No Data	No Data
	2040	No Data	No Data	No Data
	2070	No Data	No Data	No Data
Power Plants and Substations	2020	3	4	6
	2040	3	5	14
	2070	9	15	29
Hospitals	2020	0	0	0
	2040	0	0	5
	2070	0	5	7
Emergency Shelters	2020	0	0	0
	2040	0	0	1

Feature Type	Time Horizon	MHHW	1-Year Tide	10-Year Tide
	2070	1	1	10
Schools	2020	1	3	12
	2040	2	5	30
	2070	16	37	187
Marinas	2020	Data Quality Issue	Data Quality Issue	Data Quality Issue
	2040	Data Quality Issue	Data Quality Issue	Data Quality Issue
	2070	Data Quality Issue	Data Quality Issue	Data Quality Issue
Natural / Open Space Area Parcels (parks, beaches, wetlands)	2020	322	511	641
	2040	468	577	908
	2070	758	957	1,496

Notes:

[1] Excludes abandoned rail and out of service lines

[2] Major Roadways include all functional classes except for local as provided in state-wide data set (functional classes 9 and 19)

Schools and natural / open space area parcels were determined using assessor land use information.

Table 6. Miami-Dade County Exposure Outputs

Feature Type	Time Horizon	MHHW	1-Year Tide	10-Year Tide
Parcels	2020	688	2,977	9,134
	2040	2,977	6,215	26,308
	2070	17,663	29,742	104,228
Ports and Airports	2020	1	3	6
	2040	3	5	8
	2070	7	8	9
Railroads[1] (miles)	2020	0	0	0
	2040	0	0	0
	2070	0	1	8
Major Roadways[2] (miles)	2020	0	10	23
	2040	10	16	70
	2070	44	79	220
Treatment Plants (water, wastewater)	2020	1	3	3
	2040	3	3	3
	2070	3	3	5
Pump Stations (water, wastewater, stormwater)	2020	5	18	42
	2040	18	33	83
	2070	62	96	253
Power Plants and Substations	2020	4	10	12
	2040	10	10	16
	2070	14	18	25
Hospitals	2020	0	0	3
	2040	0	1	7
	2070	3	7	24
Emergency Shelters	2020	No Data	No Data	No Data

Feature Type	Time Horizon	MHHW	1-Year Tide	10-Year Tide
	2040	No Data	No Data	No Data
	2070	No Data	No Data	No Data
Schools	2020	5	8	22
	2040	8	16	79
	2070	49	86	224
Marinas	2020	13	42	108
	2040	42	87	184
	2070	157	189	219
Natural / Open Space Area Parcels (parks, beaches, wetlands)	2020	25	115	223
	2040	115	205	323
	2070	688	2,977	9,134

Notes:

[1] Excludes abandoned rail and out of service lines

[2] Major Roadways include all functional classes except for local as provided in state-wide data set (functional classes 9 and 19)

Schools and natural / open space area parcels were determined using assessor land use information.

Table 7. Monroe County Exposure Outputs

Feature Type	Time Horizon	MHHW	1-Year Tide	10-Year Tide
Parcels	2020	8,406	12,689	22,928
	2040	14,449	22,928	33,467
	2070	42,880	50,493	54,306
Ports and Airports	2020	2	3	4
	2040	3	4	4
	2070	5	5	5
Railroads[1] (miles)	2020	0	0	0
	2040	0	0	0
	2070	0	0	0
Major Roadways[2] (miles)	2020	0	1	5
	2040	1	5	18
	2070	42	65	84
Treatment Plants (water, wastewater)	2020	1	1	1
	2040	1	1	1
	2070	3	3	3
Pump Stations (water, wastewater, stormwater)	2020	0	1	2
	2040	1	2	3
	2070	3	4	4
Power Plants and Substations	2020	1	1	4
	2040	3	4	6
	2070	6	7	7
Hospitals	2020	0	0	3
	2040	2	3	3
	2070	4	4	4

Feature Type	Time Horizon	MHHW	1-Year Tide	10-Year Tide
Emergency Shelters	2020	1	3	9
	2040	3	9	13
	2070	15	15	15
Schools	2020	7	15	33
	2040	15	33	51
	2070	59	62	66
Marinas	2020	40	67	216
	2040	95	216	316
	2070	373	399	410
Natural / Open Space Area Parcels (parks, beaches, wetlands)	2020	4,488	4,842	5,030
	2040	4,923	5,030	5,060
	2070	5,084	5,093	5,094

Notes:

[1] Excludes abandoned rail and out of service lines

[2] Major Roadways include all functional classes except for local as provided in state-wide data set (functional classes 9 and 19)

Schools and natural / open space area parcels were determined using assessor land use information.

Table 8. Palm Beach County Exposure Outputs

Feature Type	Time Horizon	MHHW	1-Year Tide	10-Year Tide
Parcels	2020	314	1,039	3,236
	2040	751	2,161	7,719
	2070	5,353	8,969	18,336
Ports and Airports	2020	0	0	1
	2040	0	1	1
	2070	1	1	1
Railroads[1] (miles)	2020	0	0	0
	2040	0	0	0
	2070	0	0	0
Major Roadways[2] (miles)	2020	0	0	5
	2040	0	3	17
	2070	11	21	46
Treatment Plants (water, wastewater)	2020	0	0	0
	2040	0	0	0
	2070	0	0	0
Pump Stations (water, wastewater, stormwater)	2020	0	0	0
	2040	0	0	0
	2070	0	0	0
Power Plants and Substations	2020	0	0	0
	2040	0	0	1
	2070	0	3	4
Hospitals	2020	0	0	1
	2040	0	0	1

Feature Type	Time Horizon	MHHW	1-Year Tide	10-Year Tide
	2070	1	1	1
Emergency Shelters	2020	0	1	1
	2040	1	1	1
	2070	1	1	1
Schools	2020	0	0	6
	2040	0	4	8
	2070	7	8	12
Marinas	2020	0	4	11
	2040	1	8	29
	2070	15	31	38
Natural / Open Space Area Parcels (parks, beaches, wetlands)	2020	29	81	121
	2040	69	113	140
	2070	131	144	169

Notes:

[1] Excludes abandoned rail and out of service lines

[2] Major Roadways include all functional classes except for local as provided in state-wide data set (functional classes 9 and 19)

Schools and natural / open space area parcels were determined using assessor land use information.

3. Avoided Losses from Investing in Adaptation

This section of the report describes the approach taken to evaluate the losses that could be avoided by investing in adaptation. Avoided loss estimates, which can be considered the equivalent to the benefits provided by adaptation, are informed by a multi-step process as summarized below:

(1) Estimate the consequences to assets directly exposed to the modeled coastal hazard conditions in a no action scenario;

(2) Estimate the consequences to assets directly exposed to the modeled coastal hazard conditions in scenarios where investments in adaptation are made; and

(3) Subtract the estimated consequences in scenarios with adaptation from the estimated consequences in a no action scenario.

Once avoided losses are estimated, these values can be compared to the cost of adaptation to develop an understanding of the return on investment from taking action to mitigate coastal hazard risks.

Avoided losses, and the resulting return on investment conveyed by adaptation, are estimated through a lens of primary consequences that accounts for a subset of effects to assets directly exposed to the modeled hazard conditions and considered appropriate for inclusion in a return on investment analysis. The primary consequences evaluated in the assessment are static in nature, and do not account for the dynamic ways that economies respond to shocks and stresses, both human and nature induced. To account for these complicated economic responses, additional secondary consequences are modeled using the REMI economic impact modeling platform, accounting for direct as well as downstream indirect (e.g., supply chain) and induced effects (e.g., worker and household spending) to the economies of Southeast Florida. *While the secondary consequence results provide additional context for decision-makers, they can overlap to a degree with some of the primary consequences and should not be added together.* For example, lost output associated with a business that is subject to storm damage and has to temporarily close to undergo repairs is a primary consequence metric that is then incorporated into the REMI model to estimate lost GDP, which accounts for both output and intermediate inputs in a defined economic geography. See Section 3.2 for further description on the interrelatedness of primary and secondary consequences.

The steps taken to estimate the avoided losses and the return on investment from adaptation are described below. Return on investment estimates need to account for the cumulative costs and benefits of adaptation over the period of analysis (i.e., from 2020 to 2070). To this end, it was necessary to estimate primary consequences in the discrete analysis years of 2020, 2040 and 2070, interpolate outcomes in between these years, and sum the estimated annual effects from 2020 to 2070.

3.1 Primary Economic Consequences Overview

To inform the assessment of primary economic consequences, the Project Team selected indicators that are commonly evaluated in natural hazard assessments and could reasonably be assessed with the time, resources and data available to support this study. Core to this analysis is the assumption that different types of consequence would occur from temporary storm events (i.e., 1-year tide, 10-year tide) compared to permanent progressive sea level rise (i.e., MHHW or average daily high tide). As such, separate consequence assessment methodologies and indicators were evaluated for these different types of coastal hazard conditions, as shown in Table 9.

Table 9. Consequence Categories and Indicators Evaluated

Consequence Category	Consequence Indicator Temporary Coastal Storms	Consequence Indicator Permanent Sea Level Rise
Direct Property Impacts	Structure damage Content damage Relocation costs	Property value loss
Business and Employment Impacts	Sales output loss Income loss Job loss	Sales output loss Income loss Job loss
Fiscal Impacts	Sales tax loss Tourist development tax loss	Property tax loss Sales tax loss Tourist development tax loss

The methodologies used to assess primary consequences are detailed in Appendix E and primarily draw upon technical guidance documents and economic and planning memoranda developed by federal agencies like the Army Corps of Engineers (USACE) and Federal Emergency Management Agency (FEMA). Much of this technical guidance has been developed to support the considerations of costs and benefits relevant to decision-making around infrastructure investments, specifically actions designed to mitigate the risks from natural hazards.

3.1.1 Primary Economic Consequences Results

Primary consequence results are shown in Table 10 – Table 14. Results are representative of *event-based* impacts that could be expected if the modeled hazard events were to occur in the Study Area today. Essentially these results reflect the superimposition of future physical conditions on the existing built environment and economy. Results are organized so as to avoid double counting of impacts. To do this, property and assets exposed to tidal inundation from sea level rise are considered to be permanently impacted and taken out of the assessment of temporary event-based storm impacts, even if the same property and asset may be exposed to storm conditions simultaneously. Tidal inundation results (i.e., MHHW or daily high tide) account for one-time damages to property and one calendar year of business, employment and fiscal revenue losses. Storm flooding results (i.e., 1-year tide, 10-year tide) represent the losses from a *single* storm and are not adjusted to account for probability of the modeled storm conditions occurring. Permanent sea level rise results are not reported for 2020 model conditions, based on the assumption that assets and property do not currently face measurable risks daily from these coastal conditions.

Note results for future condition impacts can include assets that are determined to be vulnerable in the prior time horizons. However, in some cases, impacts for a similar coastal condition scenario (e.g., 1-year storm) are greater in an earlier time horizon compared to a future time horizon. This is explained by the way in which property or assets that may be at risk to a 1-year storm under 2020 conditions, for example, can become exposed to MHHW under 2040 conditions. While impacts can transfer across the coastal hazard scenarios evaluated over-time, the total impacts for each time horizon would be expected to grow over time. Further, while results are reported as event-based impacts for the modeled daily high tide conditions, both one-time and annual recurring impacts would be expected. For example, a residential property would result in one-time impacts in the form of lost market value, as well as annually recurring property tax impacts.

Table 10. Event-Based Direct Property Impacts, No Action Scenario (2019 Dollars, $Millions)

County	2020 Conditions		2040 Conditions			2070 Conditions		
	1-Year Tide	10-Year Tide	MHHW	1-Year Tide	10-Year Tide	MHHW	1-Year Tide	10-Year Tide
Broward	$0.8	$45.8	$283.6	$8.5	$701.8	$10,009.0	$231.0	$6,319.9
Miami-Dade	$199.0	$409.0	$3,085.6	$40.1	$1,582.2	$23,483.6	$831.1	$8,048.8
Monroe	$0.7	$35.3	$639.2	$17.0	$103.4	$13,501.4	$155.0	$565.9
Palm Beach	$1.5	$37.8	$163.4	$9.5	$871.0	$6,640.5	$159.9	$1,685.6

Notes:
Impacts only account for parcels, both public and private, where 25 percent or more of the parcel footprint is exposed to the modeled coastal conditions.

MHHW results account for one-time impacts equivalent to the just or market value of the parcel. Parcels impacted by MHHW conditions are excluded from 1-year and 10-year tide damages.

Results account for structure, content, land and relocation impacts.

The 1-year and 10-year tide results account for the impacts of one storm event of these magnitudes occurring. The results are not adjusted to account for the probability of the modeled storms occurring.

Results are not adjusted to account for financial discounting.

Table 11. Number of Parcels Subject to Impacts

County	2020 Conditions		2040 Conditions			2070 Conditions		
	1-Year Tide	10-Year Tide	MHHW	1-Year Tide	10-Year Tide	MHHW	1-Year Tide	10-Year Tide
Broward	160	2,046	446	771	10,786	7,590	8,323	58,101
Miami-Dade	33	1,071	1,855	242	9,155	11,269	6,139	41,815
Monroe	172	2,302	11,117	1,962	6,872	35,699	6,719	10,818
Palm Beach	45	552	115	220	2,600	2,010	1,808	8,615

Notes:
Impacts only account for parcels, both public and private, where 25 percent or more of the parcel footprint is exposed to the modeled coastal conditions.

Parcels impacted by MHHW conditions are excluded from 1-year and 10-year tide damages.

The 10-year tide counts include parcels identified to be impacted under the 1-year tide.

Table 12. Event-Based Business and Employment Impacts, No Action Scenario (2019 Dollars, $Millions)

County	2020 Conditions		2040 Conditions			2070 Conditions		
	1-Year Tide	10-Year Tide	MHHW	1-Year Tide	10-Year Tide	MHHW	1-Year Tide	10-Year Tide
Broward County								
Output Loss	$0.0	$0.4	$2.8	$0.0	$17.2	$512.6	$1.4	$70.6
Income Loss	$0.0	$0.7	$5.7	$0.0	$5.0	$184.0	$0.5	$25.0
Job Loss	0	20	110	0	130	3,780	10	580
Miami-Dade County								
Output Loss	$0.4	$5.5	$28.1	$0.3	$14.2	$720.4	$5.3	$65.5
Income Loss	$0.1	$1.7	$18.9	$0.1	$5.0	$306.0	$1.6	$22.3
Job Loss	0	50	420	0	130	6,920	40	540
Monroe County								
Output Loss	$0.0	$0.1	$4.9	$0.0	$0.3	$792.4	$0.4	$7.2
Income Loss	$0.0	$0.0	$11.8	$0.0	$0.3	$240.6	$0.1	$1.6
Job Loss	0	0	180	0	10	5,340	0	40
Palm Beach County								
Output Loss	$0.0	$0.1	$0.2	$0.0	$8.0	$199.4	$0.7	$11.0
Income Loss	$0.0	$0.0	$0.5	$0.0	$3.6	$82.6	$0.5	$4.2
Job Loss	0	0	10	0	90	1,770	10	110

Notes:
Impacts only account for parcels, both public and private, where 25 percent or more of the parcel footprint is exposed to the modeled coastal conditions.

MHHW results account for one year of impacts. These impacts would recur, annually. Businesses impacted by MHHW conditions are excluded from 1-year and 10-year tide damages.

The 1-year and 10-year tide results account for the impacts of one storm event of these magnitudes occurring. The results are not adjusted to account for the probability of the modeled storm occurring.

Results account for recapture as discussed in Appendix E.

Results are not adjusted to account for financial discounting.

Table 13. Number of Businesses Subject to Impacts

County	2020 Conditions		2040 Conditions			2070 Conditions		
	1-Year Tide	10-Year Tide	MHHW	1-Year Tide	10-Year Tide	MHHW	1-Year Tide	10-Year Tide
Broward	7	151	25	43	1,323	2,470	691	10,217
Miami-Dade	60	395	181	39	2,418	4,758	847	10,285
Monroe	5	67	44	50	272	2,537	237	417
Palm Beach	5	57	6	15	801	956	120	1,257

Notes:
Impacts only account for parcels, both public and private, where 25 percent or more of the parcel footprint is exposed to the modeled coastal conditions.

Business impacted by MHHW conditions are excluded from 1-year and 10-year tide damages.

The 10-year tide counts include businesses identified to be impacted under the 1-year tide.

Table 14. Event-Based Fiscal Impacts, No Action Scenario (2019 Dollars, $Thousands)

County	2020 Conditions		2040 Conditions			2070 Conditions		
	1-Year Tide	10-Year Tide	MHHW	1-Year Tide	10-Year Tide	MHHW	1-Year Tide	10-Year Tide
Broward County								
Sales Tax Loss	$0.0	$12.0	$79.1	$0.0	$264.0	$13,650.9	$39.0	$2,826.0
Tourism Tax Loss	$0.0	$5.0	$13.5	$0.0	$38.0	$1,546.3	$1.0	$232.0
Property Tax Loss	NA	NA	$1,024.0	NA	NA	$36,211.0	NA	NA
Miami-Dade County								
Sales Tax Loss	$20.0	$342.0	$1,023.1	$6.0	$589.0	$23,940.8	$111.0	$2,471.0
Tourism Tax Loss	$20.0	$108.0	$659.1	$0.0	$153.0	$6,073.2	$4.0	$775.0
Property Tax Loss	NA	NA	$21,902.0	NA	NA	$166,630.0	NA	NA
Monroe County								
Sales Tax Loss	$0.0	$8.0	$131.4	$0.0	$8.0	$46,145.8	$17.0	$442.0
Tourism Tax Loss	$0.0	$0.0	$0.0	$0.0	$3.0	$6,445.8	$1.0	$231.0
Property Tax Loss	NA	NA	$2,433.0	NA	NA	$51,452.0	NA	NA
Palm Beach County								
Sales Tax Loss	$0.0	$0.0	$0.0	$0.0	$303.0	$6,395.3	$27.0	$485.0
Tourism Tax Loss	$0.0	$0.0	$0.0	$0.0	$133.0	$964.9	$0.0	$205.0
Property Tax Loss	NA	NA	$612.0	NA	NA	$24,942.0	NA	NA

Notes:

Impacts only account for parcels where 25 percent or more of the parcel footprint is exposed to the modeled coastal conditions.

MHHW results account for one year of impacts. These impacts would recur, annually. Business and parcels impacted by MHHW conditions are excluded from 1-year and 10-year tide damages.

The 1-year and 10-year tide results account for the impacts of one storm event of these magnitudes occurring. The results are not adjusted to account for the probability of the modeled storm occurring.

Sales and tourism tax losses account for recapture as discussed in Appendix E.

NA = Impacts not applicable based on methodological framework. In particular, storm flooding is assumed to not result in significant property tax impacts. If property owners are able to secure a deferral in property tax payments while their structures undergo repair, this freeze on payments would be temporary and the amount of deferral could be based on the time that is required to undertake repairs.

Results are not adjusted to account for financial discounting.

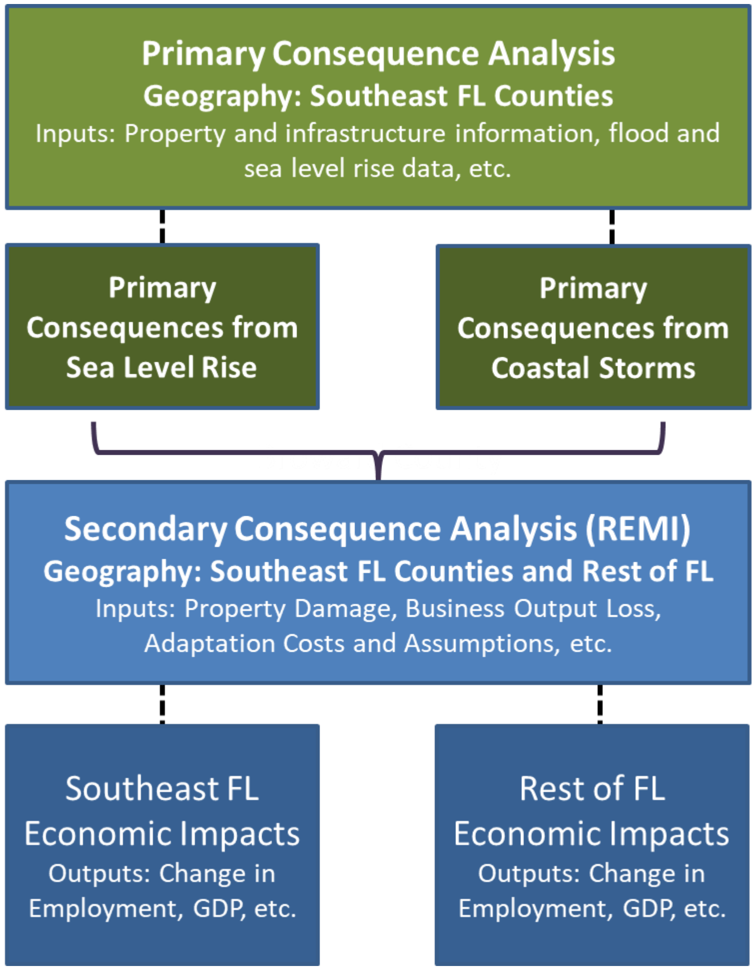
3.2 Secondary Economic Consequences Overview

Modeling the primary consequences of sea level rise and coastal storms only tells part of the story of how coastal hazards can impact the economies in Southeast Florida. The interconnectedness of regional economies and the way in which these economies will respond to coastal hazard risks is myriad and difficult to predict. For example, business closure or displacement due to property damage can result in an increased cost of goods, decreased worker productivity, and/or a decline in the regional labor force. Or, after a coastal storm, money will likely be directed to rebuilding damaged property, which would result in positive gains to the construction industry.

To account for these broader regional dynamics, the REMI PI+ modeling platform was used to evaluate secondary consequences, including direct as well as indirect and induced effects (e.g., supply chain) to the economies of Southeast Florida and the rest of Florida. The REMI model is a robust economic analysis tool that integrates features of econometric, input/output, and computable general equilibrium models to estimate the impact of policy measures on local economies throughout the U.S. The REMI model is a useful tool because it can be used to understand the cascading effects of a particular change in the economy with multiple feedback loops (e.g., a change is modeled many times as it impacts additional economic sectors). This economic impact modeling platform is particularly robust as it accounts for the common functions of an input-output model in addition to price elasticities and changes in consumer or industry behavior.

To conduct the assessment of secondary consequences, key outputs of the primary consequence modeling were integrated into the REMI modeling platform. For example, to determine broader supply chain impacts, business output loss by industry estimated in the primary consequence modeling was incorporated into the REMI model. Figure 2 provides a general overview of the relationship between the primary and secondary consequence modeling. REMI staff provided guidance on how to best include the primary consequence outputs into the secondary consequence modeling.

Figure 2. Relationship between Primary Consequence and Secondary Consequence (REMI) Modeling



3.2.1 REMI Framework

Table 15 shows the primary REMI variables used for the no action scenario. Separate model runs were undertaken to account for the different dynamics between the temporary shock of a coastal storm compared to the gradual impacts of daily high tides (i.e., MHHW) from sea level rise. The temporary no action scenarios show the impacts to the economy from a single storm event – a 1-year tide event or 10-year tide event in 2020, 2040, and 2070. The probability of the storm is not accounted for nor are damages distributed year over year based on probability. Immediate recovery within the year is captured – such as immediate responses to repair damages to structures. This can cause an increase in economic activity, such as an increase in construction jobs. However, long-term recovery efforts related to rebuilding are not shown.

For gradual sea level rise, impacts are evaluated annually, accounting for the year in which a property is first expected to be impacted by daily high tides. For example, a business operating in a building that is impacted by sea level rise in 2030 will result in sales losses in that year as well as in each subsequent year of the period of analysis (i.e. through 2070). Since the REMI model forecasts end in 2060, gradual sea level rise inputs were truncated to fit model parameters.

The variables modeled closely parallel the modeling framework that AECOM implemented to assess similar coastal hazard impacts to Dania Beach and Broward County (2018). Additional information on the REMI model framework can be found in Appendix H.

Table 15. REMI Model Variables for the No Action Scenario

REMI Model Variables	Input for Each County	
	Temporary Storm Events (1-Year and 10-Year Tide)	**Permanent Sea Level Rise (MHHW)**
Capital Stock (*Actual for Storm Events, Optimal for gradual Sea Level Rise*)	If more than 25 percent of the parcel area was impacted by the storm event, structure damages were estimated as the damages to buildings on that parcel from a single storm. For storms, actual capital stock was used to recognize that damages estimated to the structures on parcels would be repaired post event. No adjustments were made for repetitive loss properties based on number of times a parcel is subject to storm damages. Modeled for the 1-Year Tide and 10-Year Tide damages calculated for 2020, 2040, and 2070 conditions and inputted into REMI in those respective years. Assume that the structures will be repaired starting immediately after the storm.	If more than 25 percent of the parcel was impacted by MHHW, complete loss of value of property is inputted in the year that the property is lost. This is equivalent to the full just value of the property and therefore accounts for both structure and land value. For gradual sea level rise, optimal capital stock was used to model that these properties would not be rebuilt. Impacts are inputted every year as they are assumed to occur with gradual sea level rise.
Output (*Industry-Exogenous Production, Investment nullified*)	Sales loss due to disruption from a single storm by industry. Modeled for the 1-Year Tide and 10-Year Tide damages calculated for 2020, 2040, and 2070 conditions and inputted into REMI in those respective years.	Annual sales of properties impacted by MHHW by industry assuming recapture for all years that the business cannot operate. Impacts are inputted every year as they are assumed to occur with gradual sea level rise.
Consumer Price Net Household Insurance	Increase in home insurance for residential properties impacted by storm damages equivalent to their losses from structure damages in addition to damages to the contents within their home. Modeled for the 1-Year Tide and 10-Year Tide damages calculated for 2020, 2040, and 2070 conditions and inputted into REMI in those respective years.	Not applicable
Production Cost (*Lagged Market Share Response*)	Increase in production costs for non-residential properties impacted by storm damages equivalent to their losses from structure damages in addition to damages to the contents within their business. Modeled for the 1-Year Tide and 10-Year Tide damages calculated for 2020, 2040, and 2070 conditions and inputted into REMI in those respective years.	Not applicable

3.2.2 REMI Control

All REMI results are shown as they compare to the baseline, also referred to as the regional control. The regional control accounts for population and employment changes anticipated in the regions through 2060, the end year parameter of REMI. The regional control values are shown for each county and the rest of Florida for the beginning and end period of analysis: 2019 and 2060 in Table 16 and Table 17.

Table 16. REMI 2019 Regional Control for Southeast Florida and the Rest of Florida (2019 Dollars)

County	2019 Regional Control Economic Indicators		
	Population	Jobs	GDP
Broward	1,973,000	1,237,000	$120,000,000,000
Miami-Dade	2,763,000	1,817,000	$173,000,000,000
Monroe	78,000	62,000	$5,000,000,000
Palm Beach	1,504,000	950,000	$95,000,000,000
Rest of Florida	15,320,000	8,227,000	$731,000,000,000

Table 17. REMI 2060 Regional Control for Southeast Florida and the Rest of Florida (2019 Dollars)

County	2060 Regional Control Economic Indicators		
	Population	Jobs	GDP
Broward	2,621,000	1,547,000	$263,000,000,000
Miami-Dade	3,080,000	2,071,000	$344,000,000,000
Monroe	82,000	61,000	$8,000,000,000
Palm Beach	1,998,000	1,164,000	$197,000,000,000
Rest of Florida	20,671,000	10,088,000	$1,536,000,000,000

3.2.3 REMI No Action Results

Temporary Event-Based Storm Results

Results for the temporary event-based storms are shown below. Results for the four counties are shown as they compare to the regional control in the year of the modeled storm (e.g. a 2040 storm event shows the percent change from the 2040 regional control). See Appendix G for more detail on employment impacts by industry.

Table 18. Temporary Event-Based Storm REMI Results, 2020 Coastal Conditions (2019 Dollars, $Millions)

Economic Indicators	1-Year Tide		10-Year Tide	
	Results	% Change from Baseline	Results	% Change from Baseline
Broward County				
Jobs	-70	↓0.01%	-590	↓0.05%
GDP	-$10	↓0.01%	-$50	↓0.04%
Miami-Dade County				
Jobs	-580	↓0.03%	-1,490	↓0.08%
GDP	-$60	↓0.03%	-$140	↓0.08%
Monroe County				
Jobs	0	↓0.00%	-20	↓0.04%
GDP	$0	↓0.00%	$0	↓0.03%
Palm Beach County				
Jobs	-30	↓0.00%	-240	↓0.02%
GDP	$0	↓0.00%	-$30	↓0.03%
Rest of Florida				
Jobs	-70		-190	
GDP	-$10		-$20	

Notes:

Jobs rounded to nearest 10.

GDP rounded to nearest $10 million.

Results are not adjusted to account for financial discounting.

Table 19. Temporary Event-Based Storm REMI Results, 2040 Coastal Conditions (2019 Dollars, $Millions)

Economic Indicators	1-Year Tide		10-Year Tide	
	Results	% Change from Baseline	Results	% Change from Baseline
Broward County				
Jobs	-110	↓0.01%	-2,250	↓0.16%
GDP	-$10	↓0.01%	-$230	↓0.13%
Miami-Dade County				
Jobs	-190	↓0.01%	-1,750	↓0.09%
GDP	-$30	↓0.01%	-$180	↓0.07%
Monroe County				
Jobs	-10	↓0.01%	-70	↓0.10%
GDP	$0	↓0.01%	$0	↓0.07%
Palm Beach County				
Jobs	-50	↓0.00%	-2,450	↓0.23%
GDP	-$10	↓0.00%	-$270	↓0.19%
Rest of Florida				
Jobs	-50		-510	
GDP	-$10		-$60	

Notes:

Jobs rounded to nearest 10.

GDP rounded to nearest $10 million.

Results are not adjusted to account for financial discounting.

Table 20. Temporary Event-Based Storm REMI Results, 2070 Coastal Conditions (2019 Dollars, $Millions)

Economic Indicators	1-Year Tide		10-Year Tide	
	Amount	% Change from Baseline	Amount	% Change from Baseline
Broward County				
Jobs	-710	↓0.05%	-15,410	↓1.00%
GDP	-$110	↓0.04%	-$2,240	↓0.85%
Miami-Dade County				
Jobs	-230	↓0.01%	-16,120	↓0.78%
GDP	-$30	↓0.01%	-$2,240	↓0.65%
Monroe County				
Jobs	-250	↓0.40%	-680	↓1.11%
GDP	-$30	↓0.40%	-$70	↓0.97%
Palm Beach County				
Jobs	-320	↓0.03%	-3,310	↓0.28%
GDP	-$50	↓0.03%	-$490	↓0.25%
Rest of Florida				
Jobs	-190		-2,650	
GDP	-$30		-$400	

Notes:

2070 storm impacts are shown relative to 2060 REMI baseline.

Jobs rounded to nearest 10.

GDP rounded to nearest $10 million.

Results are not adjusted to account for financial discounting.

REMI Gradual Sea Level Rise Results

Results for gradual sea level rise are shown below for two time periods: 2020 through 2040 and 2040 through 2070. Employment is shown as job years over the two phases of investment. Job years is one year of work for one person – for example: a new construction job that lasts the duration of the investment phase of five years will equate to five job years. Impacts are not shown as percent change relative to the regional control given that the control changes on an annual basis. As such, results are shown only as the total difference from the regional control.

Table 21. Gradual Sea Level Rise REMI Results (2019 Dollars, $Millions)

Economic Indicators	2020-2040	2040-2070
Broward County		
Job Years	-1,840	-23,160
GDP	-$190	-$2,990
Miami-Dade County		
Job Years	-8,770	-43,120
GDP	-$790	-$5,540

Economic Indicators	2020-2040	2040-2070
Monroe County		
Job Years	-1,500	-28,550
GDP	-$140	-$3,460
Palm Beach County		
Job Years	-410	-9,180
GDP	-$50	-$1,350
Rest of Florida		
Job Years	-520	-4,300
GDP	-$60	-$630

Notes:

Jobs rounded to nearest 10.

GDP rounded to nearest $10 million.

Results are not adjusted to account for financial discounting.

Figure 3 shows the impacts of gradual sea level rise on GDP over time, while Figure 4 shows the impacts by major industry over time for all regions combined.

Figure 3. Gradual Sea Level Rise GDP Relative to Baseline

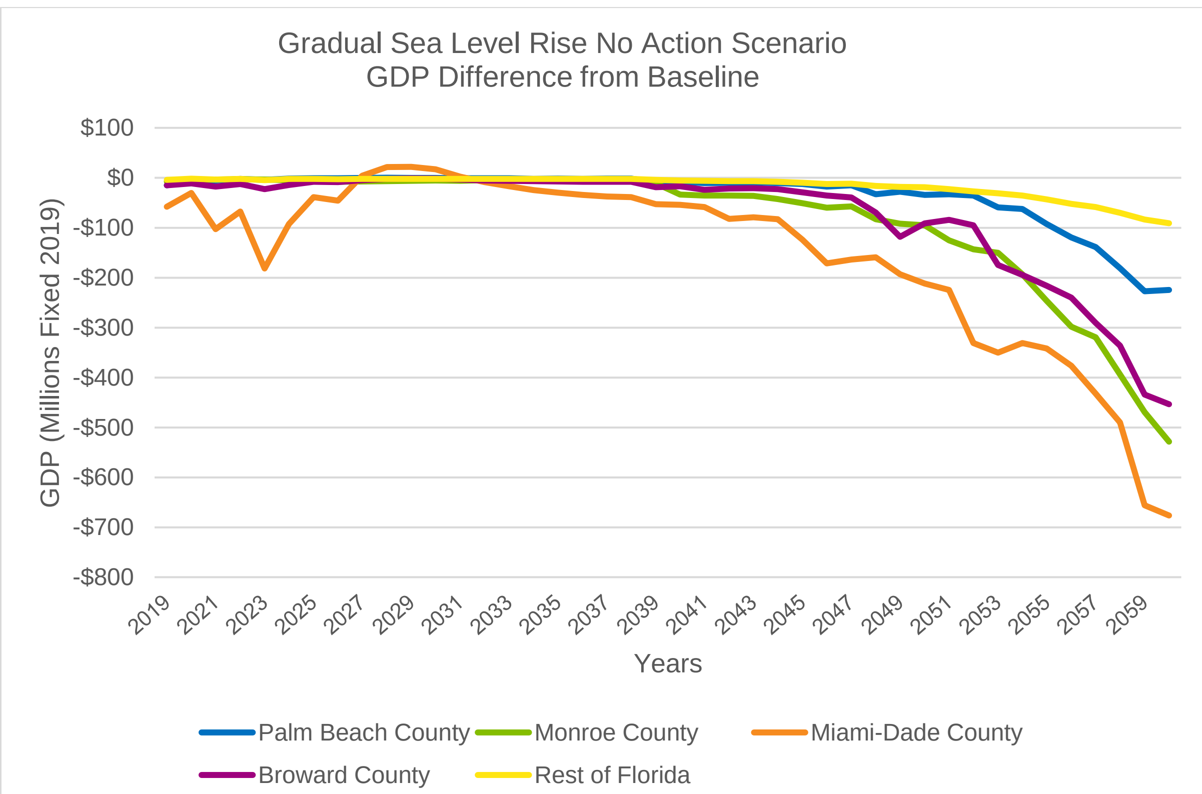
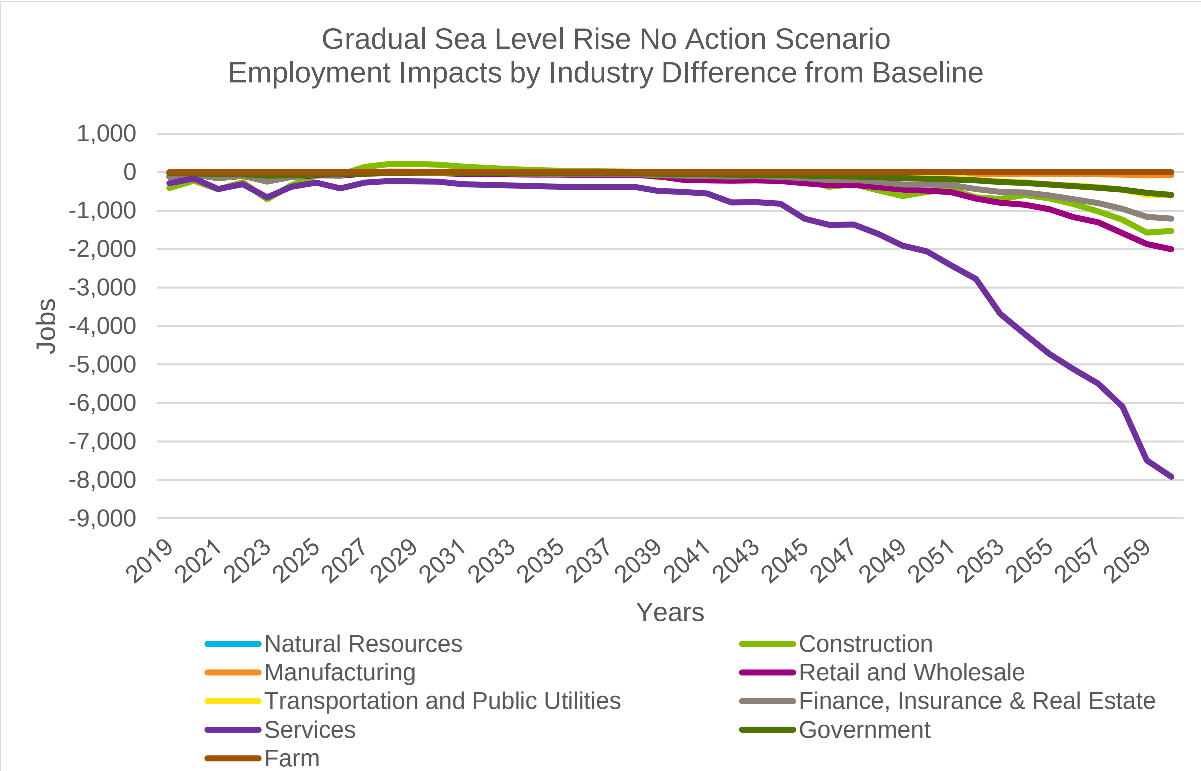


Figure 4. Gradual Sea Level Rise Employment Impacts by Industry



3.3 Adaptation Strategies Overview

Evaluating different types of adaptation actions can allow for a relative comparison of potential coastal hazard impacts in the absence of action and the benefits conveyed by investments intended to reduce coastal hazard risk.

Adaptation strategies were identified based on proposed options developed by the Project Team and feedback from the Compact Partners. The selected adaptation strategies fall into two primary buckets: (1) *systemic adaptation strategies* that provide a primary form of defence at the shoreline to minimize coastal hazard impacts; and (2) *building-level adaptation strategies* that modify physical assets to lessen the consequences of coastal hazards. In general, systemic strategies are intended to provide mitigate impacts from both temporary coastal storms and permanent sea level rise to all landward assets while building-strategies are designed to mitigate impacts for individual assets that are exposed to temporary coastal storms and not permanent sea level rise. Table 22 provides a description of the adaptation strategies evaluated for this study, and Appendix C includes additional information on the methods used to model and cost the selected adaptation strategies.

Table 22. Adaptation Strategy Types Evaluated

Adaptation Bucket	Strategy	Description
Systemic Adaptation	• Beach nourishment/dune restoration • Seawall raising • Berm construction	This scenario involves a combination of soft and hard engineering investments at the shoreline, the application of which is dependent on open coast and intercoastal determinations.
Building-Level Adaptation	• Dry and wet floodproofing • Elevating structures	This scenario involves a combination of structural improvements to property, the application of which is dependent on building type and FEMA principles and procedures.

Given the large and varied geography of Southeast Florida, simplifying assumptions and generalized and repeatable analysis techniques were used to model the selected adaptation strategies. Key considerations made in modeling the adaptation strategies are described thematically below.

Scaling of Strategies: Adaptation strategies were scaled to mitigate the majority of modeled impacts under a no action scenario; conceptually this results in the benefits of adaptation being similar to the estimated costs of inaction. For example, systemic strategies were scaled to mitigate impacts for the 10-year tide event (and respective rates of sea level rise) in 2020, 2040, and 2070. The building-level strategies were scaled to protect from the 100-year coastal storm in 2020, 2040 and 2070 (and associated rates of sea level rise), a threshold that can affect flood insurance requirements and costs for properties subject to the National Flood Insurance Program.

Phasing of Strategies*:* This study assumes that sea level rise will continue to occur over the next decades, through the coming century, and beyond. While Southeast Florida counties will face risks from high tides and coastal storm events, it is not necessary, nor likely financially feasible, to adapt all at once to the most extreme hazard scenarios evaluated in this study. Both systemic and building-level strategies were modeled using a phased investment approach informed by both economic and engineering feasibility constraints and considerations. Conceptually, investments made in 2020 are intended to effectively address the modeled hazard risks out to 2040, and the investments made in 2040 are intended to effectively address the modeled hazard risks out to 2070.

Adaptation Costing: Adaptation strategies evaluated were not detailed in design, but rather, were descriptive options to demonstrate the order of magnitude benefits of proactive investment to the costs of inaction. As such, approximated and averaged unit costs were incorporated into the analysis, drawing from publicly available data from published reports, with an emphasis on literature that best reflects economic conditions in Southeast Florida; where national research was relied upon, costs were adjusted for local prices.

3.3.1 Adaptation Strategy Results

High level costs for the systemic and building-level adaptation strategies evaluated in this study are provided in Table 23 and Table 24, respectively. The costs, presented by county, include a breakdown of individual strategies (e.g., seawall replacement, elevate structure). To account for the phasing of investment in adaptation strategies over the period of the study analysis (i.e., 2020 – 2070), both the systemic and the building-level strategies are scaled to show investments implemented in 2020 that will help to mitigate impacts from 2040 hazard conditions and actions implemented in 2040 that will help to mitigate impacts from 2070 hazard conditions. While an implementation year has been assigned for both systemic and building-level strategies, it is likely that these investments would be spread out over several years.

It is important to note that the systemic and building-level strategies are intended to be evaluated separately, with a few caveats. The systemic strategies would provide broader economic benefits than the building-level strategies as they would mitigate impacts to both property and infrastructure that are critical for economic activity (e.g., transportation network), and would also help to maintain the profiles of beaches that support a vibrant tourism-related economy. The building-level strategies, because they are focused on providing protection to individual structures, would not convey benefits to broader regional infrastructure nor would they help to maintain the counties' coastal resources that provide significant recreational and aesthetic benefits and economic value.

Table 23. Order of Magnitude Systemic Adaptation Costs (2019 Dollars, $Millions)

Adaptation Strategy	Broward	Miami-Dade	Monroe	Palm Beach
Implementation Year = 2020, Level of Protection = 2040				
Seawall Replacement	$2,866	$1,156	$5,993	$1,966
Seawall Raising	NA	NA	NA	NA
Berm Construction	NA	$23	NA	NA
Berm Raising	NA	NA	NA	NA
Nourishment	$361	$464	NA	$1,413
Total	**$3,227**	**$1,643**	**$5,993**	**$3,379**
Implementation Year = 2040, Level of Protection = 2070				
Seawall Replacement	$2,955	$783	$4,234	$1,289
Seawall Raising	$312	$126	$633	$214
Berm Construction	NA	$7	NA	NA
Berm Raising	NA	$13	NA	NA
Nourishment	$542	$696	NA	$2,119
Total	**$3,808**	**$1,625**	**$4,866**	**$3,622**
TOTAL COSTS	**$7,035**	**$3,268**	**$10,859**	**$7,001**

Notes:

Includes direct, indirect and contingency costs.

Results are not adjusted to account for financial discounting.

Table 24. Order of Magnitude Building-Level Adaptation Costs (2019 Dollars, $Millions)

Adaptation Strategy	Broward	Miami-Dade	Monroe	Palm Beach
Implementation Year = 2020, Level of Protection = 2040				
Elevate Structures	$398	$445	$296	$146
Floodproof Structures	$9	$18	$11	$3
Total	**$407**	**$463**	**$307**	**$149**
Implementation Year = 2040, Level of Protection = 2070				
Elevate Structures	$3,100	$3,790	$868	$1,142
Floodproof Structures	$86	$81	$26	$18
Total	**$3,186**	**$3,871**	**$894**	**$1,160**
TOTAL COSTS	**$3,593**	**$4,334**	**$1,201**	**$1,309**

Notes:

Results are not adjusted to account for financial discounting.

3.4 Losses Avoided and the Return on Investment from Adaptation

In order to develop an understanding of the return on investment from adaptation, it is necessary to estimate the cumulative costs and benefits associated with taking action to mitigate the modeled coastal hazard risks. The benefits conveyed by investments in adaptation are not limited to the discrete time horizon model conditions evaluated (i.e., 2020, 2040 and 2070); once adaptation strategies are implemented, they will provide recurring benefits year-over-year.

To capture the cumulative benefits provided by investments in adaptation, impacts for the no action scenario were estimated for every year over the study's period of analysis by interpolating impacts between 2020 and 2040, and 2040 and 2070. These impacts were then adjusted to account for the likelihood of the modeled hazards occurring[2], and summed to develop an estimate of cumulative impacts. A similar process was undertaken to estimate the cumulative impacts expected from implementing the systemic and building-level adaptation strategies. Impacts for both the no action and adaptation scenarios were adjusted using a 5 percent discount rate to account for the "opportunity cost" or the time value of money, allowing for the comparison of future costs and benefits in present dollars. From a financial perspective, discounting is used to reflect that a dollar today is more valuable than a dollar in the future due to the ability to invest now and create more wealth than a dollar invested in a future year. Or, extended to a social perspective as it relates to this study, the benefits provided by adaptation are more valuable in the near-term than they are in the longer-term.

While both of the adaptation strategy types will help to mitigate the modeled coastal hazard risks, they are not expected to neutralize all of the impacts from the no action scenario. The systemic adaptation scenario was estimated to mitigate 90 percent of the modeled impacts for the no action scenario. While this adaptation strategy was scaled to prevent overtopping from the modeled sea level rise and coastal storm conditions, it was not feasible to cost out this measure for the entirety of the open coast and intercoastal shoreline in the Southeast Florida region. In particular, the shoreline dataset that was used to identify what systemic strategy to implement (e.g., seawall, berm) did not provide full geographic coverage of the modeled hazard exposure zones. This was particularly the case for sections of the intercoastal shoreline. As such, the full cost to implement the systemic strategies was not estimated for all of the modeled conditions, resulting in avoided impacts being discounted based on spot checks of the coastal hazard footprint and shoreline profile extents. The building-level strategies were estimated to mitigate 80 percent of the modeled storm impacts, accounting for the residual impacts that could result with dry and wet floodproofing strategies as documented in published literature (e.g. Aerts et al. 2014).

The cumulative primary consequence impacts over the period of analysis (i.e., 2020 to 2070) for the no action scenario are shown in Table 25. Table 26 and Table 27 show the cumulative primary consequence impacts avoided from implementation of the systemic and building-level adaptation scenarios, respectively. These values reflect the degree of protective benefits conveyed by the adaptation scenarios evaluated.

[2] Consider, for example, a 10-year storm event, which has 10 percent chance of occurring in any given year. If the estimated impacts are $100,000, then this value is multiplied by 0.1 (10 percent chance), resulting in an expected annual impact of $10,000.

Table 25. Cumulative Primary Consequence Impacts for the No Action Scenario (2020-2070) (2019 Dollars, $Millions)

County	Property Impacts	Sales Output Impacts	Sales and Tourism Tax Impacts	Property Tax Impacts
Broward	$63,911	$5,279	$161	$825
Miami-Dade	$106,545	$8,354	$361	$2,388
Monroe	$20,053	$8,560	$567	$674
Palm Beach	$29,607	$2,117	$82	$548
Total	**$220,116**	**$24,310**	**$1,171**	**$4,435**

Notes:

Results are not adjusted to account for financial discounting.

Table 26. Cumulative Primary Consequence Impacts Avoided from Systemic Adaptation (2020-2070) (2019 Dollars, $Millions)

County	Property Impacts	Sales Output Impacts	Sales and Tourism Tax Impacts	Property Tax Impacts
Broward	$57,520	$4,751	$145	$743
Miami-Dade	$95,891	$7,519	$325	$2,149
Monroe	$18,048	$7,704	$510	$607
Palm Beach	$26,646	$1,905	$74	$493
Total	**$198,105**	**$21,879**	**$1,054**	**$3,992**

Notes:

Results are not adjusted to account for financial discounting.

Table 27. Cumulative Primary Consequence Impacts Avoided from Building-Level Adaptation (2020-2070) (2019 Dollars, $Millions)

County	Property Impacts	Sales Output Impacts	Sales and Tourism Tax Impacts
Broward	$22,960	$342	$10
Miami-Dade	$36,691	$317	$14
Monroe	$1,219	$3	$0
Palm Beach	$12,022	$104	$6
Total	**$72,892**	**$766**	**$30**

Notes:

Results are not adjusted to account for financial discounting.

To develop an understanding of the costs and benefits of adaptation, impact metrics commonly incorporated in federal agency BCAs (e.g., USACE, FEMA) were evaluated. In particular, primary consequences associated with real and personal property (e.g., structures, land, contents, relocation) under a no action scenario were estimated and compared to the costs and benefits of systemic and building-level adaptation strategies. Table 28 and Table 29 show, in net present value terms (which is required in a benefit-cost analysis), the estimated cumulative costs of inaction and adaptation, net impacts and resulting benefit-cost ratios for the systemic (e.g., seawalls, dunes) and building-level (e.g., elevate structure, floodproof structure) adaptation strategies.

For both the systemic and building-level adaptation strategies, the benefits outweigh the costs for all counties except Monroe. *It is important to note that the systemic and building-level strategies are intended to be evaluated separately, with a few caveats.* The systemic strategies would provide broader economic benefits than the building-level strategies as they would mitigate impacts to both property and infrastructure that is critical for economic activity (e.g., transportation network), and would also help to maintain the profiles of beaches that support a vibrant tourism-related economy. The building-level strategies, because they are focused on providing protection to individual structures, would not convey benefits to broader regional infrastructure nor would they help to maintain the counties' coastal resources that provide significant recreational and aesthetic benefits and economic value.

Further, the systemic adaptation provides the greatest net benefits, even when not explicitly accounting for the beach recreation and tourism benefits that would result from maintaining the region's beaches. This does not necessarily imply that adaptation is not a cost-effective investment for Monroe. Rather, based on the high-level model assumptions, non-exhaustive impact categories evaluated, and financial discount rate incorporated, the outcomes were not proven to be economically justified for Monroe County. To this end, future analysis should be conducted on a project-by-project basis, in Monroe County as well as in the other Southeast Florida counties, to better design and optimize the benefits that can result from investment in adaptation.

Table 28. Systemic Adaptation Strategy Return on Investment for Direct Property Primary Consequences (Net Present Value, $Millions)

County	Cumulative Impacts Avoided	Cumulative Adaptation Costs	Net Impacts	Benefit-Cost Ratio
Broward	$9,601	$4,128	$5,473	2.33
Miami-Dade	$19,461	$2,101	$17,360	9.26
Monroe	$3,182	$7,669	-$4,487	0.41
Palm Beach	$5,613	$4,325	$1,288	1.30
Total	**$37,857**	**$18,223**	**$19,634**	**2.08**

Notes:

Results account for structure, content, land and relocation impacts.

Results are presented in net present value terms using a 5 percent discount rate over the period of the analysis from 2020 to 2070.

Table 29. Building-Level Adaptation Strategy Return on Investment for Direct Property Primary Consequences (Net Present Value, $Millions)

County	Cumulative Impacts Avoided	Cumulative Adaptation Costs	Net Benefits	Benefit-Cost Ratio
Broward	$4,541	$1,495	$3,046	3.04
Miami-Dade	$9,255	$1,786	$7,469	5.18
Monroe	$459	$598	-$139	0.77
Palm Beach	$3,312	$545	$2,767	6.08
Total	**$17,567**	**$4,424**	**$13,143**	**3.97**

Notes:

Results account for structure, content, land and relocation impacts.

Results are presented in net present value terms using a 5 percent discount rate over the period of the analysis from 2020 to 2070.

4. Economic Benefits from Investing in Adaptation

Investments in adaptation can provide benefits beyond the avoided losses documented in this report. For example, monies used to construct a seawall will result in direct gains in jobs for the construction industry, as well as indirect (e.g., supply chain) and induced (e.g., worker and household spending) job gains. These cascading economic effects were modeled using REMI PI+, accounting for adaptation cost estimates and public and private spending assumptions.

4.1 Systemic Adaptation Scenario

The systemic adaptation and building-level adaptation scenarios were modeled in REMI to understand the impacts of the investment spending associated with each scenario. To model in REMI, a number of assumptions were made regarding the parties that will be expected to pay for the strategy. Below is a discussion of these assumptions as well as the results showing the investment impacts for both systemic and building-level adaptation strategies.

4.1.1 Scenario Description

The systemic adaptation scenario, which involves a combination of soft (e.g., nourishment) and hard (e.g., seawalls) engineering investments, is assumed to prevent the modeled temporary storm and permanent sea level rise impacts through 2070.

4.1.2 Scenario Costs

Input from the Compact Partners was used to identify the burden of payment amongst: Federal government, State government, County/Local government, and private property owners. Table 30 identifies the general funding breakdown by adaptation strategy for the systemic adaptation scenario. It is assumed that government spending would pay for the costs associated with the seawall to protect public parcels and would pay for all berm and nourishment-related costs. Private property owners are assumed to pay for the costs associated with seawall protection for private parcels.

Table 30. Funding Assumptions for Systemic Adaptation

Adaptation Strategy	Federal	State	Local/County	Private Property
Seawall Replacement	50% of all costs associated with public properties	25% of all costs associated with public properties	25% of all costs associated with public properties	100% of all costs associated with private properties
Seawall Raising	50% of all costs associated with public properties	25% of all costs associated with public properties	25% of all costs associated with public properties	100% of all costs associated with private properties
Berm Construction	50% of all costs	25% of all costs	25% of all costs	0%
Berm Raising	50% of all costs	25% of all costs	25% of all costs	0%
Nourishment	50% of all costs	25% of all costs	25% of all costs	0%

To determine what costs are associated with public and private properties, GIS was used to identify all parcels along the shoreline for the four counties. This information was then associated with parcel characteristics including if the parcel is on public land and an estimate of the parcel's shoreline frontage, based on the square root of the parcel's area. Further analysis was conducted to identify the portion of the private property that is residential and non-residential given their different treatment within REMI.

The systemic adaptation strategy is assumed to be a phased approach, whereby the first phase provides protection for all properties subject to impacts under the 10-year storm in 2040, and the second phase provides protection for all properties subject to impacts under the 10-year storm in 2070. Because the 10-year storm is the greatest magnitude event modeled, investments would also provide protection to parcels subject to daily high tides and the 1-year storm. Therefore, for the first phase, all frontage estimates only included parcels impacted by the 2040 10-year storm. Table 31 shows the results from this analysis and the breakdown of adaptation costs associated with each relevant party for both the first and second phase of the adaptation investment.

Table 31. Costs by Funding Source for Systemic Adaptation (2019 Dollars, $Millions)

Funding Source	Broward	Miami-Dade	Monroe	Palm Beach
Implementation Year = 2020, Level of Protection = 2040				
Federal	$551	$485	$1,440	$869
State	$275	$242	$720	$435
County/Local	$275	$242	$720	$435
Private: Residential	$1,811	$405	$2,255	$1,455
Private: Non-Residential	$314	$268	$858	$186
Total	**$3,227**	**$1,643**	**$5,993**	**$3,379**
Implementation Year = 2040, Level of Protection = 2070				
Federal	$538	$487	$751	$1,128
State	$269	$244	$376	$564
County/Local	$269	$244	$376	$564
Private: Residential	$2,491	$473	$2,772	$1,267
Private: Non-Residential	$241	$177	$593	$100
Total	**$3,808**	**$1,625**	**$4,866**	**$3,622**
TOTAL	**$7,035**	**$3,268**[1]	**$10,859**	**$7,001**

Notes:

[1] The lower reported costs for Miami-Dade County can be explained in part by the large portion of the County's southern shoreline being undeveloped and not included in the adaptation costing.

Results are not adjusted to account for financial discounting.

4.1.3 REMI Framework

Within REMI, all private residential adaptation costs are inputted as an increase in personal taxes[3], as it is assumed that the costs property owners will need to bear will increase their personal expenditures. Conceptually, as personal taxes increase, people have less real

[3] Personal taxes include taxes paid on income, including realized net capital gains, and on personal property.

disposable personal income, which can lead to a decrease in consumption, output, and value added.

All private non-residential adaptation costs are inputted as an increase in production costs for all industries. The increase in production costs can increase the cost of living and the cost of doing business within the region, which can decrease local economic activity.

The construction industry is assumed to benefit from the investment, so there is an increase in final demand for the construction industry equivalent to the costs of the investment. This major increase in construction spending can result in increased employment in the area for the construction industry as well as supporting industries. Finally, the portion of payment made by local and state government is inputted as a negative amount of government spending. A reduction in government spending shows that money that is dedicated to this investment cannot be spent on other local and state government expenditures. For state spending, only a portion of the spending is assumed to come from the impacted counties based on population. The remainder of the spending comes out of the rest of the state's government expenditures. All costs are distributed over a five-year period – from 2020 through 2024 and 2040 through 2044; the spreading of costs was required within REMI given that the amount of spending was beyond expected annual model parameters. This modeling exercise is also more similar to a likely implementation of the actions – rather than the investments all happening in one year, it is more likely that construction would happen over a multi-year period.

Table 32. REMI Variables for Systemic Adaptation

Impact Type	Input for Each County	Frequency
Personal Taxes	Increase in personal tax spending equivalent to residential costs to pay for systemic protection.	Distributed over 5 years for 2020 and 2040 investment
Production Cost *(Lagged market share response)*	Production cost increase to all industries equivalent to the non-residential costs to pay for systemic protection.	Distributed over 5 years for 2020 and 2040 investment
Exogenous Final Demand	Increase in exogenous final demand for construction industry equivalent to cost of systemic protection. Exogenous final demand was used for this scenario instead of output to account for increased leakage. Only the proportion of the demand usually supplied locally is added to local production, while the remainder is assumed to be produced elsewhere and imported to the region.	Distributed over 5 years for 2020 and 2040 investment
Local Government Spending	Enter in as a negative amount the cost assumed to be paid for by the local government for systemic protection.	Distributed over 5 years for 2020 and 2040 investment
State Government Spending	Enter in as a negative amount the cost assumed to be paid for by the state government for systemic protection.	Distributed over 5 years for 2020 and 2040 investment

4.1.4 REMI Results

The results for the two phases of the systemic adaptation scenario are shown in Table 33 by region as compared to the baseline. The table shows the primary impacts on GDP and job years. Job years is one year of work for one person – for example: a new construction job that lasts the duration of the investment phase of five years will equate to five job years. Overall, the systemic adaptation scenario has a general positive impact to GDP and employment for the four counties over the two investment phases. There is a general trend of negative overall economic impact to the rest of Florida as the economic activity of the investment benefits the four counties and draws government spending and employment away from the rest of Florida. See Appendix G for more detail on employment impacts by industry.

Table 33. Economic Indicators for Systemic Adaptation Scenario Shown in Two Phases (2019 Dollars, $Millions)

Economic Indicators	Investments in 2020	Investments in 2040
	Combined Difference from Baseline	*Combined Difference from Baseline*
Broward County		
Job Years	6,780	5,280
GDP	$660	$780
Miami-Dade County		
Job Years	15,200	9,550
GDP	$1,600	$1,380
Monroe County		
Job Years	19,370	9,230
GDP	$1,260	$810
Palm Beach County		
Job Years	9,470	9,910
GDP	$730	$1,170
Rest of Florida		
Job Years	-15,050	-11,320
GDP	-1,340	-1,230

Notes:

Jobs rounded to nearest 10.

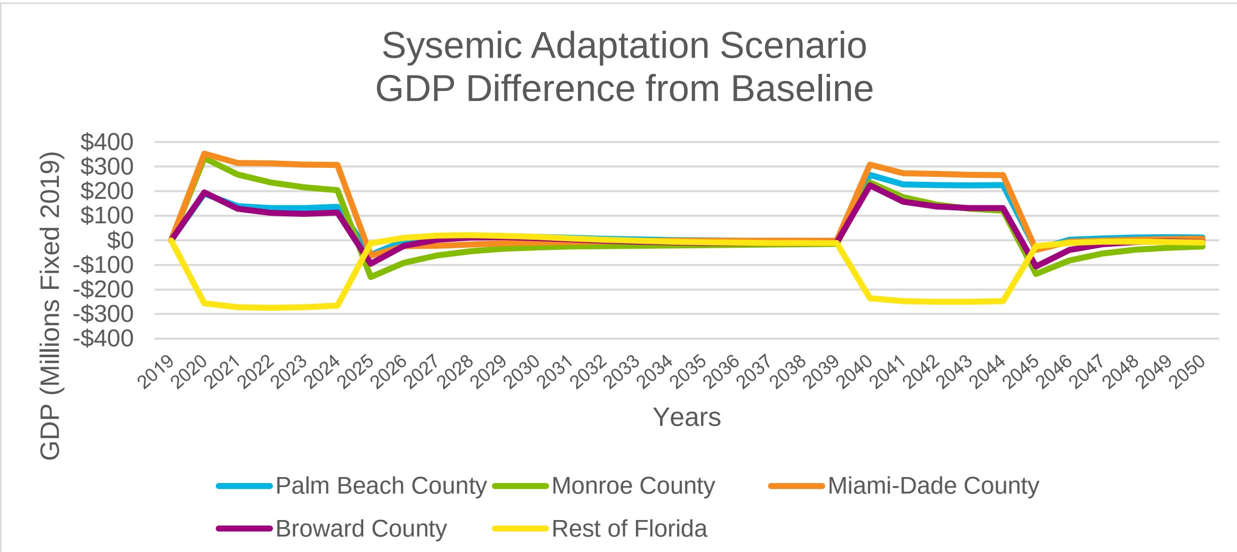
GDP rounded to nearest $10 million.

Job years is equivalent to one year of work for one person – for example: a new construction job that lasts two years will equate to two job years.

Results are not adjusted to account for financial discounting.

Figure 5 shows the systemic adaptation scenario impact on GDP for the four counties and the rest of Florida over the time period covering the two phases of the investment. The rest of Florida experiences lower GDP under this scenario relative to the baseline as the economic activity of the investment benefits the four counties and draws government spending and employment away from the rest of the state.

Figure 5. Systemic Adaptation Scenario GDP Impact 2019-2050



4.2 Building-Level Adaptation Scenario

4.2.1 Scenario Description

In the building-level adaptation scenario, parcels with structures that are subject to storm damages are assumed to be protected through strategies such as elevating and floodproofing. This strategy will not protect from permanent inundation and also will not protect properties that only start to be impacted under 2070 storm conditions. Instead, the strategy protects all properties that are subject to the 10-year storm in 2040.

4.2.2 Scenario Costs

Input from the Compact Partners was used to identify the burden of payment amongst: Federal government, State government, County/Local government, and private property owners. Table 34 identifies the general funding breakdown by adaptation strategy within the building-level scenario. Similar to the systemic adaptation scenario, it was assumed that the public would pay for the costs associated with public parcels. Private property owners are assumed to pay for half of the costs associated with private parcels, with federal funding paying the gap.

Table 34. Funding Assumptions for Building-Level Adaptation

Adaptation Strategy	Federal	State	Local/County	Private Property
Elevate	50% of all costs associated with public properties 50% of all costs associated with private properties	0%	50% of all costs associated with public properties	50% of all costs associated with private properties
Floodproof	50% of all costs associated with public properties 50% of all costs associated with private properties	0%	50% of all costs associated with public properties	50% of all costs associated with private properties

Similar to the systemic adaptation scenario, parcel data was used to identify public vs private ownership. Further analysis was conducted to identify the portion of the private property that is residential and non-residential for properties that would be subject to the building-level adaptation investment given their different treatment within REMI.

The building-level adaptation strategy is assumed to be a phased approach, whereby the first phase provides a level of protection against the modeled storms through 2040, and the second phase provides a level of protection against the modeled storms through 2070. Note that the first investment phase protects properties subject to storm impacts in 2020, while the second investment phase protects properties subject to storm impacts in 2040. Costs were not developed for properties that are first subject to coastal storm impacts in 2070 because of difficulty in estimating the actual year when these properties would first be subject to storm impacts, which is a necessary condition to be considered in the cumulative assessment of the costs and benefits of adaptation. Table 35 shows the results from this analysis and the breakdown of adaptation costs associated with each relevant party for both the first and second phase of the adaptation investment.

Table 35. Costs by Funding Source for Building-Level Adaptation (2019 Dollars, $Millions)

Funding Source	Broward	Miami-Dade	Monroe	Palm Beach
Implementation Year = 2020, Level of Protection = 2040				
Federal	$204	$232	$154	$75
State	$0	$0	$0	$0
County/Local	$9	$4	$3	$0
Private: Residential	$189	$207	$143	$73
Private: Non-Residential	$6	$20	$7	$1
Total	**$407**	**$463**	**$307**	**$149**
Implementation Year = 2040, Level of Protection = 2070				
Federal	$1,593	$1,936	$447	$580
State	$0	$0	$0	$0
County/Local	$28	$9	$6	$1
Private: Residential	$1,496,	$1,824	$419	$552
Private: Non-Residential	$69	$102	$22	$27
Total	**$3,186**	**$3,871**	**$894**	**$1,160**

Funding Source	Broward	Miami-Dade	Monroe	Palm Beach
TOTAL COSTS	$3,593	$4,334	$1,201	$1,309

4.2.3 REMI Framework

Within REMI, all private residential adaptation costs are inputted as an increase in personal taxes[4], as it is assumed that the costs property owners will need to bear will increase their personal expenditures. Conceptually, as personal taxes increase, people have less real disposable personal income, which can lead to a decrease in consumption, output, and value added.

All private non-residential adaptation costs are inputted as an increase in production costs to the industries for parcels that were categorized as investing in elevation or floodproofing of structures. The increase in production costs can increase the cost of living and the cost of doing business within the region, which can decrease local economic activity. Additionally, these industries are expected to experience losses associated with the period that they need to close during construction – it was estimated that these losses would be equivalent to two months' worth of sales losses, though it is assumed that some of the losses will be able to be recaptured. Recapture factors account for the ability for employees to be able to conduct business off-site or for businesses to increase output rates upon reopening, such as through extended hours, to make up for losses during closure. Furthermore, while output losses can cause disruption for local businesses, the variable was entered as Firm within the REMI model to acknowledge the potential benefits to other businesses nearby that could absorb some of the output loss.

The construction industry is assumed to benefit from the investment, so there is an increase in output for the construction industry equivalent to the costs of the investment. This major increase in construction spending can result in increased employment in the area for the construction industry as well as supporting industries. Finally, the portion of payment made by the local government is inputted as a negative amount of government spending. A reduction in government spending shows that money that is dedicated to this investment cannot be spent on other local government expenditures. All costs are distributed over a five-year period – from 2020 through 2024 and 2040 through 2044; the spreading of costs was required within REMI given that the amount of spending was beyond expected annual model parameters. This modeling exercise is also more similar to a likely implementation of the actions – rather than the investments all happening in one year, it is more likely that construction would happen over a multi-year period.

[4] Personal taxes include taxes paid on income, including realized net capital gains, and on personal property.

Table 36. REMI Variables for Building-level Adaptation

Impact Type	Input for Each County	Frequency
Personal Taxes	Increase in personal tax spending equivalent to residential costs of elevation and floodproofing.	Distributed over 5 years for 2020 and 2040 investment
Production Cost *(Lagged market share response)*	Production cost increase to all industries equivalent to the non-residential costs to pay for elevation and floodproofing.	Distributed over 5 years for 2020 and 2040 investment
Output *(Firm)*	Output decrease for businesses that will need to close for elevation and floodproofing. Firm sales were used to acknowledge that sales are competitive with other firms in the area, which may absorb some of the loss.	Distributed over 5 years for 2020 and 2040 investment
Output *(Industry-Exogenous Production)*	Output increase for construction industry equivalent to cost of elevation and floodproofing.	Distributed over 5 years for 2020 and 2040 investment
Local Government Spending	Enter in as a negative amount the cost assumed to be paid for by the local government for elevation and floodproofing.	Distributed over 5 years for 2020 and 2040 investment

4.2.4 REMI Results

The results for the two phases of the building-level adaptation scenario are shown in Table 37 by region as compared to the baseline. The table shows the primary impacts on GDP and job years. Job years is one year of work for one person – for example: a new construction job that lasts the duration of the investment phase of five years will equate to five job years. Overall, the building-level adaptation scenario has a general positive impact to GDP and employment over the two investment phases. See Appendix G for more detail on employment impacts by industry.

Table 37. Economic Indicators for Building-Level Adaptation Scenario Shown in Two Phases (2019 Dollars, $Millions)

Economic Indicators	Investments in 2020	Investments in 2040
	Combined Difference from Baseline	*Combined Difference from Baseline*
Broward County		
Job Years	2,530	15,010
GDP	$240	$1,970
Miami-Dade County		
Job Years	3,190	18,470
GDP	$350	$2,670
Monroe County		
Job Years	2,560	5,600
GDP	$180	$530
Palm Beach County		
Job Years	1,270	7,020
GDP	$120	$880
Rest of Florida		
Job Years	300	1,130
GDP	$30	$140

Notes:

Jobs rounded to nearest 10.

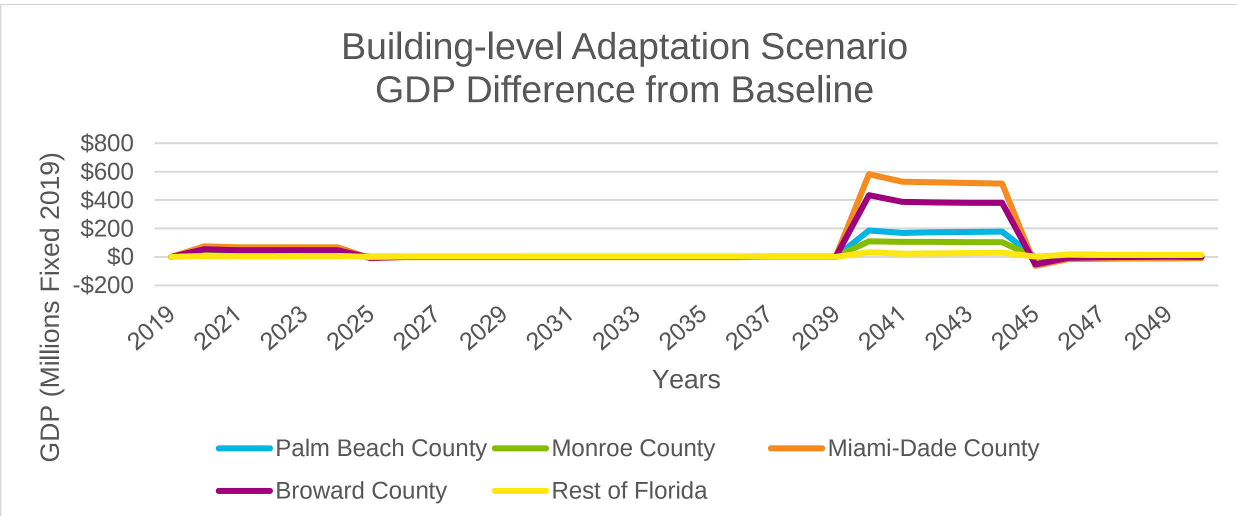
GDP rounded to nearest $10 million.

Job years is equivalent to one year of work for one person – for example: a new construction job that lasts two years will equate to two job years.

Results are not adjusted to account for financial discounting.

Figure 6 shows the building-level adaptation scenario impact on GDP for the four counties and the rest of Florida over the time period covering the two phases of the investment.

Figure 6. Building-Level Adaptation Scenario GDP Impact 2019-2050



5. Additional Adaptation Benefit Considerations

5.1 Property Value and Related Considerations

Investing in adaptation provides direct benefits in the form of avoided losses to property, as well as the potential for indirect benefits such as reductions in insurance premiums, stabilization and/or enhancement of property values and associated tax revenues. It is common knowledge that coastal property is priced at a premium compared to similar property not located by the coast. However, living near the coast comes with the risk of being subject to the impacts of coastal hazards. Hazard risks have been shown to be capitalized in the value of property; in particular, properties subject to hazard risks are often sold at a discount compared to similar properties not subject to these risks, all else considered equal. For example, a property with a government-backed mortgage in a FEMA special flood hazard area is generally required to purchase insurance. Consider a rational consumer that is faced with the decision of purchasing one of two identical properties. One property is located in a flood hazard area that requires the owner buy insurance, while the other property is not in a flood hazard area and, as such, the owner is not required to buy insurance. The rational consumer would be expected to place a lower value on the former property, accounting for the added cost of ownership associated with ongoing insurance premiums.

There is a growing body of literature that addresses the relationship between flood risk and property values. Property value impacts associated with these environmental, climate-exacerbated risks are hard to predict at the local level without detailed study. Yet, published academic and gray literature on this topic can provide a basis for considering how coastal hazard risks can affect property values and the balance sheets of local governments that depend on property tax revenues to fund their operations and provide governmental services.

Studies (e.g., Bernstein et al. 2018, Keenan et al. 2018, McAlpine and Porter 2018) that attempt to answer the question of how coastal hazard risks impact property values generally share a similar analytical approach. Specifically, these studies employ hedonic pricing techniques where regression analysis is used to understand how different characteristics of a property (e.g., size, condition) and the surrounding environment (e.g., schools, parks) affect the price of a property. Hedonic models have been used extensively in environmental and natural resource economics to explain how consumers value different bundles of property and non-property attributes. As it relates to this study, the question to be answered is if consumers do or do not demonstrate a willingness to pay to avoid flood risk.

Hedonic studies attempting to estimate how flood risk impacts property values have shown mixed results. This is in part because of the stochastic nature of flood events that are difficult for the public to understand, different underlying social, economic and environmental conditions in the geographies being evaluated, varying levels of flood risk awareness and disclosure, and insurance offerings such as those provided by FEMA's National Flood Insurance Program (NFIP) that are not actuarially sound or accurately reflective of expected risks. Studies also reveal various effects that account for the time dependency and frequency of hazard events. For example, some studies show declines in property values immediately following a flood event, only for prices to rebound in short order, while other studies reveal that repeated events, especially of significant effect, can result in longer-term price discounts.

Previous studies show that the price discounts for property located in a floodplain can range from 3 to 12 percent, as reviewed by Bin and Polasky (2004). In addition to their review of past studies, Bin and Polasky estimated changes in home values pre- and post-Hurricane Floyd. Findings from their analysis showed that the market value of property located within the floodplain was on average 6 percent less than the market value of comparable properties not located within the floodplain. Further, their analysis showed that the estimated discount for properties within the floodplain more than doubled post Hurricane Floyd. This indicates that consumers capitalized the economic risks posed by flooding after the landfall of Hurricane Floyd more so than they did prior to the event occurring. Additionally, the study revealed that the price reductions for post-Floyd sales were greater than capitalized insurance premiums while the discount for property values were less than capitalized insurance premiums prior to the landing of Hurricane Floyd. The authors theorize that when property owners are aware of potential flood risks and are fully insured, the expected reduction of property value within a floodplain would be equal to or greater than the capitalized value of flood insurance premiums. The study attributes price discounts that are greater than capitalized insurance costs to non-insurable and/or non-monetary effects associated with flooding (e.g., displacement or temporary relocation, loss of personal items with sentimental value).

Additional studies by Bin and colleagues (2006, 2008) showed a 5 to 10 percent discount for properties in a floodplain, with a greater discount for properties located in areas subject to more frequent flooding (e.g., 100-year floodplain vs. 500-year floodplain). Both studies demonstrated that the price differentials for property are generally equivalent to the capitalized value of flood insurance premiums, with the exception of properties that are located close to the shore. Properties in closer proximity to the coast, which in theory face greater flooding risks, were shown to be less sensitive to price reductions compared to property located further inland. The authors explain this muted effect by the positive amenities associated with living close to the shore, which are reflected in the premium paid to purchase a waterfront property. These studies and their nuanced results show the challenges to disentangling the relationship between flood risk and coastal amenities on properties values, and the potential limits of applying a one-size fits all approach to estimating the discounts to property values at different locations within a flood zone.

Sea level rise, unlike coastal storms, is occurring at a rate that is more predictable to quantify. In the past few years, a number of studies have evaluated the effects of sea level rise to property values. For example, Bernstein et al. (2018) examined how markets price long-term risks from sea level rise. The authors show that coastal properties in the continental U.S. that face exposure to sea level rise sell at a nearly 7 percent discount compared to similar properties. Additionally, this price discount is strongly driven by properties that will not be exposed to sea level rise for over 50 years, showing that investors are internalizing risks far out into the future. The authors note that this price discount is most acute in markets with sophisticated investors and is correlated to perceptions of future sea level rise risks. McAlpine and Porter (2018) estimated the accrued loss in property values in Miami-Dade County from recurrent tidal inundation and future sea level rise forecasts. The authors find that properties that are projected to be inundated with flooding from a king tide in the next 15 years are decreasing in value by approximately $3.08 per square foot annually, and that properties that are not at risk to tidal inundation, but are adjacent to roads that will be inundated are decreasing in value by approximately $3.71 per square foot annually. These results are consistent with the general findings from Keenan et al. (2018) that show property in Miami-Dade County at higher elevations in flood risk areas appreciating at a higher rate than property at lower elevations. Keenan and his co-authors identified patterns of population redistribution and investment into areas that face less risk to flooding due to their higher elevation. The authors note that this is a signal of climate gentrification, where the value of property is influenced by its ability to accommodate human settlement and supporting infrastructure.

The results from both the Bernstein, McAlpine and Porter and Kennan et al. must be considered carefully. The findings do not represent a decline in property prices in absolute terms, rather they account for lost appreciation. Simply put, the prices of tidally exposed properties appreciated at a lower rate than comparable property not exposed to tidal flooding. This does not rule out that property values could decline in absolute terms in the future. However, the potential for this to occur is difficult to predict at this time and will depend on myriad of factors including market sentiments, activity in the mortgage and insurance sectors and measures taken to adapt (MGI 2020).

Increasing risks from sea level rise and tidal flooding has the potential to undermine the strength of Florida's real estate market. The devaluation of real estate prices could have cascading effects, including foregone property taxes, the cost and/or access to insurance coverage and mortgage financing and loss of wealth and/or income for property and business owners. This in turn could affect municipal bond ratings and the ability of local governments to fund and finance investment in adaptive and resilience community infrastructure and services (MGI 2020). The cascading effects from real estate devaluation could fundamentally alter the desirability of living and working in coastal communities, which in turn could result in the redistribution of populations and public and private investment all of which can have significant impacts to local, regional and state economies.

Much that has been written about the consequences to Florida's coastal real estate market and additional knock-on effects from growing coastal hazard risk is illustrative of potential future outcomes. Currently, Florida's real estate market is quite robust, and current and future coastal hazards have not been shown to result in an absolute decline in real estate prices. A real decline in asset prices is a possibility in the future, but this outcome is dependent on a number of factors, such as the level of consumer recognition of the risks posed by coastal hazards, adjustments in insurance premiums to more accurately price risk, and efforts taken by the public and private sector to plan for and adapt to changing coastal conditions.

A number of speculative assumptions and uncertainties would be included in any attempt to quantify the timing and degree of absolute declines in asset values as well as the cascading effects resulting from price devaluation. To this end, analysis was undertaken to estimate the tangible financial impacts for properties subject to future daily high tides from sea level rise. Once a property is subject to daily high tides, this study assumes that it is no longer a functionally safe asset and would need to be abandoned. In effect, this would result in a reduction in capital stock on local government tax rolls, and as such a quantifiable loss in property tax revenues.

Cumulative property tax losses were estimated for each county by estimating the approximate year in which properties will be subject to daily high tides in the future. The year in which properties become subject to exposure from daily high tides was estimated by accounting for the modeled daily high tide inundation depths in 2040 or 2070 and the expected rate of sea level rise between these years. For example, a parcel exposed to 6 inches of inundation for the 2040 daily high tide modeled conditions would be expected to be subject to daily high tide inundation in a prior year. Based on the sea level rise rates incorporated into the analysis, 6 inches of sea level rise is expected to occur from 2028 to 2040. In this example, the property is assumed to no longer be a viable asset in 2028. This equilibrium-based approach of adjusting stillwater elevations according to accrued rates of sea level rise provides an approximation of when property tax losses would begin to accrue and serves as a basis for estimating cumulative year-over-year property tax losses over the period of analysis (i.e., 2020 to 2070).

The findings, shown in Table 38 can help to inform an understanding of the return on investment of public funds intended to mitigate long-term property tax losses. These results do not discount the possibility for an absolute decline in property values in the future, and the cascading consequences of this outcome. Yet to date there are too many unknowns concerning when consumers and the insurance industry will capitalize these risks in their decision-making and rate structures to speculate about these impacts.

Table 38. Cumulative Property Tax Impacts from Permanent Sea Level Rise (MHHW) (2019 Dollars, $Millions)

County	Property Tax Impacts by Decade					
	2020 - 2030	2030 - 2040	2040 - 2050	2050 - 2060	2060 - 2070	2020 - 2070
Broward	$12	$20	$34	$138	$620	$825
Miami-Dade	$114	$215	$249	$466	$1,345	$2,388
Monroe	$9	$22	$41	$142	$460	$674
Palm Beach	$9	$11	$24	$87	$418	$548
Total	**$144**	**$268**	**$348**	**$833**	**$2,843**	**$4,435**

Notes:

Impacts only account for parcels where 25 percent or more of the parcel footprint is exposed to the modeled coastal conditions.

Results are not adjusted to account for financial discounting.

5.2 Tourism and Beaches

Florida's ocean economy, which accounts for ocean tourism, ocean transportation, marine industries, ocean recreation and living resources, directly contributed to over $37 billion in GDP in 2018 (FOA 2020). This value doubles to nearly $74 billion in GDP when accounting for indirect contributions from the suppliers that support ocean-related industries and induced contributions that account for the spending by employees directly and indirectly participating in the ocean economy. Ocean tourism, a measure of monies spent on lodging and eating, accounted for over 65 percent of direct GDP contributions (~$24.7 billion) and over 70 percent of total jobs (~395,000) in 2018 (FOA 2020).

The foundational role that ocean tourism plays in Florida's coastal regions is closely linked to the presence of world class beaches. The recreational and leisure opportunities provided by the state's beaches has been documented as being the most significant draw for out-of-state tourists (EDR 2015). This is of relevance as out-of-state tourists inject new money that overwhelmingly stays with the local economy where it is spent, and much of this spending is subject to taxes that local and state government rely upon to fund their operations and service provisions. However, as of 2015, a majority of the state's beaches were experiencing erosion. While erosion is a naturally occurring phenomenon for beaches, storms of increasing frequency and/or magnitude and sea level rise can further accelerate beach erosion in the state. Historically, the state has invested in beach nourishment and other forms of beach management practices to maintain the size and quality of beaches. In particular, the Department of Environmental Protection's Beach Management Funding Assistance Program was created to partner with local, state and federal entities to support the protection, preservation and restoration of beaches (EDR 2015).

To determine the economic benefits provided by state monies directed to local beach management and restoration activities, a return on investment analysis was undertaken by the State Office of Economic and Demographic Research (EDR 2015). The assessment was focused on tangible financial gains or losses associated with state investments rather than broader social and environmental outcomes. In particular, the return on investment analysis accounted for tax revenues resulting from out-of-state visitor spending attributable to the state's beach management and restoration programmatic activities (contributions from local and federal spending were not included). The analysis, which evaluated state beach-related spending for the 2010/2011 – 2012/2013 fiscal years, showed a positive return on investment of 5.4. This implies that for every $1.00 invested by the state, they secured $5.40 in revenues.

The findings of EDR's return on investment analysis are important to consider in the context of the systemic adaptation strategies modeled in this study. In particular, beach nourishment and dune restoration were included as part of this adaptation strategy bucket. It was not feasible to quantify the return on investment for these beach management related investments due to a paucity of data on beach visitation across the region. However, there is little debate that these investments will provide co-benefits in the form of mitigating some of the damages from the modeled coastal conditions while also maintaining the quality of beaches that are key draw for visitors that make significant contributions to local and state economies.

5.3 Case Studies

Select case studies of flooding and/or adaptation are described below to demonstrate examples of projects that have been undertaken in the Southeast Florida region to adapt to sea level rise and/or coastal flooding. Case studies were prepared by Brizaga.

Monroe County Roadway Pilot Project

In 2017, Monroe County conducted a pilot study and engineering technical analysis that considered sea level rise and its related effects on two communities: Twin Lakes in Key Largo, Florida and Sands in Big Pine, Florida. The primary goal of this study was aimed towards deriving appropriate design recommendations applicable to roadways within each community. The team utilized modeling scenarios, in accordance with previous flooding events, and applied them to determine practical options for long-term roadway improvements. Stemming from two historic events, the Green Keys Sustainability Adoption Plan, and the 2015 King Tide event, which caused problematic flooding, Monroe County was inspired to spearhead this project, to safeguard the future roadways of Monroe County.

The project team considered several ideologies, ranging from best stormwater management practices to local climate policy, and developed technical, design, and economic data, as it pertained to sea level rise projections for future road elevation and drainage. Multiple sources were used to identify probable flooding recurrence scenarios in the year 2040. The project team followed suit with the Southeast Florida Regional Climate Change Compact (“Compact”) and utilized the same high sea level rise scenarios from the Intergovernmental Panel on Climate Change (“IPCC”) AR5 Median and United States Army Corps of Engineers (“USACE”) to determine further future risk of flooding recurrence while drawing from past events.

Sea level rise, climate change, and sustainability were inherently immersed throughout the various stages of the project. Notably, the team developed key design approaches, as it pertained to future flooding, by testing scenarios with 6”, 12”, 18” and 28” of road elevation. These findings provided meaningful insight for Monroe County relative to how each design, and its particular degree of road elevation, may benefit from such resilient improvements, as well as the respective differences in cost. Final recommendations of this study estimated that for the Twin Lakes Community, selective areas of the roadways should be raised around 5” of elevation NAVD88, and for the Sands Community, selective areas of the roadways should be raised around 11” of elevation NAVD88.

Seawalls, Waterfront Access, and the Marine Industry

The marine industry is an essential part of the economy and lifestyle in Southeast Florida. With hundreds of miles of waterfront, countless access points, and rising seas challenging it all, how this community addresses the interface between land and sea defines the future of adaptation in many ways, including from a physical protection standpoint and from protecting the drivers of our economy - real estate and the marine industry. Across Southeast Florida, communities are learning how to proactively address tidal flooding overtopping seawalls and other waterfront infrastructure.

The City of Fort Lauderdale has instituted one of most progressive seawall ordinances in terms of paving the way for fundamental triggers for upgrades or modifications. The ordinance sets the old maximum seawall height as the new minimum height of 3.9’ NAVD, set the maximum seawall height as the Base Flood Elevation, which is around 5-7’ NAVD for much of coastal areas in Fort Lauderdale, and creates mechanisms for repair or replacement of the seawall. Specifically, seawalls must be repaired or replaced when individuals fail to maintain a seawall in good repair, if major changes are made to the property or seawall, if tidal waters are entering their property and impacting other properties or the public right of way. The ordinance considers the flood protection nature of seawalls with rising sea levels. Other cities in the region are using the Fort Lauderdale ordinance as an innovative and essential template for seawall ordinances.

The City of Miami Beach increased the minimum seawall height. The City now requires new private and public seawalls to be constructed at a minimum elevation of 5.7’ NAVD, which was previously 3.2’ NAVD. Seawalls that are not being repaired or replaced are allowed to remain as is, as long as they meet a 4.0’ NAVD minimum and can structurally accommodate up to 5.7’ NAVD in the future.

In Broward County, a land use amendment aimed to create consistency for tidally-influenced properties across the County. Notably, tidally-influenced municipalities must adopt an ordinance that uses the regionally consistent top elevations for seawalls, banks and berms, and other waterfront infrastructure within the next two years. The County also passed an ordinance that applies to unincorporated Broward County. The new regulation additionally applies to waterfront infrastructure, such as boat ramps.

In order to address the challenges of direct water access, the City of Hollywood upgraded the Hollywood Marine Boat Ramp to address frequent tidal flooding in the area. The project received a grant from the Florida Department of Environment Protection to aid with the cost of the project. This is an example of the importance of waterfront infrastructure upgrades to reduce flooding likelihood and increase access to the water for the general public.

Seawalls are a primary coastal defense for Southeast Florida and have become an integral part of our flood protection infrastructure. The decision made today will affect the resilience of the community for decades to come. Proactive changes now, which add minimal construction cost, will save the need for substantial changes with significant cost down the road.

Fort Lauderdale A1A Improvements, Post Superstorm Sandy

In 2012, Superstorm Sandy moved along the eastern U.S. seaboard causing devastating erosion that stretched for miles throughout the Fort Lauderdale beaches. The inherent destruction that came with Superstorm Sandy undermined roadways and coastlines alike, causing sand and saltwater to encroach well past the shoreline infiltrating the thoroughfare. Whereas natural disasters, such as hurricanes, are readily abundant in Florida, our rapidly changing climate is worsening the frequency and severity of these events.

The City of Fort Lauderdale, Broward County, and the Florida Department of Transportation worked together to improve the resilience of the emergency repair reconstruction project. As a result of the damage caused by Superstorm Sandy, this project increased adaptation efforts by incorporating additional resilience into existing structures, as well as building completely new essential infrastructure. Notably, one of the improvements to Fort Lauderdale's A1A, was the installation of a sheet pile that is 40' deep and was designed to withstand 15' of scour. Several other reconstruction improvements included raising the roads 2', building a 1' higher wall, and installing new backwalls.

On Sunrise Boulevard, a back wall was added to prevent sand and saltwater from reaching the roadways. This back wall served a multitude of purposes by also preventing marine wildlife from entering the roadways and subsequently reducing light pollution from nearby traffic. The improvements made during this project were of necessity, and not considered "new money." Resilience was deemed imperative as part of the overall project and reflected the dire need to continuously improve roadways and other public infrastructure amidst our changing climate.

Palm Beach County Living Shorelines Program

Palm Beach County is home to a wide array of ecosystems, both natural and man-made, all of which may thrive in urban environments when suitable sediment, habitat, and water quality conditions exist. Over the course of several years, the Palm Beach County Living Shorelines Program focused on reinforcing ecological resilience into these communities. Living shorelines have become an increasingly viable method of natural resilience and habitat restoration, while also being cost-effective, sustainable, and aesthetically pleasing. These shorelines act as natural barriers to wave energy and storm surge, in addition to creating crucial habitats for native wildlife.

A mixture of tactics was used to develop living shorelines along the South Cove Natural Area and Currie Park within Palm Beach County's Lake Worth Lagoon. The largest estuary in Palm Beach County, the Lake Worth Lagoon, is between two permanent man-made inlets. A mixture of seagrass, mangrove, spartina, and oyster habitat was created using clean sand and natural limestone reefs, clean sand, and paths were put in to improve the ecosystem, while providing recreational benefits, educational opportunities, and ecotourism. These projects helped improve water quality and increased habitats for fisheries and wildlife, while creating added storm protection for the area.

In 2012, Palm Beach County's South Cove Natural Area prioritized the creation of natural habitats for wildlife, as well as the development of green infrastructure that encouraged educational and ecotourism activities. Expanding upon the existing seawall, a mangrove planter was installed to soften the edges and create a more natural shoreline within this urban estuary. Moreover, South Cove had historically been used as a dredge hole site. The dredge hole had slowly filled in with organic muck, which when re-suspended can negatively impact water quality. This project enabled the creation of critical tidal islands, seagrass habitat, and oyster reefs by filling the existing dredge hole with clean sand and thus capping the muck at the bottom of the hole. As a result, the restoration efforts of this project sanctioned six acres of mangrove, seagrass, and oyster habitat in the middle of downtown West Palm Beach complete with an elevated boardwalk and observation deck.

Five years after the South Cove Natural Area restoration project, the County, alongside the City of West Palm Beach, worked towards rehabilitating the shoreline of Currie Park by using the previously applied successful methods of habitat restoration. The Currie Park project consisted of creating seven mangrove and spartina planters alongside a concrete seawall. Similar to the South Cove Natural Area, Currie Park's living shoreline was created with limestone rock and filled with clean sand to create the planters and soften the edges along the linear seawall. In addition, this project was centered around involving local community members through volunteering opportunities, such as planting and clean-up events as well as continuing recreational activities within the park as well. All of the resilience measures prioritized in each restoration project allotted for an enhanced ecosystem where countless native species may thrive for generations to come.

A key, yet often overlooked, component for these types of projects is the beneficial re-use of existing suitable materials to create the various habitats. Clean rock and sand is often generated in urbanized estuaries through the management and operation of both the working waterfront and the adjacent navigational waterways. Handling and disposal of this material is usually costly and results in the loss of the material within the system. By partnering with public and private entities generating this material through dredging and excavation projects, living shorelines can often utilize this material at a significant cost savings to all parties, resulting in habitat improvements and coastal resilience while supporting the local marine community.

City of North Miami Repetitive Loss Property Conversion to Stormwater Park

The Arch Creek Basin is a low-lying area within the City of North Miami that regularly suffers from flooding and includes multiple FEMA-designated Repetitive Loss Properties. Several of these sites have remained vacant for years. The City reimagined a pilot site that transformed a Repetitive Loss Property into additional storage and retention for their stormwater management system through the creation of a stormwater park. The *Good Neighbor Stormwater Park* was previously owned by an individual whose home flooded at least within a ten-year period generating a claim from the National Flood Insurance Program. This enabled the City of North Miami to “buy out” the property. It was vacant for several years, but the City's initiative transformed it into a space where community members can cherish its beauty as well as its functionality.

The conversion from a Repetitive Loss Property to a requisite stormwater management system, allotted the City of North Miami to strengthen its resiliency efforts and significantly increased the pilot site's ability to mitigate problematic flooding. The innovative use of this land has made it possible for all residents of North Miami to enjoy a shared space that emphasizes both a sense of social and environmental resiliency.

Repetitive Loss Properties are increasingly disruptive to many communities causing excessive flooding not only in the specific household, but also in neighboring properties. During a recent rainstorm the City anecdotally noted that the stormwater park flooded, as it was designed, and the areas surrounding the site experienced reduced flooding. This is a correlated benefit to buying out Repetitive Loss Properties and transforming them into an integral tool of stormwater management. Additionally, revamping sites such as the *Good Neighbor Stormwater Park* also warrants homeowners the ability to move to a safer location and at the same time, lessens the burden on NFIP by reducing the amount of flood damage claims.

The Business Case for Miami Beach's Stormwater Resilience Program

Miami Beach conducted a business case analysis of their stormwater resiliency program to assess the effectiveness of resilience investments throughout Miami Beach at the individual, neighborhood, and city-wide level. The study examined the benefits of targeted resilience investments and how they can beget substantial economic and societal advantages. This pilot study researched stormwater investments through data analysis and cutting-edge modeling, focusing primarily on the potential benefits related to lowered flood risk, increased property values, and reduced flooding.

Various factors impact the structure of constructively communicating the Business Case for Miami Beach's Stormwater Resiliency Program. Property values, insurance premiums, tourism revenues, potential property damage, traffic disruptions, and business closures are among a few prevalent points of interest that concern the City of Miami Beach's economic stability. To further emphasize the need for resilience investments at all levels, the project teams deployed a mixture of models that analyzed catastrophic risk, integrated flooding, and property values. Applying these models to the individual homeowner level, the team found that personal adaptation plays a significant role in magnifying resilience, and must be acted upon, in addition to the City's targeted investments.

When applying those same models to the neighborhood level, the project teams found that said investments in more resilient infrastructure contribute to protecting property values and increasing social resiliency, and that the benefits of the resilience investments far outweigh their costs overall. At the city-wide level, it is critical that investments in stormwater resilience take place now, in order to minimize the monetary expense of potential damages attributed to future sea level rise projections.

6. Strategies and Recommendations for Advancing Economic Resilience

Economic resilience in the context of this study accounts for the ability of communities to: (1) prepare for and withstand coastal hazard risks, and (2) respond and recover when these risks manifest. Investment in actions that can reduce coastal hazard risk and support adaptation to changing conditions is of critical importance. These actions can help to protect people, property, businesses, and infrastructure, and reduce the amount of resources and investment needed to respond to and recover from coastal hazard events over the long term. As discussed in this report, investing in adaptation now is critical given the significant vulnerabilities faced by the public and private sector. For instance, this study identified that nearly $145 million in property tax revenues could be lost in across the four counties evaluated in the coming decade alone, with a total of $4.4 billion in property tax revenue losses between now and 2070 (undiscounted). A loss in revenue at this scale could limit the ability of local and regional governments to invest in core infrastructure and community services that businesses and residents rely on.

A primary goal of investing in economic resilience is to ensure that when coastal hazard events do occur, the shocks are manageable and not disruptive. Not all forms of coastal hazard risk can be fully mitigated. For instance, to prevent a majority of the impacts from a higher category hurricane would likely require a level of investment that could not be met by local communities, even with support from state and federal government. However, risk can be planned for and mitigated to a degree that meets the tolerance of residents and decision-makers, while accounting for relevant engineering and economic constraints.

Protective investments can help to minimize the shocks from coastal hazards, yet they will not address underlying chronic stresses present in local and regional economies (e.g., social equity, poverty, unemployment, lack of industry diversification) that will affect the capacity of communities to respond to and recover from immediate and more distant coastal hazard risks. Communities should attempt to identify the underlying structural factors that will affect their ability to be resilient to changing conditions. This includes developing an understanding of the strengths and weaknesses of local and regional economies, and the opportunities for improving business-as-usual practices so communities do not just survive but are best positioned to thrive. This will require investment in strategic policies, programs, and projects that can enhance the quality of life in communities, including improved access to housing and jobs and the strengthening of institutions that can facilitate these gains.

Key to promoting economic resilience is ensuring the continuity of business activity, which is heavily dependent on the function of community lifeline assets (e.g., utilities, roads). Interruption to business activity, be it from direct or indirect coastal hazard impacts, can slow recovery and affect the creditworthiness businesses and government (which rely on revenues generated from the business community), which can further constrain the ability of these entities to raise needed capital for investments in adaptation or other purposes. As such, it is critical that the business community continues to have a seat at the table in discussions on how and when to invest in economic resilience.

Public sector actors working to convene the business community in decisions on how to build economic resilience in the face of changing conditions should identify representatives from the firms, suppliers and service providers that underpin existing economic clusters (e.g., tourism, marine industries, recreation) in the region, as well as leaders in emerging industries (e.g., cleantech, life sciences, information technology, logistics and distribution, financial and professional services) (FOA 2013, 2020). These actors have helped to position the region to be competitive for jobs and private investment, and efforts should be taken to account for the needs of these critical economic agents. The public sector should also take efforts to engage representatives of economic anchors (e.g., hospitals, universities, large corporations, sports franchises, leisure and culture institutions) that have an enduring presence in a community and play an outsized role in the economy through their spending and investment, employment, generation of knowledge and incubation and support for new businesses. These industries represent local and regional economic strengths, and failure to address changing environmental and economic conditions could result in challenges in retaining businesses and the workforce that play a significant role in promoting economic activity and community well-being.

These diverse private sector economic agents, alongside other community actors (e.g., non-profits, philanthropy) that can speak to the needs of disenfranchised populations, can partner with public sector to identify economic and workforce development strategies and initiatives that can be aligned with broader adaptation planning and resilience goals. Having skilled and trained professionals available locally will help address these issues and protect essential community services. Where feasible, investments in resilience should be directed to local institutions in a manner that strengthens the economic and social fabric of communities that bear the brunt of coastal hazard impacts. Further, decision-making on investment needs should draw upon lessons learned from prior coastal hazards events. For instance, in the aftermath of Hurricane Irma, client base changes post hurricane such as decreased expendable income of customers, lack of financial operating capital, structural damages, and lack of workforce and available housing were identified as key challenges to recovery faced by the private sector. Accounting for these considerations can help to minimize future impacts, including outcomes to vulnerable workers and industries, and identify pathways for investment that can promote a thriving economy that is both innovative and inclusive.

Solutions must meet the magnitude of the problem and account for the reality that coastal hazards are indifferent to jurisdictional boundaries. While it may be the impulse of individual communities to tackle adaptation on their own, the scale of the challenge is much larger than any one community can take on. A coordinated regional effort can provide a platform for sharing ideas and resources, while also helping to identify the interdependencies between communities and the mutual benefits that can be gained from collaborative approaches to adaptation. The Southeast Florida Climate Change Compact is evidence of the role that regional collaboration can play in advancing knowledge of climate-related risks and approaches for adapting to these risks. Local communities in Southeast Florida, and the residents and businesses they serve, directly benefit from this collaboration. These entities will play a leading role in efforts to advocate for the mainstreaming of climate adaptation and resilience in relevant policy, programs and projects.

A regional strategy can also reduce individual risk and cost. Reducing the cost per property owner is critical to maintaining housing affordability and attractiveness in the region despite rising infrastructure expenses. While not quantified in this report due to a variety of uncertainties, both the systemic and building-level adaptation strategies could help to minimize the devaluation of real estate in the future. This would help to mitigate a variety of related effects such as foregone property taxes, increased cost and/or barriers to access insurance coverage and mortgage financing, loss of wealth and/or income for property and business owners and downgrades to municipal bond ratings (MGI 2020). These cascading effects from real estate devaluation could fundamentally alter the desirability of living and working in coastal communities, which in turn could result in the redistribution of populations and public and private investment all of which can have significant impacts to local, regional and state economies.

Key strategies that communities in the Southeast Florida region can take to evaluate and advance their capacity for economic resilience are discussed thematically below. Additional case study analyses follow the resilience strategy recommendations to illuminate some of the regional interdependencies that support the need for coordinated planning and investment.

Key Economic Resilience Strategies and Recommendations

Increase Climate Risk Awareness: Fundamental to resilience is increasing climate risk awareness. Information about climate change risks and their knock-on effects is not incorporated into most policies that govern public and private institutions. As a result, risky behavior is often incentivized and/or subsidized. At some point in the future, economic and financial realities will demand that climate risk is better accounted for in public and private sector policies and programs. To avoid significant shocks to the economies and communities in Southeast Florida, it will be important to introduce mechanisms that account for climate change-related risk in an orderly manner, informed by public sector and private sector collaboration and negotiation.

The public sector can continue to educate their citizens and businesses on coastal hazard risks through the continued funding and dissemination of climate science research and coastal hazard vulnerability and adaptation assessments. Because of the challenges associated with planning for and adapting to coastal hazard risks now and in the future, investment should be directed to technical assistance programs (e.g., Sea Grant[5]) that would pair qualified professionals with community planners and decision-makers to develop robust and actionable pathways for investing in adaptation and resilience.

The private sector can also play a role in increasing awareness of climate-related risks. For example, the real-estate industry could disclose coastal hazard risk by including flooding and

[5] The National Sea Grant College program was established by the U.S. Congress in 1966 and works to create and maintain a healthy coastal environment and economy. The Sea Grant network consists of a federal/university partnership between the National Oceanic and Atmospheric Administration (NOAA) and 33 university-based programs in every coastal and Great Lakes state, Puerto Rico, and Guam. The network draws on the expertise of more than 3,000 scientists, engineers, public outreach experts, educators and students to help citizens better understand, conserve and utilize America's coastal resources.

inundation maps prior to the point of sale of property. In 2018, the Natural Resources Defense Council (NRDC) undertook an analysis to identify and grade efforts taken by states to disclose flood risk exposure. Florida was given an “F” rating as the state has no statutory or regulatory requirements for sellers to disclose the flood risks of their property or past flood damages to a potential buyer. The analysis notes that while the Florida real estate industry has developed a disclosure form for sellers to use, the form is voluntary, as such the seller is not required to provide this information to a potential buyer. In 2019, the National Association of Realtors commissioned a survey to gather information on mandated disclosures related to flood hazards at the state level. The survey came to a similar conclusion to that found by the NRDC analysis. Important to note is that in the NRDC study, nearby states, including Mississippi and Louisiana were given an “A” rating. As an example, in Mississippi, the Real Estate Commission developed a mandatory seller disclosure form that requires the seller to divulge if any portion of a residence has experienced water damage for any reason, has been subject to water or moisture-related damage from flooding (and steps taken to mitigate this risk), and if the property is in a FEMA designated flood hazard zone. If flood insurance is required, the current cost and the last premium adjustment must be indicated. Because climate-related risk disclosure of this kind could result in a change in consumer behavior, one could argue that there is a disincentive for realtors to advocate for this type of disclosure. As such, it may fall on relevant decision-making and regulatory entities to require this form of disclosure in property transactions.

There are other avenues for increasing climate risk awareness, and the pricing of this risk in consumer decision-making and broader market transactions. For instance, the insurance industry could also include premium forecasts that account for increasing climate risks in their asset portfolios to encourage informed and responsible investment. The banking and mortgage financing industry could explicitly state in their loan terms that if a property becomes uninsurable due to hazard risk, the loan can go in default, or that they have the option to purchase insurance on behalf of the borrower and add this cost to the recurring mortgage payment. This purchase of insurance would protect the collateral of the financier, but likely at high cost to the borrower, so it would be preferred to have these expectations detailed in the loan terms to encourage responsible investment decision-making.

Invest in Key Vulnerable and Emerging Industries: Underlying industry vulnerabilities can stem from operating in close proximity to the coast and from the interdependencies between industries. The former in Southeast Florida would include industries that support tourism (e.g., lodging and dining, cruise ship terminals), while the latter would account for industries such as retail and attractions that may not be located on the coast but are patronized by coastal and ocean tourists, or industries that depend on broader supply chains or regional infrastructure that are vulnerable to coastal hazards.

Recent events have already shown how these vulnerabilities translate to economic losses to specific industries. It was estimated that Hurricane Irma cost Florida 1.8 million out-of-state visitors with a total economic loss of $2.5 billion to the tourism industry in 2017 (Tourism Economics, 2018), while NOAA’s 60-day regional evaluation of impacts from Irma to the fishing community estimated damages to vessel owners and businesses at over $95 million and revenue losses of nearly $98 million (NOAA, 2018). More recently, the Covid-19 pandemic has shown the magnitude of impacts that can result to tourism-related industries in Southeast Florida. These industries, which account for billions of dollars in economic impact annually, have been shuttered (temporarily) in many cases, resulting in significant impacts to businesses, employees and local, regional and state government.

It is of critical importance that businesses are in a position to continue their operations in as close to a business-as-usual environment when coastal hazards do occur. Businesses can act now to develop continuity plans that account for potential physical and economic impacts as well as potential responses and recovery mechanisms. Developing these plans can help businesses to minimize impacts to economic output and maintain their share of market activity when hazards occur. Business continuity plans should account for a number of factors including onsite vulnerabilities to coastal hazards, as well as offsite vulnerabilities such as impacts to lifeline infrastructure that can affect the ability of employees to get to work (e.g., transportation networks) or conduct their work (e.g., wastewater service provision). Businesses can also review what their insurance policy covers to determine if they are covered for both direct as well as indirect hazard impacts.

There are a number of resources that businesses can use to develop a continuity plan for coastal hazards, including information and tools developed by the U.S. Small Business Administration and the U.S. Department of Homeland Security. These resources can help business owners to identify key considerations for hazard-related preparedness planning, including, but not limited to, identifying an alternate location where work could be conducted, keeping inventory in a location that is not subject coastal hazard exposure, having a geographically diverse supply chain, and making investments in a back-up power source. Additionally, businesses can reach out to trade associations and other business organizations in their sector and/or industry to learn how others are preparing for and adapting to coastal hazard risks.

Protection and diversification are two other strategies for economic resilience for vulnerable industries. Southeast Florida is highly dependent on the economic activity generated from tourism, recreation, marine industries, ocean transportation, real estate and related industries, all of which are subject to the direct and indirect impacts of coastal hazards. Modeling of 2070 conditions found that the two most at-risk industries to sea level rise in the four counties were accommodation and food services (14 percent of annual output exposed) and retail (13 percent of annual output exposed). Continued efforts should be taken to identify the types of adaptation investments that will increase the resilience of these industries to coastal hazards. This could include investments to physically protect or relocate property so there is more redundancy and spatial distribution within industries.

Monies should also be directed to developing and attracting new industries to ensure that communities are prepared for changing environmental as well as economic conditions. Communities that are heavily reliant on a few industries (e.g., Monroe County – where the tourism sector employs about half of the workforce) should account for potential hazard vulnerabilities to these key industries. A common strategy for financial investors is to have a diversified portfolio which in turn can reduce the variability of returns and help to minimize overall risk when market conditions change. This investment strategy, known as the portfolio effect, is transferrable to many domains, including local and regional economies which can be subject to both gradual and abrupt changes, both natural and man-made. Research has shown that economic diversity can assist in weathering the downturn following natural hazards, helping to speed up the return to long-term patterns of employment and income growth (e.g., Xiao and Drucker 2014).

To further diversify the economies in Southeast Florida, invest in research and development by offering resources or incentives and continuing to partner with research institutions in the state. The resilience economy could create new occupations and a set of science-related industries to develop a host of applications for how to adapt to chronic interruptions and event-based hazards, such as how to prevent saltwater intrusion into aquifers. Better understanding of how the existing innovation ecosystem works and incubating opportunities that may still be largely unknown could minimize economic loss in the long-term. Universities are key partners in this and are already playing a critical role with research and development related to resilience, such as The Florida Climate Institute.

Develop an Occupational Roadmap to Resilience: Certain workers may be more vulnerable to coastal hazards such as workers in vulnerable industries, workers with less adaptable skillsets, lower wage workers, and workers who travel far to get to work. Many of the workers subject to the impacts of coastal hazards work in tourism-related businesses that underpin the economy of coastal communities. These individuals are often lower income, make close to the minimum wage, and do not live in the communities where they work. The literature on natural hazard impacts (e.g., Kroll, et al. 2018) demonstrates that higher-income households are better equipped to address the shocks of a disaster compared to lower-income households, and that natural disasters can further exacerbate economic and racial inequality (Elliot and Pais 2006). At the same time, recovery efforts and adaptation investments will favor certain occupations over others, such as emergency responders and construction workers, a field that already has high demand and impending labor shortages in the region as noted in the Resilient305 Strategy. Across the four counties, the systemic adaptation scenario modeled in REMI for this analysis estimated that over 14,400 jobs would be supported in the construction industry per year over the period of investment.

Communities should develop coordinated workforce and economic development initiatives to grow the local labor pool capable of providing the services needed to prepare for and recover from coastal hazard events. This includes individuals in specialized design, engineering and construction fields, as well as project management and administrative support roles. This would also include investment in education and placement services that link job training with job creation (NACO 2013). The importance of having a qualified, responsive and local workforce to address coastal hazard risks was discussed in a recent report authored by the Resilience Force and the New Florida Majority (2020). The report, “A People’s Framework for Disaster Response: Rewriting the Rules of Recovery after Climate Disasters”, recommends growing the resilience workforce with state and national job programs. Increasing the portion of response workers that are local could potentially keep more recovery funds in impacted communities, decrease some of the burden on supportive infrastructure (e.g., workers that came to support post-disaster in Florida faced challenges finding essential needs such as housing, food and water due to the property damages and business closures), and also expand job skills training and potential future income earning potential as disasters continue to occur with increasing frequency. Additionally, it can provide a faster road to recovery - Post Hurricane Irma, reconstruction efforts in the Florida Keys suffered due to the lack of professionals qualified to address the construction, electric, plumbing, and roofing needs.

An occupational roadmap to resilience could support efforts to prioritize workforce training investments and address current gaps in career resources. The Miami Foundation conducted a Workforce Asset Mapping Report (2020) to analyze Miami-Dade County's labor force and understand the short-term and long-term pipeline of workers to identify areas of investment and promote access to economic prosperity. The study engaged key stakeholders in focus groups and interviews and identified a number of barriers including a skills gap challenge whereby the workforce is concentrated in low-wage sectors, such as hospitality and tourism, and that these workers often lack the skills necessary to succeed in many in-demand fields such as maintenance and customer-service. Another key finding of the report was that there was no evidence of a region-wide career pathway system or occupational crosswalks to show the steps from a job that might be low-wage and at risk to automation to an occupation in a high-growth industry. The findings from the market research and stakeholder discussions led to recommendations for a subset of nine occupations selected out of 700 for the Miami region to focus investment, accounting for numerous factors including an emphasis on economic resilience and green jobs.

A quantitative workforce analysis that identifies occupations vulnerable to coastal hazards and pathways for skill development focused on the resilience economy could build upon methodologies that have been used to identify other occupation vulnerabilities, such as automation (e.g., Osborne and Frey 2013). To conduct the analysis, data could be collected on skills, abilities, and knowledge and evaluated to identify similarities across occupations and universal skills. A subset of industries could be focused on to examine the top quartile of industries that may fall under the broader umbrella of economic resilience and green jobs. Findings could be tailored to overlap with existing and projected economic conditions and coastal hazards and be offered as an interactive online resource as a career pathway system.

Engage with and Provide Support to the Small Business Community: Small businesses are foundational to local, regional, and state economies, employing on aggregate nearly half of the workforce of the United States. If small businesses in Southeast Florida's coastal communities are not prepared for coastal hazards, the impacts will be felt broadly. The fact that many small businesses have had to permanently shut their doors after a major disaster is of particular concern (IBHS 2005). Small businesses generally have fewer resources to develop an understanding of coastal hazard risks and to make detailed plans to assist in response and recovery when events occur. When small businesses are subject to the impacts of coastal hazards, they often lack the capital reserves, access to financing, or insurance coverage necessary to absorb a loss of income and the additional expenses that come with rebuilding. Further, small businesses that derive a majority of their income in specific times of the year (e.g., ocean and coastal tourism) face significant barriers to recovery if coastal hazards affect their operations in their peak season(s). As shown in Table 39 through Table 42[6], a majority of firms in the Southeast Florida are small businesses (i.e., less than 500 employees), illustrating the importance of having initiatives and resources dedicated to bolstering preparedness to coastal hazards.

According to a recently published article (Portero 2020), small businesses in South Florida were experiencing revenue losses of greater magnitude during the Covid-19 pandemic than nearly all other major U.S. metropolitan areas. The article cites data from Harvard University's Opportunity Insights Economic Tracker, which tracks consumer spending and small business revenues. As of the latter part of April 2020, the Miami-Fort Lauderdale metro area experienced a 62 percent decrease in revenue, which was a greater observed loss than all U.S. metros besides New Orleans, Boston, Washington D.C, Honolulu and San Francisco; nationwide, small business revenue fell approximately 40 percent over the same time period. The article points to the pandemic travel restrictions and temporary closure of leisure and hospitality businesses as key drivers for these revenue losses, industries that are also highly vulnerable to coastal hazards.

Streamlined access to capital and financing is critical to ensuring continued operations and related financial outcomes. These resources are needed to prepare for and respond to coastal hazards, requiring both private and public sector institutions that can provide these services in an expedited manner. These funding and financing entities, when possible, should explicitly account for the barriers faced by smaller businesses that lack financial documentation, collateral, and the required resources to be considered creditworthy and bankable. While the primary burden to develop business continuity plans is on the private sector, the public sector should actively advocate for and provide technical assistance to increase the adoption of such plans. Providing this support is fundamentally in the interest of the public sector, which is heavily dependent on revenues (e.g., sales taxes, property taxes) that are supported directly or indirectly by businesses.

Engaging with small businesses may be difficult given competing demands (Miami Foundation, 2020) but improved communications, such as through digital platforms, can help to serve as places for information exchange, both between the public and private sector. As noted in FEMA's 2017 Hurricane Season After-Action Report, which addressed lessons learned from Hurricanes Harvey, Irma, and Maria, "public and private sector response and recovery efforts were too 'stove piped' to share timely information, too slow to consult, and as a result, often too late to synchronize stabilization efforts." After an event, sending out an online survey to understand unmet needs could help to prepare for the next event. The County of Monroe conducted a survey post Hurricane Irma to better understand barriers to recovery – only 11

[6] Employment size data comes from the U.S. Census Bureau 2016 County Business Patterns, which was published in the middle of 2019. The Census Bureau defines a "firm" as a business organization consisting of one or more domestic establishments in the same state and industry that were specified under common ownership or control and an "establishment" as a single physical location at which business is conducted or services or industrial operations are performed.

percent of the responses came from businesses that had over 20 full or part-time employees. Such surveys can better help identify areas for investment in protection and future recovery efforts.

Table 39. Broward County Employment Size Characteristics

Number of Employees	% of Firms	% of Establishments	% of Employment
<20	89%	79%	21%
20-99	6%	6%	16%
100-499	2%	2%	13%
500+	3%	13%	50%
Total	100%	100%	100%

Note: Census Bureau 2016 County Business Patterns, published 2019.

Table 40. Miami-Dade County Employment Size Characteristics

Number of Employees	% of Firms	% of Establishments	% of Employment
<20	90%	81%	22%
20-99	6%	6%	16%
100-499	2%	3%	15%
500+	2%	11%	46%
Total	100%	100%	100%

Note: Census Bureau 2016 County Business Patterns, published 2019.

Table 41. Monroe County Employment Size Characteristics

Number of Employees	% of Firms	% of Establishments	% of Employment
<20	88%	81%	33%
20-99	6%	7%	26%
100-499	2%	3%	10%
500+	5%	10%	31%
Total	100%	100%	100%

Note: Census Bureau 2016 County Business Patterns, published 2019.

Table 42. Palm Beach County Employment Size Characteristics

Number of Employees	% of Firms	% of Establishments	% of Employment
<20	88%	79%	23%
20-99	7%	6%	19%
100-499	2%	3%	15%
500+	3%	12%	43%
Total	100%	100%	100%

Note: Census Bureau 2016 County Business Patterns, published 2019.

Strategically Prioritize Projects and Monitor Efficacy: While the adaptation strategies modeled in this study generally show that taking action to mitigate coastal hazard risk is economically justified (i.e., benefits outweigh the costs), there is a high price tag associated with the implementation of these strategies. Given the finite financial resources available for adaptation, communities and regions will be faced with difficult decisions on where investment should be directed, what types of adaptation projects should be pursued, when these investments should be made, and how much money should be borrowed to accelerate investments in resilience in a way that is commensurate with expected risks.

Efforts should be taken to develop criteria for investing in adaptation that responds to local community needs and that provides a transparent, standardized approach to project prioritization. Criteria can be tailored to include specific requirements that ensure local job creation, ongoing community lifeline services, and responsible and sustainable development (e.g., building regulations and codes). Any adaptation investment should be evaluated for potential tradeoffs and, where feasible, adaptation strategies should be designed to produce co-benefits (e.g., community amenities, access to open space).

Project planning for adaptation should follow a holistic approach. Identifying the linkages and interdependencies across planning institutions and their programs can assist in advancing both independent and collective resilience outcomes, including the ability to effectively prioritize and deploy funds to mitigate coastal hazards, and promote coordination when coastal hazard events occur. This includes advancing institutional capacity and coordination between the public and private sector with a systems view that acknowledges that when one element of the system is compromised, the entire system is weakened, and resilience is compromised. To this end, plans for economic development, workforce development, land-use, capital improvements and hazard mitigation should be aligned where feasible. The Resilience Officers and related professionals working in the region can continue to play a key role in supporting ongoing coordination in climate resilient planning and investment.

Community lifelines, such as energy, water, transportation, and communications infrastructure, as well as emergency shelter and health and medical facilities are core to maintaining a functional economy and society. As identified in the exposure assessment (see Table 5 though Table 8), there are a significant number of community lifeline assets at risk to the modeled coastal hazards, including 65 power plants and substations vulnerable to a 10-year storm under 2070 conditions. Previous studies (e.g., Brattberg and Sundelius 2011, Chang et al. 2002, Okuyama 2007, Deshmukh et al. 2011) show that when these assets are compromised, there can be far-reaching direct and indirect consequences to society. To this end, funding should be dedicated to further assess the vulnerabilities of these assets to coastal hazards, and the way in which these assets support economic activity. Because of the varied investment needs and finite financial resources available, it will be important to have a coordinated body of representatives from lifeline agencies, non-governmental organizations and the business community to develop consensus on what infrastructure investments should take priority, and to further advocate for new funding to shore up the vulnerabilities faced by these assets and facilities.

To ensure that future adaptation projects provide their intended return on investment, the effectiveness of implemented adaptation strategies should be evaluated where feasible. To begin to quantify effectiveness, it will be critical to understand business-as-usual conditions. To this end, communities could establish a database of businesses and other community lifelines (e.g., wastewater treatment plants, key transportation corridors) and use this inventory as a benchmark for measuring the effectiveness of adaptation and recovery actions. This database could also include information on which businesses and assets are expected to be most vulnerable to coastal hazards, which can assist communities in targeting the deployment of resources in support of adaptation and disaster response (EDA 2014).

Ongoing data should then be collected in the event of coastal hazards. Efforts can be taken to quantify the avoided impacts resulting from past investments in adaptation and compare them to the expected mitigation benefits that these adaptation investments were intended to provide. Communities can also track the efficacy of resources intended to meet the needs of disadvantaged populations. To support real time data collection, the public sector/communities will need to establish communication systems that can facilitate the exchange of information before, during and after a hazard event as well as technologies such GIS, LIDAR, drones, and crowd sourced platforms that can enable a cost-effective and real-time assessment of impacts.

Findings and lessons learned from ongoing monitoring and evaluation can help communities tailor their future adaptation strategies to provide an equitable and positive return on investment. Communities have a variety of resources that they can draw from to develop a measuring and monitoring framework, such as the frameworks developed by the United Nations Development Program (UNDP 2009, 2009) or the C40 Cities Climate Leadership Group (2019).

Develop Actionable Funding and Financing Plans to Pay for Resilience: The risks posed by a changing climate are too great for any one sector to take on alone, and the benefits provided by making investments in climate resilience are shared across sectors. As such, considerations on how to fund and finance adaptation and resilience should be made with an eye towards all of the entities that would benefit from or would be most suitable to paying for such investments, including public and private sector actors. For any funding strategy, it is critical to consider the capacity for specific individuals and populations to bear the burden of anticipated costs.

Funding and financing adaptation can be particularly challenging due to the existing, and at times, competing, financial demands private sector and public sector entities face. Additional challenges relate to laws and regulations that place barriers to raising new sources of revenue or constraints on how existing revenue sources can be deployed. To address these challenges, a panel of regional experts across economic development, public and private finance, land use planning, among others, could be convened to evaluate and recommend the most promising funding and financing tools for advancing investment in adaptation and resilience.

A mix of funding and financing tools will be required to pay for adaptation and resilience. Many of these tools are already widely used in Florida to pay for infrastructure, including general obligation bonds, revenue bonds, tourist development taxes, grants, and special assessments. Additional tools may be considered based on the type of project. There are strengths, weaknesses, and limitations to different funding and financing tools related to a wide variety of factors such as what they can be used for (e.g., transportation, capital vs operations and maintenance) and whether or not they are subject to referendum approval. Some key questions to help identify appropriate funding and financing tools are shown in Table 43, along with specific tools that may be suitable as a piece of a funding and financing plan.[7,8]

Many funding tools can be regressive and burden certain populations over others, if not implemented strategically. Commonly applied social equity principles related to raising funds include: the benefits principle, in which charges are imposed relative to the services that are received, and the ability-to-pay principle, in which income is accounted for in determining appropriate charges. Relating to how money is spent, common principles include market equity, opportunity equity, and outcome equity. Market equity relates to whether the spending of the funds is proportional to who is paying for the project. Opportunity equity means spending is distributed evenly, such as equally between jurisdictions. Outcome equity means spending is based on the outcome for each payer, for example the same protection from sea level rise for each jurisdiction (Taylor 2004). When developing a funding and financing plan, consider these equity principles and work with community stakeholders to understand other equity implications.

Table 43. Considerations for Suitability of Funding and Financing Tools for Adaptation and Resilience Projects in Florida

Question	Potential Suitable Funding and Financing Tools
Does the project confer specific quantifiable benefits to certain properties? Alternatively, does the project provide a public purpose and broad general benefit?	For projects that directly benefit specific properties, a special assessment may be well suited for the project. For large general public benefit projects, a general obligation bond or ad valorem tax may be well suited.
Does the project support infrastructure for new development?	If yes, impact fees may be well suited for the project.
Will the project result in quantifiable benefits that increase property value?	If yes, tax increment financing may be well suited for the project.
Does the project support stormwater and drainage systems?	If yes, special assessments and stormwater and drainage fees may be well suited for the project.
Does the project support to beach nourishment or erosion control?	If yes, local governments could use ad valorem taxes and Municipal Services Taxing Units (MSTUs). Local governments can also levy tourist development taxes which can be used to finance beach improvement, nourishment, restoration, and erosion control.
Does the project generate significant cost savings or avoided damages?	If yes, a pay-for-success financing tool may be well suited for the project.
Does the project generate revenue?	If yes, a public-private partnership may be well suited for the project.
Does the project support road construction and maintenance?	If yes, special assessments and Charter County and Regional Transportation System Surtaxes, and fuel taxes may be used.

[7] Information in this table was identified from a range of reports, in particular Florida's "Local Government Financial Information Handbook" (2019), Florida Sea Grant "Sea Level Rise Adaptation Financing at the Local Level" (2015), Florida Environmental and Land Use Law Section "Sea Level Rise Adaptation Funding Sources" (2017), and Harvard Kennedy School of Government "Financing Climate Resilience: Funding and Financing Models for Building Green and Resilient Infrastructure in Florida" (2019).

[8] Additional research on what funding and financing tools are being leveraged to support on-the-ground coastal adaptation and resilience in Southeast Florida, including lessons learned, could further support community and regional investment decision-making; this type of effort would require jurisdictional interviews which were beyond the scope of this analysis.

Question	Potential Suitable Funding and Financing Tools
Does the project plan, restore, or manage urban forest resources, greenways, forest preserves, wetlands, or other aquatic zones?	If yes, a green utility fee may be suitable for counties with a population of 500,000 or more and municipalities with a population of 200,000 or more.
Does the project include land acquisition for protection of natural resources?	For general infrastructure capital funding and financing, local governments may look to the Local Government Infrastructure Surtax which allows a county to levy a 0.5 or 1.0 percent tax if majority electorate approval in a referendum to finance, plan, and construct infrastructure and to acquire land for protection of natural resources.
Does the project aim to preserve/conserve land in a specific area?	If yes, Transferable Development Rights (TDR) may be well suited. TDRs allow landowners to sell development rights in ecologically valuable areas or sensitive lands to areas where development is more encouraged.

Case Studies

Employment Density by Industry

For illustrative purposes, an analysis was undertaken to identify the 3 zip codes in each Southeast Florida county that have the greatest number of employees working at businesses that are expected to be directly impacted by the modeled 2040 10-year storm conditions. Note that these values represent the total number of reported employees at impacted locations. However, not all workers will be impacted in a manner that will prevent them from conducting their work onsite, and some workers will be able to conduct work offsite. For instance, in a multi-story building, employees on the ground floor would experience direct impacts from storm flooding making work onsite unlikely until sufficient repairs are undertaken. Employees working on higher floors, however, may only face indirect impacts and could return to work on site in short order (e.g., need to take stairs until repairs are made to elevators).

As shown in Table 45 through Table 48 below, the concentration of industries subject to coastal storm impacts is not homogenous within or across counties, but some common themes do emerge. In particular, there are a high number of impacted employees in industries that directly support coastal and ocean tourism (e.g., accommodation and food services; arts, entertainment and recreation; and retail trade). High impacts to these industries would be expected, as noted in the discussion of key characteristics and attractions located in the identified zip codes in each Southeast Florida County. Additionally, as shown in Table 44, anywhere from 10 percent to 40 percent of employees working in the zip codes evaluated commute 25 miles or more (one-way) to get to work (U.S Census Bureau, Longitudinal Employer-Household Dynamics [LEHD] database). It follows that many impacted workers live in other municipalities or even counties, and that barriers to working and getting paid could have cascading impacts to economies throughout the Southeast Florida region.

Table 44. Distance Traveled by Employees Working at Locations Subject to 2040 10-Year Coastal Storm Conditions for Zip Codes with Greatest Number of Impacted Employees

County	Zip Code	Less than 10 Miles	10 to 24 Miles	25 to 50 Miles	> 50 Miles
Broward	33301	50%	33%	8%	9%
	33004	46%	32%	8%	14%
	33316	50%	34%	7%	10%
Miami-Dade	33139	52%	33%	6%	9%
	33140	54%	37%	4%	5%
	33131	43%	40%	7%	10%
Monroe	33040	62%	7%	6%	25%
	33042	59%	18%	3%	21%
	33050	51%	9%	12%	28%
Palm Beach	33480	54%	23%	8%	15%
	33401	43%	28%	13%	17%

County	Zip Code	Less than 10 Miles	10 to 24 Miles	25 to 50 Miles	> 50 Miles
	33432	46%	30%	11%	14%

In Broward County, zip code 33301 contains a significant portion of downtown Fort Lauderdale, as well as the waterfront neighborhoods of Seven Isles, Idlewyld, Hendricks and Venice Isles, among others. This zip code also contains important public buildings, such as the Broward County Courthouse and Broward County Main Library. Zip code 33004 encompasses the City of Dania Beach, part of the Fort-Lauderdale-Hollywood International Airport, and the Dr. Von D. Mizell-Eula Johnson State Park. Zip code 33316 contains Port Everglades, an important port for both shipping containers and the cruise industry. In addition, the Broward County Convention Center, several beachfront hotels, and waterfront residential neighborhoods of Harbor Beach, Lauderdale Harbors, and Rio Vista are within this zip code.

Table 45. Number of People Employed at Businesses Subject to Impacts from 2040 10-year Coastal Storm Conditions for Zip Codes with Greatest Number of Impacted Employees, Broward County

NAICS Industry	# of Employees at Impacted Businesses: 33301 Zip Code	NAICS Industry	# of Employees at Impacted Businesses: 33004 Zip Code	NAICS Industry	# of Employees at Impacted Businesses: 33316 Zip Code
Professional and technical services	1,480	Arts, entertainment, and recreation	415	Health care and social assistance	180
Administrative and waste services	140	Educational services	125	Professional and technical services	160
Accommodation and food services	85	Retail trade	120	Other services, except public administration	115
Other services, except public administration	65	Administrative and waste services	100	Arts, entertainment, and recreation	85
Arts, entertainment, and recreation	60	Professional and technical services	60	Accommodation and food services	80
All other industries	195	All other industries	160	All other industries	105
Total Employees	**2,020**	**Total Employees**	**980**	**Total Employees**	**720**

Notes:

Employees rounded to nearest 5.

In Miami-Dade County, zip code 33139 is home to the world-famous South Beach and Miami Beach, which attract visitors from across the globe. This area boasts beaches, a vibrant nightlife, and an Art Deco historic district. The neighboring zip code to the north, 33140, is home to Bayshore, Mid-Beach, Nautilus, and La Gorce. Two golf courses, numerous beachfront hotels, and the Mt. Sinai Medical Center are located within this zip code. Zip code 33131 contains Downtown Miami, that is host to a variety of industries and is a draw for tourists.

Table 46. Number of People Employed at Businesses Subject to Impacts from 2040 10-year Coastal Storm Conditions for Zip Codes with Greatest Number of Impacted Employees, Miami-Dade County

NAICS Industry	# of Employees at Impacted Businesses: 33139 Zip Code	NAICS Industry	# of Employees at Impacted Businesses: 33140 Zip Code	NAICS Industry	# of Employees at Impacted Businesses: 33131 Zip Code
Accommodation and food services	1,115	Public administration	225	Accommodation and food services	580
Retail trade	1,095	Accommodation and food services	220	Real estate and rental and leasing	225
Real estate and rental and leasing	420	Arts, entertainment, and recreation	185	Other services, except public administration	35
Other services, except public administration	350	Health care and social assistance	95	Professional and technical services	35
Professional and technical services	240	Real estate and rental and leasing	80	Retail trade	30
All other industries	1,145	All other industries	265	All other industries	85
Total Employees	**4,360**	**Total Employees**	**1,075**	**Total Employees**	**985**

Notes:

Employees rounded to nearest 5.

In Monroe County, zip code 33040 contains Key West, the Naval Air Station, historical tourist attractions, and a U.S. Coast Guard station. Zip code 33042 contains Sugarloaf Key, Upper Sugarloaf Key, Big Torch Key, and Middle Torch Key to name a few. Many hotels and the Summerland Key Cove Airport operate within this zip code. Zip code 33050 is home to the towns of Marathon and Key Colony Beach, among others. This area boasts recreational options such as Sombrero Beach, golf courses, animal sanctuaries and aquariums, and The Florida Keys/Marathon International Airport.

Table 47. Number of People Employed at Businesses Subject to Impacts from 2040 10-year Coastal Storm Conditions for Zip Codes with Greatest Number of Impacted Employees, Monroe County

NAICS Industry	# of Employees at Impacted Businesses: 33040 Zip Code	NAICS Industry	# of Employees at Impacted Businesses: 33042 Zip Code	NAICS Industry	# of Employees at Impacted Businesses: 33050 Zip Code
Public administration	1,325	Accommodation and food services	35	Retail trade	15
Educational services	100	Construction	10	Information	10
Other services, except public administration	30	Educational services	5	Construction	5
Arts, entertainment, and recreation	25	Retail trade	5	Accommodation and food services	5
Construction	20	Real estate and rental and leasing	5	Professional and technical services	5
All other industries	35	All other industries	5	All other industries	5
Total Employees	**1,535**	**Total Employees**	**65**	**Total Employees**	**50**

Notes:

Employees rounded to nearest 5.

In Palm Beach County, zip code 33480 contains the City of Palm Beach, and is home to many beachfront hotels and clubs, golf courses, and residences. Zip code 33432 also boasts expansive beaches and contains parts of Boca Raton and Deerfield Beach. In addition to beach clubs and golf clubs, this zip code is home to shopping centers such as Mizner Park mall and cultural attractions such as the Boca Raton Museum of Art and the Mizner Park Cultural Center. Zip code 33401 contains the downtown area of the city of West Palm Beach, the most populous city in Palm Beach County.

Table 48. Number of People Employed at Businesses Subject to Impacts from 2040 10-year Coastal Storm Conditions for Zip Codes with Greatest Number of Impacted Employees, Palm Beach County

NAICS Industry	# of Employees at Impacted Businesses: 33480 Zip Code	NAICS Industry	# of Employees at Impacted Businesses: 33401 Zip Code	NAICS Industry	# of Employees at Impacted Businesses: 33432 Zip Code
Accommodation and food services	2,260	Professional and technical services	225	Real estate and rental and leasing	135
Professional and technical services	445	Health care and social assistance	110	Accommodation and food services	60
Finance and insurance	380	Wholesale trade	95	Professional and technical services	50
Retail trade	320	Public administration	80	Health care and social assistance	40
Health care and social assistance	290	Accommodation and food services	55	Finance and insurance	20
All other industries	625	All other industries	185	All other industries	100
Total Employees	**4,320**	**Total Employees**	**750**	**Total Employees**	**400**

Notes:

Employees rounded to nearest 5.

Roadway Impacts

To illustrate the vulnerabilities of core lifeline infrastructure of regional importance, an assessment was undertaken to identify heavily used major roadways that are subject to modeled coastal hazards in this study. Specifically, the modeled 10-year storm conditions for 2020, 2040 and 2070 were evaluated to determine impacts on vehicle access, connectivity, and commuting. One case study was chosen for each of the Southeast Florida counties. Data on traffic flows was retrieved from the Florida Department of Transportation (FDOT) Roadway Characteristics datasets and data on commuting was sourced from the U.S. Census Bureau's LEHD database.

An important caveat of this analysis is that the exposure of roadways does not account for the expected depth of flooding. In some cases, depth of flooding could potentially be shallow enough to allow for vehicle access. However, shallow flooding would still cause substantial slowdowns and congestion, especially for highly trafficked roadways. For the purpose of this analysis, it was assumed that selected roadways subject to flooding are completely cut off. Additionally, exposure was only assessed for major roads. Major roads are defined as those that are included within FDOT's statewide Roadway Characteristics datasets. In general, this dataset includes all highways, major corridors, and major/minor arterials, but does not include local neighborhood roads or roads within suburban blocks. To determine if an area was cut off by flooding, a visual inspection of satellite imagery was used to confirm that there were no alternate routes using local roads. However, in figures displaying exposed roadways, only major roads are shown.

Palm Beach Coastal Communities

Palm Beach County

While Palm Beach County's topography is such that compared to the other three counties, less inland area is vulnerable to the modelled coastal hazard conditions, the communities situated on barrier islands along the coast are very vulnerable to coastal hazards. Impacts to road network connectivity are especially acute because along the barrier islands, there are frequent choke points where only a single road runs north to south. If that road is flooded, even for just a short stretch, this could cut off vehicle access for large areas.

For example, under 2040 10-year storm conditions, access to more than 3 miles of barrier islands, running from Ocean Ridge in the south to portions of Palm Beach in the north, could be cut off. Figure 7 shows this area, along with the timing of vulnerability to major roads, with access points indicated. Table 49 summarizes each of the access routes, when they are projected to be impacted, and the average daily traffic as counted by FDOT in 2018. In addition to direct impacts on access (including access for emergency vehicles), 3,100 people commute into this area and 1,800 people leave this area for work, meaning that access to almost 5,000 jobs could be cut off under 2040 10-year storm conditions.

Figure 7. Major Roads Impacted by 10-year Storm Conditions and Key Access Routes Palm Beach Barrier Islands

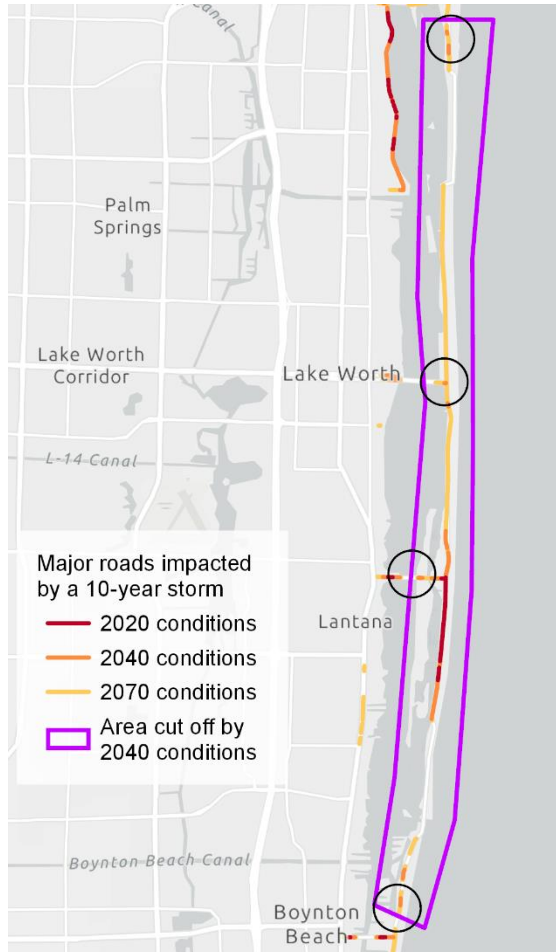


Table 49: Summary of Access Routes to Palm Beach Coastal Communities

Access Route (south to north)	Average Annual Daily Traffic (2018)	Horizon Year Impacted by 10-year Storm Conditions
Ocean Blvd / SR A1A	6,400	2040
East Ocean Ave	11,300	2020
Lake Ave / SR 802	12,100	2040
Ocean Blvd / SR A1A	9,700	2040

Downtown Fort Lauderdale

Broward County

Downtown Fort Lauderdale is a major economic center for both Broward County and the Southeast Florida region. Most of this dense central business district is vulnerable to flooding under 2040 10-year storm conditions with a few major roads already vulnerable to flooding under 2020 conditions. Table 50 and Table 51 summarize under which condition each street is projected to be impacted, and the average daily traffic as counted by FDOT in 2018.

Table 50: Summary of East/West Streets in Downtown Fort Lauderdale

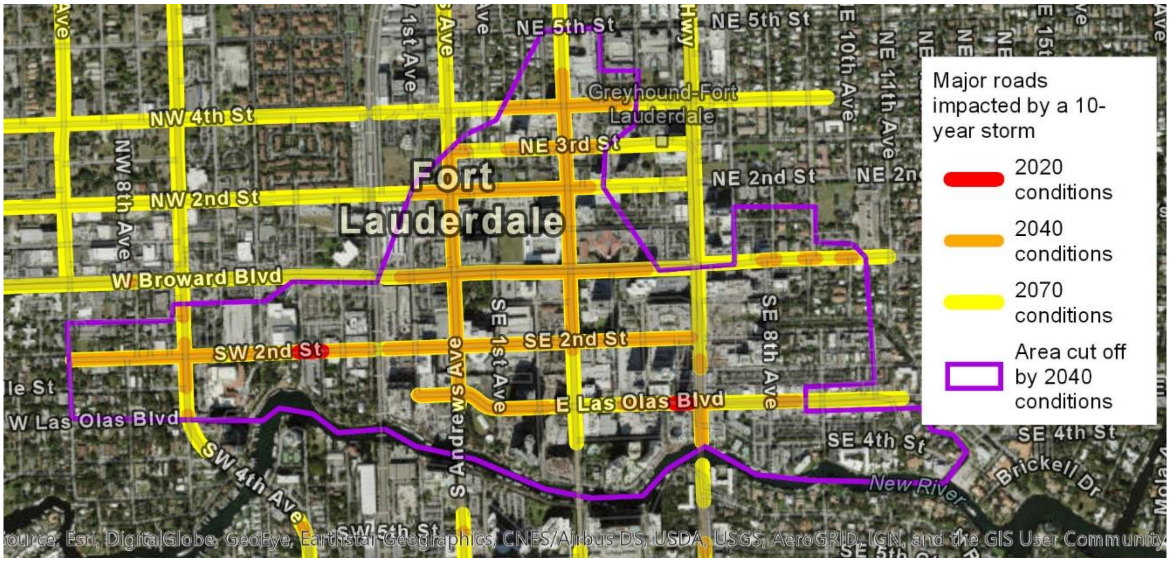
East/West Streets (from north to south)	Average Annual Daily Traffic (2018)	Horizon Year Impacted by 10-year Storm Conditions
NE 4th St	3,500	2040
NE 3rd St	2,400	2040
NE 1st St	No data	2040
E Broward Blvd / SR 842	37,000	2040
SE 2nd St	10,800	2020
E Las Olas Blvd	14,300	2020

Table 51: Summary of North/South Streets in Downtown Fort Lauderdale

North/South Streets (from west to east)	Average Annual Daily Traffic (2018)	Horizon Year Impacted by 10-year Storm Conditions
N Andrews Ave	16,800	2040
NE 3rd Ave	25,500	2040
Federal Hwy / US-1	47,500	2040

Even though the area to which access would be cut off under 2040 10-year storm conditions is only 0.5 square miles, 27,600 people commute into this area to work (LEHD 2017). Figure 8 shows major roads impacted by horizon year, area subject to flooding by horizon year, as well as the area could be cut off under 2040 10-year storm conditions. Note that the impacted area includes the Riverwalk Linear Park and Downtown Riverwalk District.

Figure 8: Major Roads Impacted by 10-year Storm Conditions in Downtown Fort Lauderdale



Miami Beach

Miami-Dade County

Miami Beach is both a residential and employment center that is particularly vulnerable to coastal flooding. Vehicular access to the area is limited to six routes. Three of these are vulnerable to flooding under 2020 10-year storm conditions, on/off ramps to I-195 could become partially blocked, and the other two routes are vulnerable under 2040 10-year storm conditions. Some of the impacted roads are also evacuation routes. In the event of storms coinciding with high tides, evacuating times could be affected.

Based on current traffic patterns, if commuters are forced to take one of the northern routes, this could add up 1 hour to a rush hour commute between downtown Miami and downtown Miami Beach. Note that this estimate does not account for the added congestion associated with other commuters re-routing as well. In the area cut off under 2040 10-year storm conditions, which includes Surfside and Bal Harbor in addition to Miami Beach, 50,400 people commute in from outside, and 29,000 people commute from the area to work elsewhere (LEHD 2017). This means that under 2040 10-year storm conditions, access to almost 80,000 jobs could be blocked by flood waters.

Figure 9: Major Roads Impacted by 10-year storm Conditions and Key Access Routes to Miami Beach

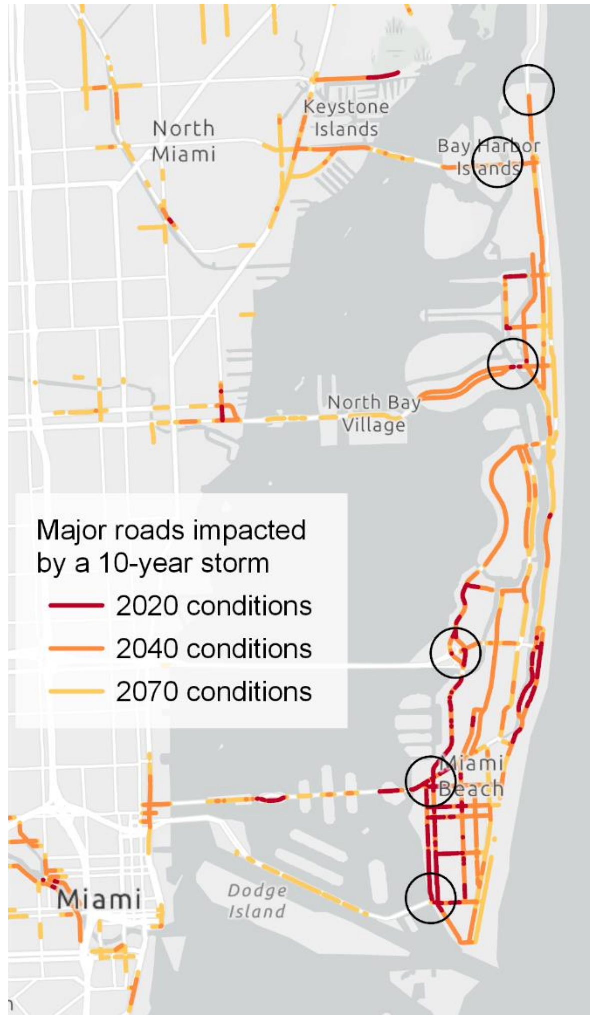


Table 52 summarizes the six access routes, under which condition they are projected to be impacted, and the average daily traffic as counted by FDOT in 2018. In some cases, while the bridges crossing Biscayne Bay are not impacted, all routes to access a bridge are impacted.

Table 52: Summary of access routes to the Miami Beach area

Access Route (south to north)	Average Annual Daily Traffic (2018)	Horizon Year Impacted by 10-year Storm Conditions
SR A1A / MacArthur Causeway	66,000	2020
Venetian Way / Dade Blvd	12,400	2020
I-195	115,000	2040*
SR 934 / NE 79th St	10,500	2020
SR 922 / NE 123rd St	31,500	2040
SR A1A / Collins Ave	46,500	2040

Notes:
*Some onramps/offramps impacted by 2020

Lower Matecumbe Key

Monroe County

The majority of the Florida Keys are connected to the mainland, and to each other by the US-1. Preventing flooding on this road is of critical importance, both to the local economy and for evacuation planning. Most of the highway is well above sea level, but under 2070 10-year storm conditions there are several stretches that could be subject to flooding. One particularly long stretch is in Lower Matecumbe Key, where more than 2.5 miles of US-1 are vulnerable to flooding. As Lower Matecumbe Key is a narrow strip of land, there are no alternative routes and during flood events, access to the rest of the southwestern Keys, including Key West, would be completely cut off.

This stretch of the US-1 has a traffic volume of 15,100 vehicles per day on average (FDOT 2018). In the region southwest of Lower Matecumbe Key, 6,800 people commute in from outside, and 10,400 people commute from the area to work elsewhere (LEHD 2017), meaning that under 2070 10-year storm conditions, access to more than 17,000 jobs could be blocked. In addition, access for the 19,200 people who live and work within the area would likely also be impacted by additional flooding points along the US-1.

Figure 10: Major roads impacted by the 10-year storm by horizon year on Lower Matecumbe Key

7. References

Aerts, J.C., Barnard, P.L., Botzen, W.J., Grifman, P., Hart, J.A., Moel, H.D., Mann, A.N., Ruig, L.T., & Sadrpour, N. (2018). Pathways to Resilience: Adapting to Sea Level Rise in Los Angeles. Annals of the New York Academy of Sciences, 1427 1*, 1-90.*

Aerts, J.C., Botzen, W.J., Emanuel, K., Lin, N., Moel, H.D., & Michel-Kerjan, E.O. 2014. Evaluating Flood Resilience Strategies for Coastal Megacities. Science, *344*, 473-475.

American Shore and Beach Preservation Association (ASBPA). 2017. National Beach Nourishment Database.

Bernstein, A., Gustafson, M.T., & Lewis, R. 2019. Disaster on the Horizon: The Price Effect of Sea Level Rise. Journal of Financial Economics 134.2: 253-272.

Bin, O., & Polasky, S. 2004. Effects of Flood Hazards on Property Values: Evidence Before and After Hurricane Floyd. Land Economics, 80*,* 490 - 500.

Bin, O, & Kruse, J.B. 2006. Real Estate Market Response to Coastal Flood Hazards. Natural Hazards Review 7.4: 137-144.

Bin, 0., Kruse, J.B., & Landry, C.E. 2008. Flood Hazards, Insurance Rates, and Amenities: Evidence from the Coastal Housing Market. Journal of Risk and Insurance 75.1: 63-82.

Bin, O., Crawford, T.W., Kruse, J.B., & Landry, C.E. (2008). Viewscapes and Flood Hazard: Coastal Housing Market Response to Amenities and Risk. Land Economics, 84*,* 434 - 448.

Brattberg, E., & Sundelius, B.A. 2011. Mobilizing for International Disaster Relief: Comparing U.S. and EU Approaches to the 2010 Haiti Earthquake. Journal of Homeland Security and Emergency Management, 8.

Broward County Environmental Planning and Community Resilience Division. 2018. Proposed Minimum Seawall Height Policy.

Broward County GeoHub. 2020. Broward County Hospitals.

Broward County GeoHub. 2020. Broward County Emergency Shelters.

Broward County, Environmental Planning and Community Resilience Division. 2018. Proposed Minimum Seawall Height Policy.

Bureau of Labor Statistics, Broward County and Miami-Fort Lauderdale-West Palm Beach, FL MSA. 2017. Annual Averages from the Quarterly Census of Employment and Wages.

C40 Cities: 2019. Measuring Progress in Urban Climate Change Adaptation: Monitoring, Evaluating, Reporting Framework.

Centers for Disease Control and Prevention (CDC). The Social Vulnerability Index.

The Center for Climate Integrity Resilient Analytics. 2019. High Tide Tax: The Price to Protect Coastal Communities from Rising Seas.

The Council for Adult and Experiential Learning. 2020. The Greater Miami Workforce Asset Mapping Report.

Chang, S.E., Svekla, W., & Shinozuka, M. 2002. Linking Infrastructure and Urban Economy: Simulation of Water-Disruption Impacts in Earthquakes. Environment and Planning B-planning & Design, 29, 281-301.

Consumer Price Index. 2019. U.S. City Average All Urban Consumers (CPI-U): All Items.

Deshmukh, A., Oh, E.H., & Hastak, M. 2011. Impact of Flood Damaged Critical Infrastructure on Communities and Industries. Built Environment Project and Asset Management, 1(2):156-175.

Elliot, J.R., & Pais, J. 2006. Race, Class, and Hurricane Katrina: Social Differences in Human Response to Disaster. Journal of Social Science Research.

Environmental Systems Research Institute (ESRI). 2019. Business Analyst.

Federal Emergency Management Agency (FEMA). 2018. 2017 Hurricane Season FEMA After-Action Report.

Federal Emergency Management Agency (FEMA). 2016. Benefit-Cost Sustainment and Enhancements: Baseline Standard Economic Value Methodology Report.

Federal Emergency Management Agency (FEMA). 2013. Selecting Appropriate Mitigation Measures for Floodprone Structures.

Federal Emergency Management Agency (FEMA). 2013. Multi-hazard Loss Estimation Methodology Flood Model Technical Manual.

Federal Emergency Management Agency (FEMA). 2013. Selecting Appropriate Mitigation Measures for Floodprone Structures.

Federal Emergency Management Agency (FEMA). 2013. Multi-hazard Loss Estimation Methodology Earthquake Model Technical Manual.

Federal Emergency Management Agency (FEMA). 2012. Final Sustainability Benefits Methodology Report.

Federal Emergency Management Agency (FEMA). 2009. Homeowner’s Guide to Retrofitting. Second edition.

Florida Department of Environmental Protection (DEP). 2018. Strategic Beach Management Plan: Florida Keys Region.

Florida Department of Revenue. 2020. Florida History of Local Sales Tax and Current Rates.

Florida Department of Revenue. 2019. Index of Tax Roll Data Files.

Florida Department of Revenue, Property Tax Oversight. 2018. Statewide Property Tax Overview.

Florida Department of Transportation, Transportation Data and Analytics Office. 2019. RCI Features & Characteristics Handbook.

Florida Environmental and Land Use Law Section. 2017. Sea Level Rise Adaptation: Funding Sources.

Florida Legislature Office of Economic and Demographic Research (EDR). 2019. Local Government Financial Information Handbook.

Florida Legislature Office of Economic and Demographic Research (EDR). 2015. Economic Evaluation of Florida's Investment in Beaches.

Florida Ocean Alliance (FOA). 2020. Securing Florida's Blue Economy: A Strategic Policy Plan for Florida's Oceans and Coasts (Draft).

Florida Ocean Alliance (FOA). 2013. Florida's Oceans and Coasts: An Economic and Cluster Analysis.

Florida Revenue Estimating Conference. 2020. Florida Tax Handbook Including Fiscal Impact of Potential Changes.

Florida Wildlife Research Institute. Florida Shoreline (1 to 2,000,000 Scale).

Frey, C.B., & Osborne, M.A. 2017. The future of employment: How susceptible are jobs to computerisation?

GEI Consultants, Inc. 2015. COAST Modeling for Broward County, Florida. Final Report for the University of South Florida.

Heberger, M.G., Cooley, H., Herrera, P., & Gleick, P.H. 2009. The Impacts of Sea-Level Rise on the California Coast.

The Institute for Business & Home Safety (IBHS). 2005. Open for Business: A Disaster Planning Toolkit for the Small to Mid-Sized Business Owner.

Keenan, J.M., Hill, T., & Gumber, A. (2018). Climate gentrification: from theory to empiricism in Miami-Dade County, Florida. Environmental Research Letters, 13, 054001.

Kroll, C., Lu, B., Olsem, A., & Wein, A. 2018. An Analysis of the Economic Effects of the HayWired Scenario Using the ABAG REMI Model (Draft).

McAlpine, S.A., & Porter, J.R. 2018. Estimating Recent Local Impacts of Sea-Level Rise on Current Real-Estate Losses: A Housing Market Case Study in Miami-Dade, Florida. Population Research and Policy Review, 37, 871 - 895.

McKinsey Global Institute (MGI). 2020. Will Mortgages and Markets Stay Afloat in Florida.

Monroe County. 2019. Hurricane Irma Business Recovery Unmet Needs Survey.

Monroe County. Irma: Business and Tourism Revitalization.

Miami-Dade County Open Data Hub. 2018. Port Boundary.

Miami-Dade County Open Data Hub. 2020. Hospital facilities.

National Association of Counties (NACO). 2013. Strategies to Bolster Economic Resilience: County Leadership in Action.

National Association of Realtors. 2019. State Flood Hazard Disclosure Survey.

National Beach Nourishment Database. American Shore & Beach Preservation Association, Regional Sediment Management Program, APTIM.

National Oceanic and Atmospheric Administration (NOAA). Tides and Currents. Lake Worth Pier, Atlantic Ocean, FL - Station ID: 8722670

National Oceanic and Atmospheric Administration (NOAA). 2018. NOAA Releases Economic Impact Evaluations for Hurricanes Irma and Maria Disasters.

Natural Resources Defense Council (NRDC). 2018. How States Stack Up on Flood Disclosure.

Office of Management and Budget (OMB). 2017. North American Industry Classification System (NAICS) Manual.

O'Connell, L., & Connors, K. 2019. Financing Climate Resilience: Funding and Financing Models for Building Green and Resilient Infrastructure in Florida. Harvard University. Prepared for the Florida Chapter of The Nature Conservancy.

Okuyama, Y. 2007. Economic Modeling for Disaster Impact Analysis: Past, Present, and Future. Economic Systems Research, 19, 115 - 124.

Portero, A. 2020. South Florida Small Business Sustained Greater Losses During Covid-19 than US Average. South Florida Business Journal.

Regional Economic Models, Inc. (REMI). 2020. REMI PI+ Model.

Resilience Force and the New Florida Majority. 2020. A People's Framework for Disaster Response: Rewriting the Rules of Recovery after Climate Disasters.

Resilient Greater Miami and The Beaches. 2019. Resilient 305.

RSMeans. 2019. Square Foot Costs with RSMeans Data. 41st Edition.

Ruppert, T., & Stewart, A, 2015. Sea-Level Rise Adaptation Financing at the Local Level in Florida. Prepared in part by Florida Sea Grant.

Southeast Florida Climate Change Compact. 2019. Updated Southeast Florida Regional Climate Change Compact Recommended Sea Level Rise Projections.

Southeast Florida Regional Climate Change Compact Inundation Mapping and Vulnerability Assessment Work Group. 2012. Analysis of the Vulnerability of Southeast Florida to Sea Level Rise.

State of Florida. 2020. Florida Tax Handbook: Including Fiscal Impact of Potential Changes.

Sweet, W.V., Kopp, R.E., Weaver, C.P., Obeysekera, J.T., Horton, R.M., Thieler, E.R., & Zervas, C.E. 2017. Global and Regional Sea Level Rise Scenarios for the United States.

Taylor, B. 2004. The Geography of Urban Transportation Finance. Edited by Susan Hanson and Genevieve Giuliano, 3rd edition.

Tourism Economics. 2018. The Impact of Hurricane Irma on the Florida Tourism Economy.

University of Florida Sea Level Scenario Sketch Planning Tool.

University of Florida GeoPlan Center (UFL). 2013. Development of a Geographic Information System Tool for the Preliminary Assessment of the Effects of Predicted Sea Level and Tidal Change on Transportation Infrastructure.

United Nations Development Program (UNDP). 2007. Monitoring and Evaluation Framework for Adaptation to Climate Change.

United Nations Development Program (UNDP). 2009. The Handbook on Planning, Monitoring and Evaluating for Development.

U.S. Army Corps of Engineers (USACE). Sea Level Tracker.

U.S. Army Corps of Engineers (USACE). 2015. North Atlantic Coast Comprehensive Study (NACCS): Resilient Adaptation to Increasing Risk. Physical Depth-Damage Function Summary Report.

U.S. Army Corps of Engineers (USACE). 2013. Southeast Florida Sediment Assessment and Needs Determination (SAND) Study.

U.S. Army Corps of Engineers (USACE). 2006. Depth-Damage Relationships for Structures Contents, and Vehicles and Content-to-Structure Value Ratios (CSVR) in Support of the Donaldsonville to the Gulf, Louisiana Feasibility Study. Prepared by Gulf Engineers and Consultants.

U.S. Census Bureau. 2019. County Business Patterns.

US Census Bureau. 2017. Longitudinal Employer-Household Dynamics (LEHD) Data.

U.S. Department of Transportation, Bureau of Transportation Statistics. 2020. North American Rail Lines.

U.S. Economic Development Administration (EDA) 2014. Economic Resilience Planning Evaluation Tool.

Xiao, Y., & Drucker, J. 2014. Does Economic Diversity Enhance Regional Disaster Resilience? Journal of American Planning Association.

Appendix A – Selection of Sea Level Rise and Water Level Conditions

The selection of existing and future water level conditions and related mapping products is foundational to the assessment of exposed assets and property, which serves as a basis for the assessment of economic and fiscal consequences of potential coastal hazard impacts. An evaluation of water levels corresponding to existing high frequency coastal conditions, including the average daily high tide, annual tide, and the 10-year storm tide was undertaken, accounting for sea level rise projections adopted by the Southeast Florida Climate Change Compact (2019).

Daily and Storm Tide Levels – Existing Conditions

To account for spatial variability of water levels along the Southeast Florida coastline, average tide levels were obtained for the locations of three National Oceanic and Atmospheric Administration (NOAA) tide stations and assigned to the Compact Counties based on their proximity to each station (see Table 53).

Table 53. Representative Tide Stations for the Compact Counties

Compact County	Assigned NOAA Tide Station
Palm Beach	Lake Worth Pier (#8722670)
Broward	Virginia Key (#87723214)
Miami-Dade	Virginia Key (#87723214)
Monroe	Key West (#8724580)

Tidal datums available through NOAA's website are calculated based on a 19-year tidal cycle, known as the National Tidal Datum Epoch (NTDE). The most recently published epoch is 1983-2001 and is centered on the year 1992. To account for sea level rise that has occurred since 1992, the U.S. Army Corps of Engineers (USACE) Sea Level Tracker tool was used to obtain the most recent tidal datums centered on the year 2010 for the Virginia Key and Key West tide stations. Post-1980 observed sea level trends for the Key West (0.14 inches/year) and Virginia Key (0.23 inches/year) locations (obtained from the USACE Sea Level Tracker Tool) were then used to adjust the 2010 water levels to the year 2020.

Sea level trends for the Lake Worth Pier were not available on the USACE Sea Level Tracker tool, resulting in the use of tide levels from the NOAA tide station website. Sea level rise that has occurred at Lake Worth Pier from 1992 to 2020 was accounted for by applying the historically observed rate of sea level rise (0.14 inches/year).

In addition to tidal datums, storm tide conditions were obtained from each of the three NOAA tide stations. Storm tides include the effects of the astronomical tide and storm surge (due to atmospheric pressure, oceanographic, and meteorological effects). The existing storm tide levels were estimated by NOAA using a statistical analysis of measured annual maximum water level data. Observed sea level rise occurring from 1992 to 2020 was applied to the storm tides at each station to represent present day conditions.

To account for high-frequency tide conditions that may impact infrastructure and other assets in the region, the following conditions were evaluated: the mean higher high water (MHHW), 1-year tide level, and the 10-year tide level. MHHW represents average daily high tide conditions and reflects areas that may be exposed to permanent tidal inundation conditions. The 1-year tide level represents tide conditions that are expected to occur 1-2 times each year. The 10-year tide level represents a small coastal storm or infrequently occurring raising of coastal water levels due to regional oceanographic conditions (such as has occurred over the past few years in Southeast Florida) that may result in temporary flooding of low-lying areas. Table 54 presents the relative tide conditions at each station. Water levels are presented relative to the North American Vertical Datum of 1988 (NAVD88), the national standard for referencing sea level elevations.

Table 54. Existing Daily and Storm Tide Levels in Southeast Florida (2020)

Physical Scenario	Tide Levels Relative to NAVD88		
	Lake Worth Pier (#8722670)	Virginia Key (#8723214)	Key West (#8724580)
MHHW (average daily high tide)	0.88 ft (10.5 in)	0.60 ft (7.2 in)	0.35 ft (4.2 in)
1-year Tide Level (annual tide event)	1.68 ft (20.2 in)	1.41 ft (16.9 in)	0.95 ft (11.4 in)
10-year Tide Level (coastal storm event)	3.06 ft (36.8 in)	2.79 ft (33.5 in)	1.80 ft (21.6 in)

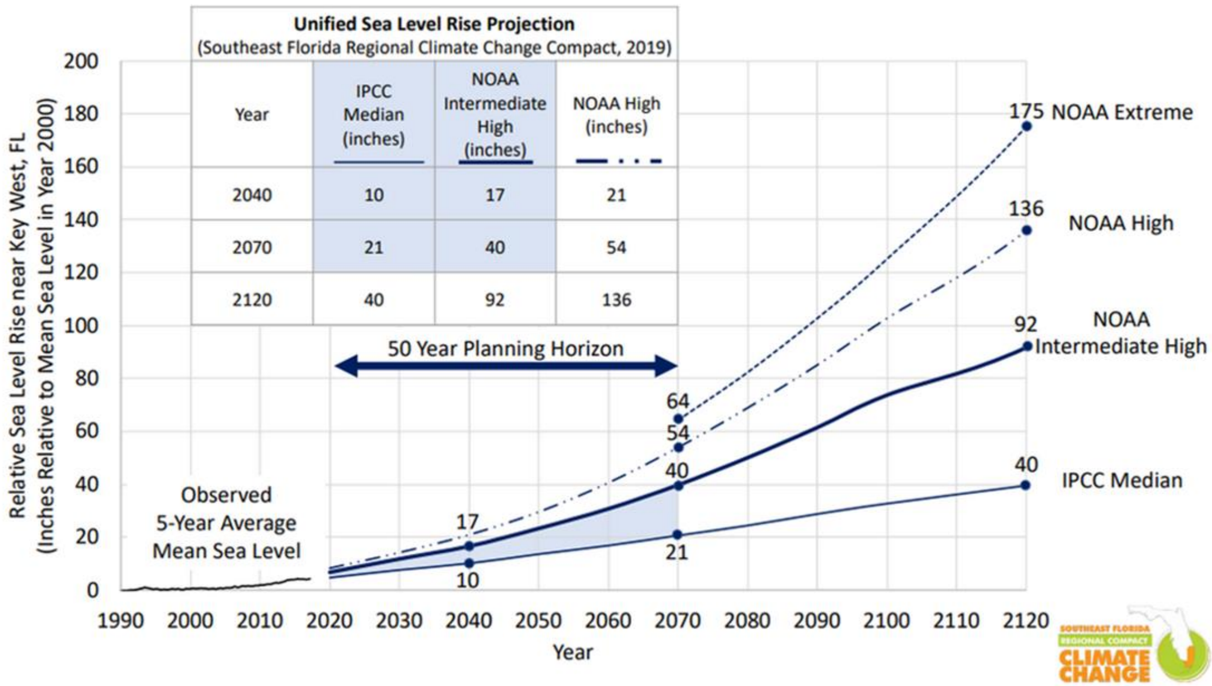
Notes:
Definitions are available at https://tidesandcurrents.noaa.gov/datum_options.html
NAVD88 is the current national standard to reference sea level elevations.
Tide conditions have been adjusted to be relative to 2020

Daily and Storm Tide Levels – Future Conditions

In December 2019, the Southeast Florida Regional Climate Compact updated recommended regional sea level rise projections to reflect findings of the NOAA's sea level rise scenarios (Sweet et al. 2017). The updates reflect significant advances in understanding of changes in the cryosphere and regional factors contributing to sea level rise, includes an extreme scenario for sea level rise caused by rapid ice sheet loss from the West Antarctica ice sheet, and are associated with risk-based (probabilistic) planning capabilities.

For the Project, NOAA Intermediate High projections were selected for the planning time horizons of 2020 (existing conditions), 2040, and 2070 to align with Compact recommendations for near-term infrastructure planning (see Figure 11).

Figure 11. Updated Southeast Florida Regional Climate Change Compact Recommended Sea Level Rise Projections



Each planning horizon (2020, 2040, and 2070) was evaluated under the three water level conditions: 1) average daily high tide, 2) annual tide, and 3) coastal storm tide. Sea level rise for each planning horizon was added to the existing conditions water levels to estimate future water level conditions (see Table 55, Table 56 and Table 57).

Table 55. Future Tide Conditions for Lake Worth Pier Tide Station (Palm Beach County and Broward County)

Year	Tide Level Relative to NAVD88		
	MHHW (Average Daily High Tide)	1-year Tide Level (Annual Tide Event)	10-year Tide Level (Coastal Storm Event)
2020	0.88 ft (10.5 in)	1.68 ft (20.2 in)	3.06 ft (36.8 in)
2040	1.70 ft (20.3 in)	2.50 ft (30.1 in)	3.88 ft (46.6 in)
2070	3.63 ft (43.5 in)	4.43 ft (53.2 in)	5.81 ft (69.8 in)

Table 56. Future Tide Conditions for Virginia Key Tide Station (Miami-Dade County)

Year	Tide Level Relative to NAVD88		
	MHHW (Average Daily High Tide)	1-year Tide Level (Annual Tide Event)	10-year Tide Level (Coastal Storm Event)
2020	0.60 ft (7.2 in)	1.41 ft (16.9 in)	2.79 ft (33.5 in)
2040	1.42 ft (17.0 in)	2.23 ft (26.8 in)	3.61 ft (43.3 in)
2070	3.35 ft (40.2 in)	4.16 ft (49.9 in)	5.54 ft (66.5 in)

Table 57. Future Tide Conditions for Key West Tide Station (Monroe County)

Year	Tide Level Relative to NAVD88		
	MHHW (Average Daily High Tide)	1-year Tide Level (Annual Tide Event)	10-year Tide Level (Coastal Storm Event)
2020	0.35 ft (4.2 in)	0.95 ft (11.4 in)	1.80 ft (21.6 in)
2040	1.17 ft (14.1 in)	1.77 ft (21.2 in)	2.62 ft (31.4 in)
2070	3.10 ft (37.2 in)	3.70 ft (44.4 in)	4.55 ft (54.6 in)

Sea Level Rise Scenarios and Mapping Layers

Tidal inundation and storm flooding maps are a valuable tool for evaluating the potential exposure of infrastructure and other assets to current and future water level conditions. The maps are a useful means to evaluate the timing and extent of inundation and/or flooding that may be experienced based on projections of sea level rise. Tidal inundation and storm flooding maps can also assist decision-makers in identifying critical exposure thresholds where an entire area may be impacted.

The effort to map the coastal hazard exposure of assets and property in Southeast Florida relied on readily-available sea level rise mapping layers prepared as a part of the University of Florida's Sea Level Scenario Sketch Planning Tool. The Sea Level Scenario Sketch Planning Tool mapping provides the geographical extent of water surface elevations corresponding to future sea level projections. The data sources and methodology used to create the mapping layers are presented in the Sea Level Scenario Sketch Planning Tool technical memorandum (UFL 2013).

Mapping layers corresponding to the closest selected sea level rise projections for 2020, 2040, and 2070 were retrieved from the Sea Level Scenario Sketch Planning Tool database and used to create the tidal inundation and coastal storm flooding maps for the exposure assessment. Table 58, Table 59 and Table 60 list the Sea Level Scenario Sketch Planning Tool mapping layer year and identification code that was used for each scenario and planning horizon. Reported values of the closest available water levels have been adjusted to be relative to NAVD88 for consistency.

Table 58. Closest Available Sea Level Rise Inundation Mapping Layer (Palm Beach County and Broward County)

Year	Tide Level Relative to NAVD88		
	MHHW (average daily high tide)	1-year Tide Level (annual tide event)	10-year Tide Level (coastal storm event)
2020	0.95 ft (11.4 in)	1.65 ft (19.8in)	2.95 ft (35.4 in)
2040	1.75 ft (21.0 in)	2.55 ft (30.6 in)	4.15 ft (49.8 in)
2070	3.55 ft (42.6 in)	4.35 ft (52.2 in)	5.85 ft (70.2 in)

Table 59. Closest Available Sea Level Rise Inundation Mapping Layer (Miami-Dade County)

Year	Tide Level Relative to NAVD88		
	MHHW (average daily high tide)	**1-year Tide Level** (annual tide event)	**10-year Tide Level** (coastal storm event)
2020	0.61 ft (7.3 in)	1.41 ft (16.9 in)	2.61 ft (31.3 in)
2040	1.41 ft (16.9 in)	2.21 ft (26.5 in)	3.81 ft (45.7 in)
2070	3.21 ft (38.5 in)	4.40 ft (48.1 in)	5.51 ft (66.1 in)

Table 60. Closest Available Sea Level Rise Inundation Mapping Layer (Monroe County)

Year	Tide Level Relative to NAVD88		
	MHHW (average daily high tide)	**1-year Tide Level** (annual tide event)	**10-year Tide Level** (coastal storm event)
2020	0.45 ft (5.3 in)	0.95 ft (11.4 in)	1.85 ft (22.2 in)
2040	1.15 ft (13.8 in)	1.85 ft (22.2 in)	2.45 ft (29.4 in)
2070	3.05 ft (36.6 in)	3.65 ft (46.8 in)	4.45 ft (53.4 in)

Appendix B – Exposure Analysis Mapping

The assessment of exposure to coastal storms and sea level rise and involved conducting a spatial analysis in GIS to estimate the timing and extent of temporary flooding and permanent inundation of the region's critical assets as well as flood/inundation depths for all parcels in the four counties. Sea level rise layers were overlaid on the locations of assets to estimate exposure to future water level conditions.

Obtaining Sea Level Rise Inundation and Coastal Flood Data

GIS mapping layers corresponding to the closest selected sea level rise projections for 2020, 2040, and 2070 were obtained from the University of Florida GeoPlan Center's Sea Level Scenario Sketch Planning Tool database. This resource utilizes multiple data inputs to model inundation surfaces that will be used as a screening tool to identify assets that may be exposed to future sea level conditions. The map inputs include sea level rise projections, tide station datum information (e.g., mean sea level, mean higher high water, etc.) from NOAA tide stations in Florida, and digital elevation data, including LiDAR-derived datasets. Using this information, the GeoPlan Center created county-wide water surface digital elevation models (DEMs) relative to tidal datums recorded at each tide station to represent local conditions. The map layers include depth and extent of future flooding and inundation. These data are filtered for hydrologic connectivity to remove inland low-lying areas not connected to a major waterway and clipped all layers at shoreline and canal geometries to remove areas that are already open water.

These readily-available sea level rise inundation mapping layers were selected to correspond with water level elevations of future average daily high tide and high-frequency storm events for each of the Compact Counties, as described in Appendix A. The mapping layers represent an extension of the water surface at the shoreline over inland topography and are used to evaluate potential vulnerability to sea level rise and high-frequency coastal conditions. In this assessment, overtopping only considers the stillwater levels associated with astronomical tides and storm surge and does not account for "wave overtopping," which may occur along segments of the shoreline prior to stillwater overtopping.

The maps used in this analysis do not account for wave height, rainfall, or other potential variations in conditions that could affect the depth of inundation at any given location. The methodology is GIS-based and does not consider the associated physics of overland flow, dissipation, levee/seawall overtopping, storm duration, effects of groundwater or potential shoreline or levee erosion associated with extreme water levels and waves. To account for these processes, a more sophisticated modeling effort would be required. However, given the uncertainties associated with sea level rise, future land use changes, development, and geomorphic changes that will occur over the next half century, a more sophisticated modeling effort may not necessarily provide more accurate results.

Calculating Flood Depths by Parcel

Parcel maps were obtained for all four counties from the Florida Department of Revenue. Attribute information, including land use and just value, were then joined to each parcel by parcel ID. These data are submitted annually to the Department of Revenue by the assessor offices of each county and represent the most accurate parcel information available.

The average depth of flooding was calculated for each parcel under each combined sea level rise and flooding scenario to serve as inputs for the economic modeling. The average flood depth of each parcel for each storm and tidal inundation scenario for each of the three time horizons (i.e., 2020, 2040, and 2070) was calculated using a GIS zonal statistics tool. This algorithm calculated the mean of the values of all flooded pixels within the area of each parcel from each of the flood depth datasets and assigned those values to the parcel by parcel ID.

The average depth of flooding was preferred over maximum depth of flooding because it is less likely to result in overestimated damages; there were many cases where high maximum depth values were caused by parcels extending near open water or parcels that included ponds or other low topography where flooding would not realistically result in measurable impacts. This analysis resulted in tabular outputs that indicate the water depth at each parcel under each flooding and inundation scenario. These outputs were incorporated into the economic modeling.

Note that for the economic modeling, for each parcel flood depth values for a given scenario, flood and inundation depth values were only assigned if more than 25 percent of the footprint of a parcel was exposed. As flood and inundation depths were calculated by parcel rather than by building, using this approach reduced incidents of flood and inundation depths being applied to structure damage calculations when in reality only non-structural portions of a parcel were flooded.

Exposure Analysis by Asset Type

This analysis identified critical assets that are exposed to inundation or flooding under each of the modeled coastal hazard conditions. The asset types assessed in this study closely mirror those included in the Southeast Florida Compact Vulnerability Study (2012).

As flood depths had already been calculated for every parcel across the Southeast Florida counties in the previous step, exposure of individual asset types was assessed by identifying the parcels containing or contained by that asset type. Parcels with flood depth values greater than 0 for a given coastal condition scenario were considered impacted, while those with no flood depth values were not. Parcels for each asset type were selected using a variety of methods based on the format of the available asset data, which was often different between counties for the same asset type as described below.

Polygon Data: Data for large assets (e.g., ports, airports) were generally available as polygons, which were used to select the underlying parcels. Multiple parcels that made up a single asset (e.g., one port) were grouped together.

Point Data: GIS data for most asset types were available as points. Flood depths were not calculated for the points directly, because this method could result in assets being excluded if the point's location does not intersect with the modeled floodplains; conceptually inundation or flooding could intersect with the asset but not overlap with the georeferenced point feature.

Instead, the points were used to select the underlying parcels so that inundation and flood results would be based on the entire asset, not just the point.

Manual Selection: In some cases where data for large assets was not provided by the Southeast Florida counties (either because the data was provided as points or because no data was available), satellite imagery and/or maps and plans available online were used to identify, manually select, and group the correct parcels. This manual selection was only performed for asset types were there was a small total number of assets that could be easily located via desktop research (e.g., ports, airports), but not for asset types where it was not feasible for the project team to identify the asset locations, either because the locations are not shared publicly (e.g., emergency shelters in some counties), or because there were too many assets to manually locate (e.g., pump stations in some counties).

Selection Via Land Use Codes: For some asset types such as schools, GIS data was not uniformly available across all Southeast Florida counties. In such cases it was determined more accurate to identify schools by parcel via land use codes in the County Assessor data. Similarly, while some GIS datasets for protected natural lands were available, it was determined that the most accurate way to identify all open spaces was via land use codes.

Exposure Analysis for Linear Assets (road and rail)

For linear assets (i.e., road and rail), polygon inundation and flooding data was used to perform an overlay analysis that identified the linear assets exposed under each coastal condition scenario.

Assigning Location Attributes: Before the overlay, it was necessary to assign location information to the assets so that the output tables could be summarized by county, city, or zip code. County, city and zip code boundaries were downloaded from the corresponding Southeast Florida counties publicly available GIS data portals. For each county, the county boundary, city limits and zip codes were converted to the same projection system and then merged into a single layer. In the case of Monroe County, the boundary was modified so that stretches between the Keys were still included. These composite boundary layers were then merged with the road and rail datasets so that the attribute information included county, city, and zip code fields.

Roads: GIS data of major roads was acquired from the Florida Department of Transportation. While these data represent a subset of the complete street network, it was determined that these data were preferable compared to complete street data for the Southeast Florida counties because: 1) the attribute information included a road hierarchy that was uniform across all four counties; and 2) traffic volume data from FDOT could be joined to each segment. As the FDOT major streets layers containing functional class information and traffic volume information had identical geometries, these data could be merged into a single dataset via a spatial join.

After the input major roads dataset was processed, it was clipped to the inundation or flooding area for each model of the model conditions. The lengths of the inundated portions under each modeling scenario were calculated.

Rail: GIS rail lines were acquired from the US Department of Transportation. This dataset was compared to satellite imagery to verify accuracy. No rail lines were identified in Monroe County. The dataset included the Miami Metrorail, a majority of which is elevated above the ground. To ensure that no elevated track was incorrectly identified as impacted by flooding, the project team conducted a visual inspection of the entire rail dataset and filtered out sections of track that were elevated. Track elevated on raised earth was not filtered, as this elevation is reflected in the digital elevation models that informed the inundation layers.

After the rail dataset was processed, it was clipped to the inundation or flooding area for each modeling scenario. The lengths of the inundated or flooded portions under each modeling scenario were calculated.

The USDOT rail dataset does include several types of rail that were determined to not be consequential for the analysis, such as abandoned rail lines, rail lines converted into trails, and switchyard track. These sections of track were filtered out using post-GIS processing.

Table 61. GIS Data Sources

Asset Type	Broward County	Palm Beach County	Miami-Dade County	Monroe County
Parcels (shapefiles and assessor data tables)	Florida Department of Revenue	Florida Department of Revenue	Florida Department of Revenue	Florida Department of Revenue
Airports	Broward County (data from 2012 study)	Parcels selected manually by AECOM (data provided by county was in points)	Miami-Dade County	Parcels selected manually by AECOM
Ports	Broward County (data from 2012 study)	Parcels selected manually by AECOM (data provided by county was incomplete)	Miami-Dade County	Parcels selected manually by AECOM
Railroads	US DOT	US DOT	US DOT	US DOT
Major Roadways	FL DOT	FL DOT	FL DOT	FL DOT
Treatment Plants (water, wastewater)	Broward County (data from 2012 study)	Palm Beach County	Miami-Dade County	Monroe County (did not include WWTPs)
Pump Stations (water, wastewater, stormwater)	not provided	Palm Beach County (did not include stormwater pump stations)	Miami-Dade County	Monroe County (potable water pump stations only)
Power Plant	Broward County (data from 2012 study)	Palm Beach County	Miami-Dade County	Monroe County (subset of critical facilities dataset)
Substations	Broward County (data from 2012 study)	Palm Beach County	Miami-Dade County	Monroe County (subset of critical facilities dataset)

Asset Type	Broward County	Palm Beach County	Miami-Dade County	Monroe County
Hospitals	Broward County	Palm Beach County	Miami-Dade County	Monroe County (subset of critical facilities dataset)
Emergency Shelters	Broward County	Palm Beach County	Not provided**	Monroe County (subset of critical facilities dataset)
Schools	Florida Department of Revenue (parcel-level land use codes)	Florida Department of Revenue (parcel-level land use codes)	Florida Department of Revenue (parcel-level land use codes)	Florida Department of Revenue (parcel-level land use codes)
Marinas	Broward County (data from 2012 study) *	Palm Beach County	Miami-Dade County	Monroe County
Natural / Open Space Areas (parks, beaches, wetlands)	Florida Department of Revenue (parcel-level land use codes)	Florida Department of Revenue (parcel-level land use codes)	Florida Department of Revenue (parcel-level land use codes)	Florida Department of Revenue (parcel-level land use codes)

Notes:

*While point data for marinas was provided by Broward County, the dataset was determined to be unusable for this analysis because the point locations of each marina were located on streets in front of the marinas, not within the Marinas themselves. Therefore, these point locations could neither be used to identify marina parcels nor be assessed for exposure directly.

** Emergency shelter locations were not provided by Miami-Dade County due to security concerns.

Figure 12. Broward County Exposure to Average Daily High Tide (MHHW)

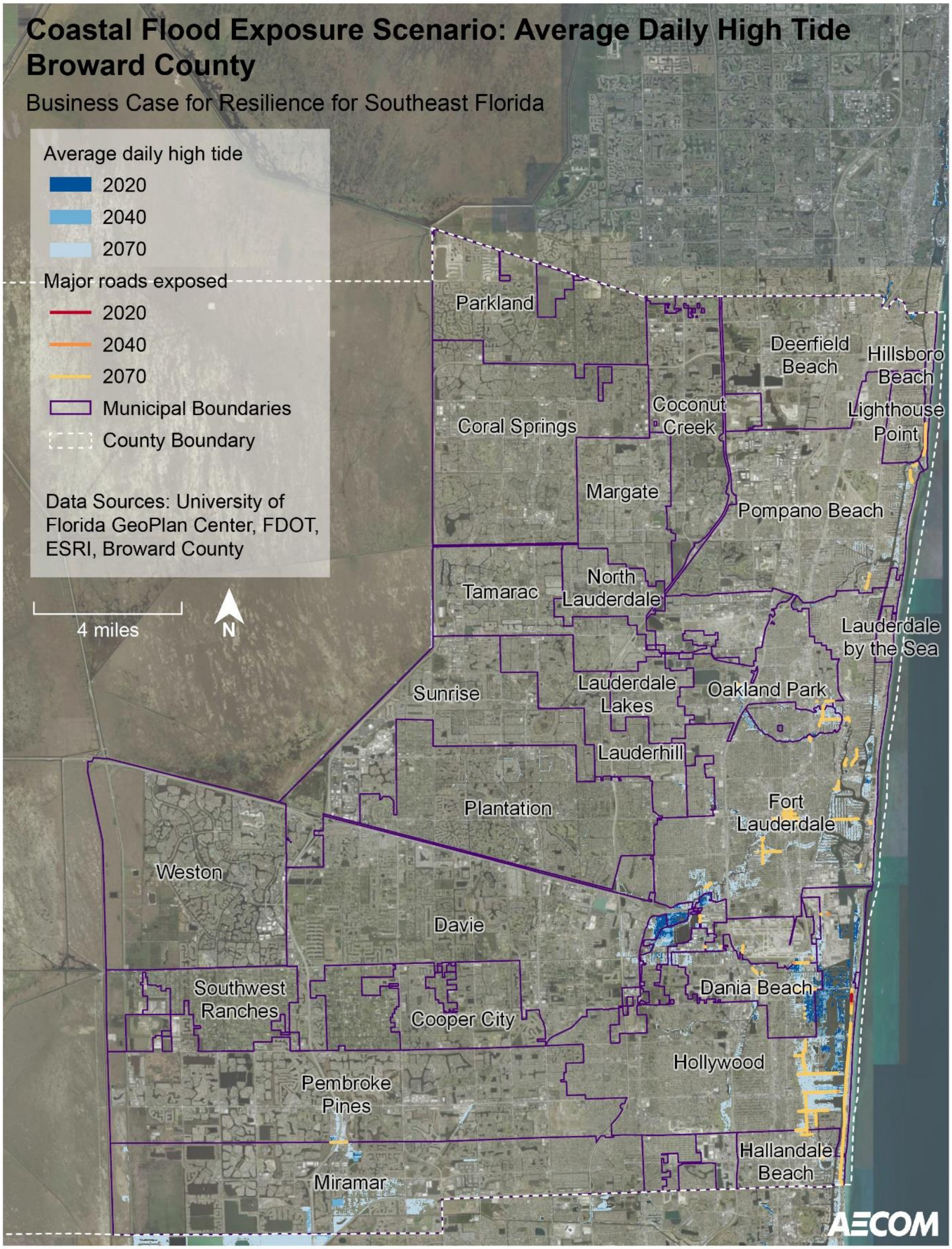


Figure 13. Broward County Exposure to 1-Year Tide Event (King Tide)

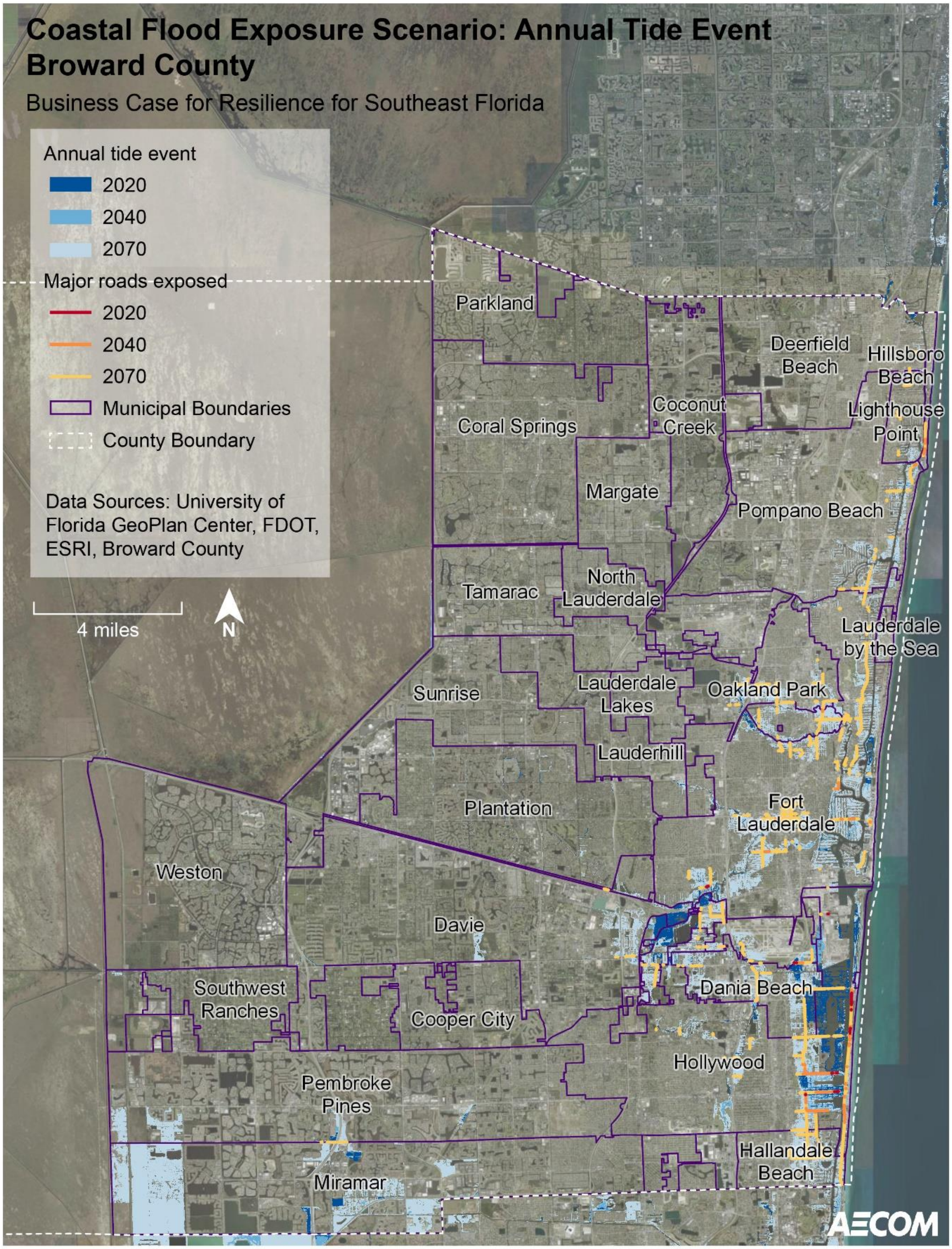


Figure 14. Broward County Exposure to 10-Year Tide Event

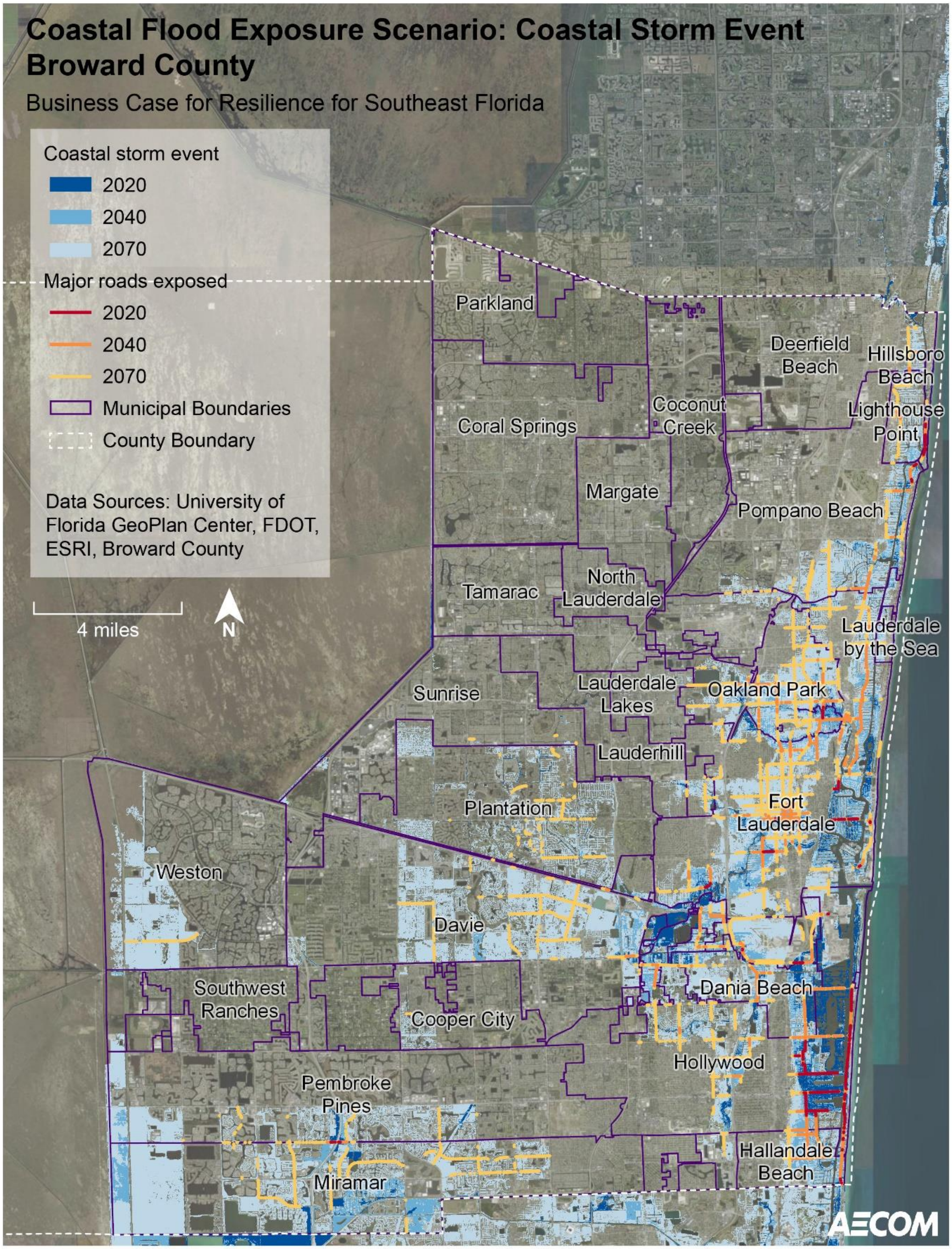


Figure 15. Miami-Dade County Exposure to Average Daily High Tide (MHHW)

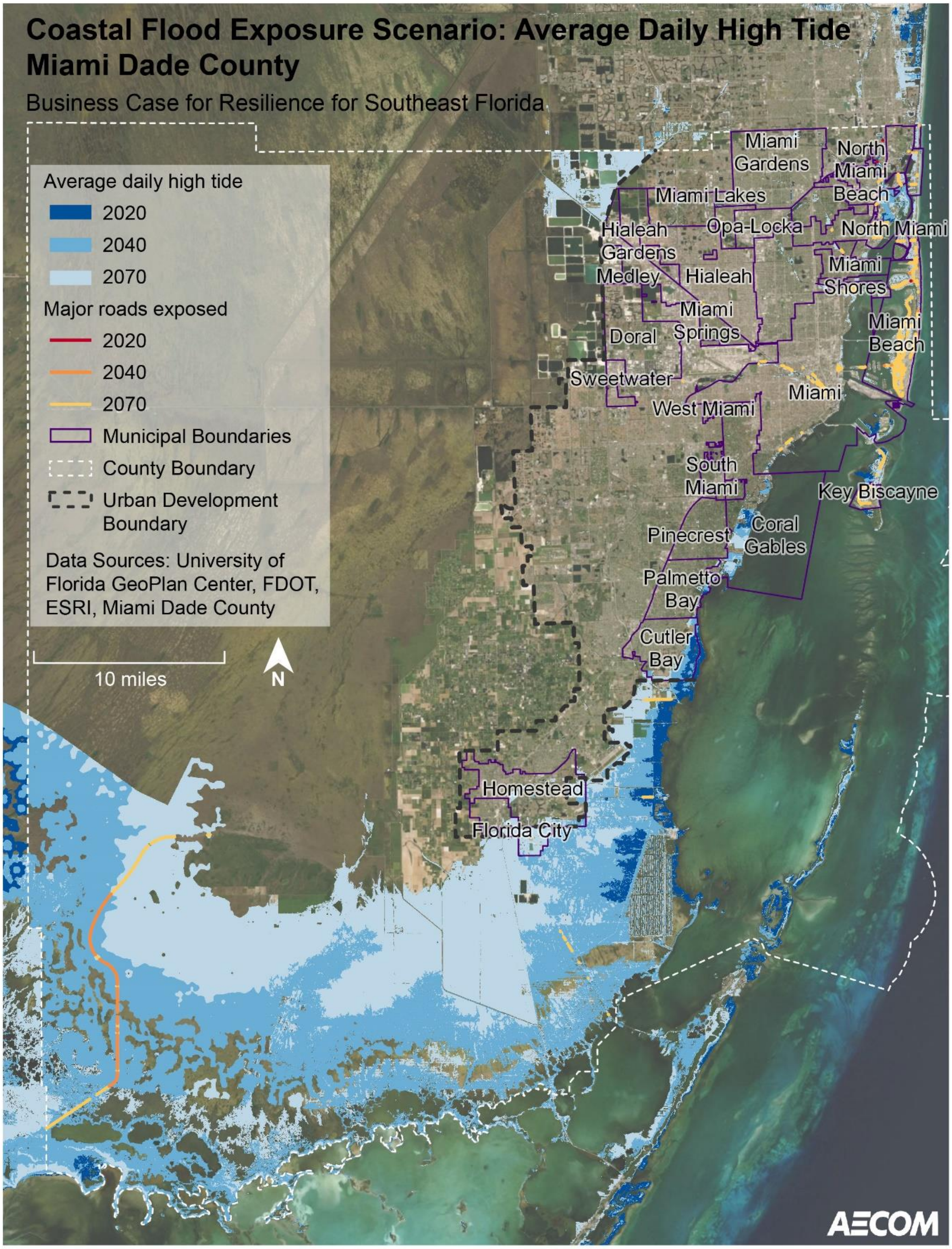


Figure 16. Miami-Dade County Exposure to 1-Year Tide Event (King Tide)

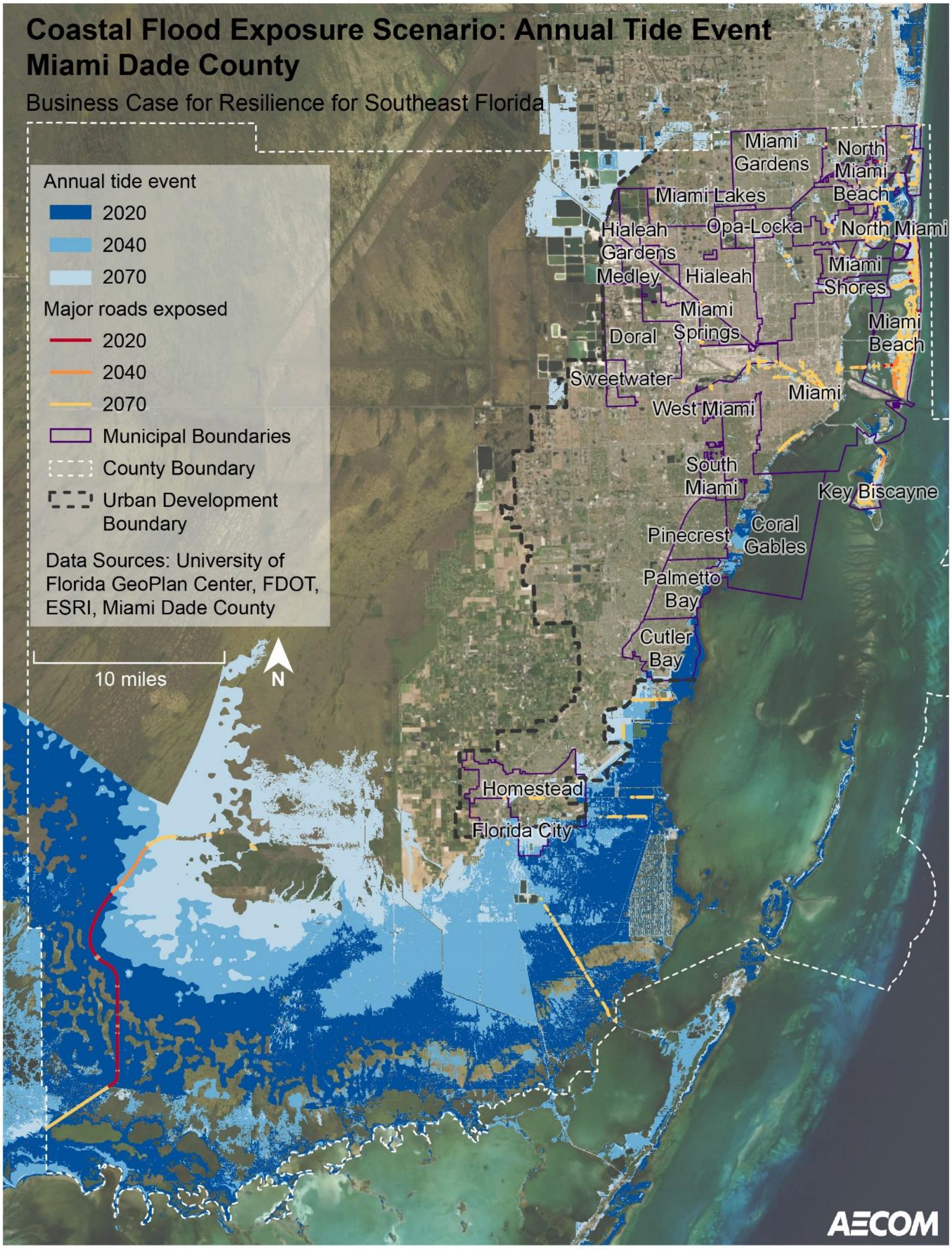


Figure 17. Miami-Dade County Exposure to 10-Year Tide Event

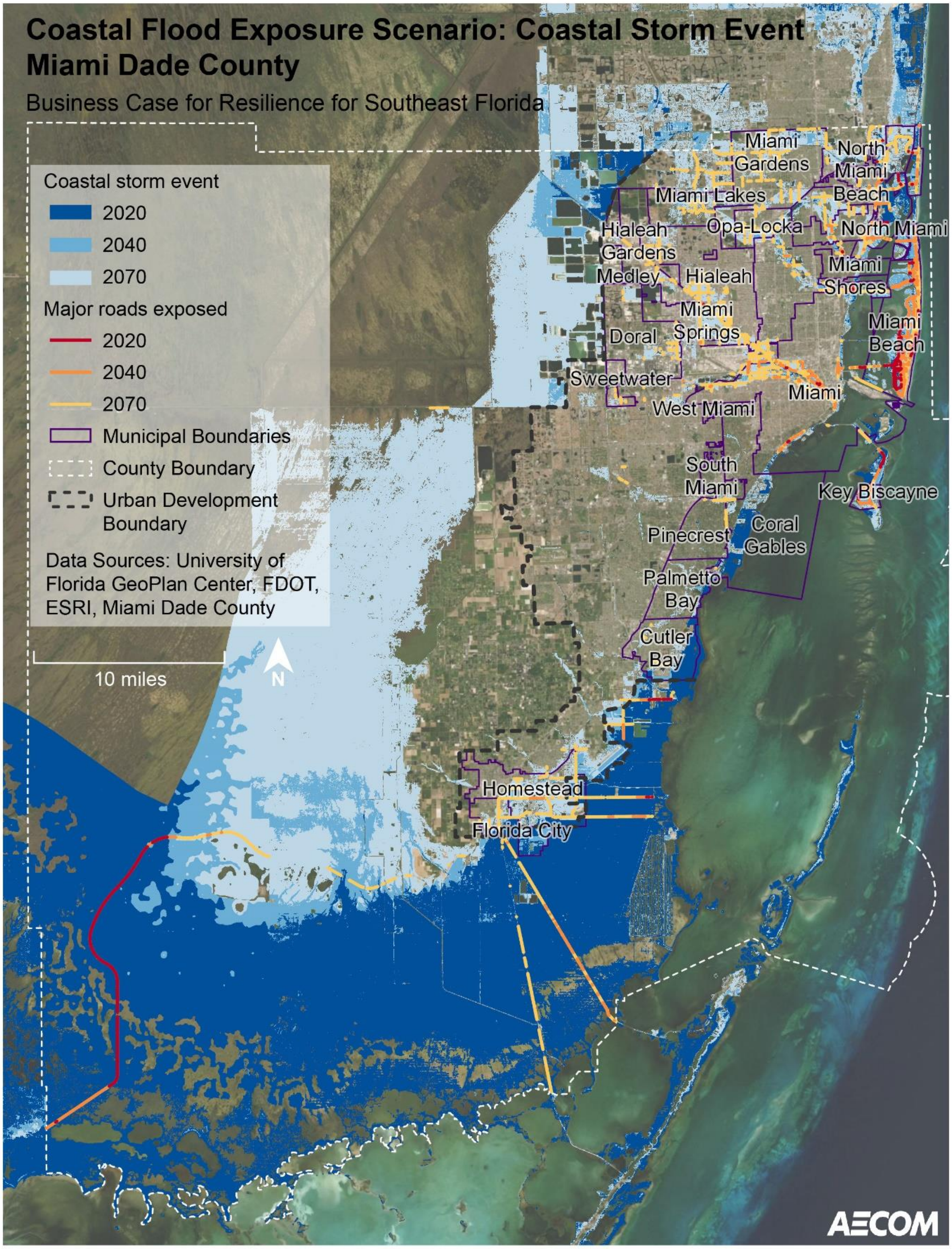


Figure 18. Monroe County Exposure to Average Daily High Tide (MHHW)

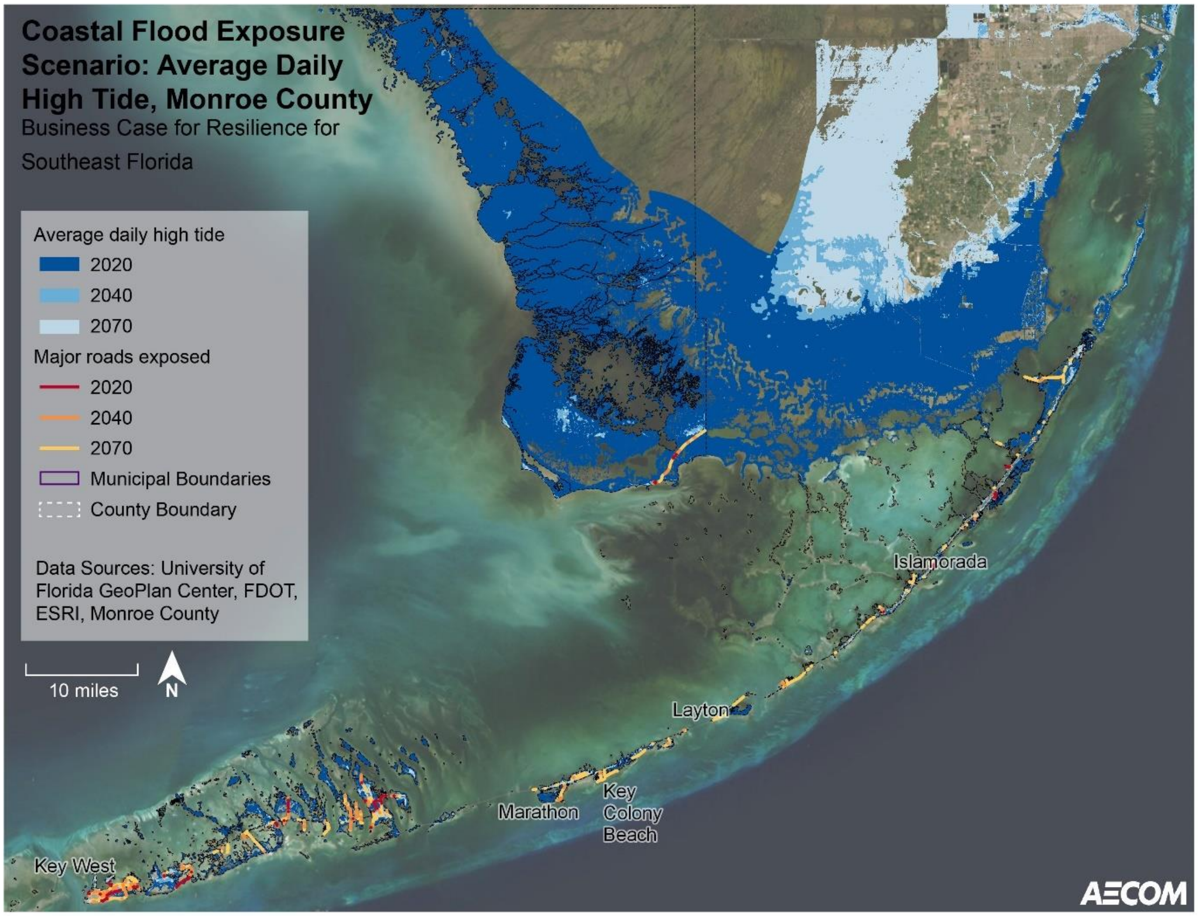


Figure 19. Monroe County Exposure to 1-Year Tide Event (King Tide)

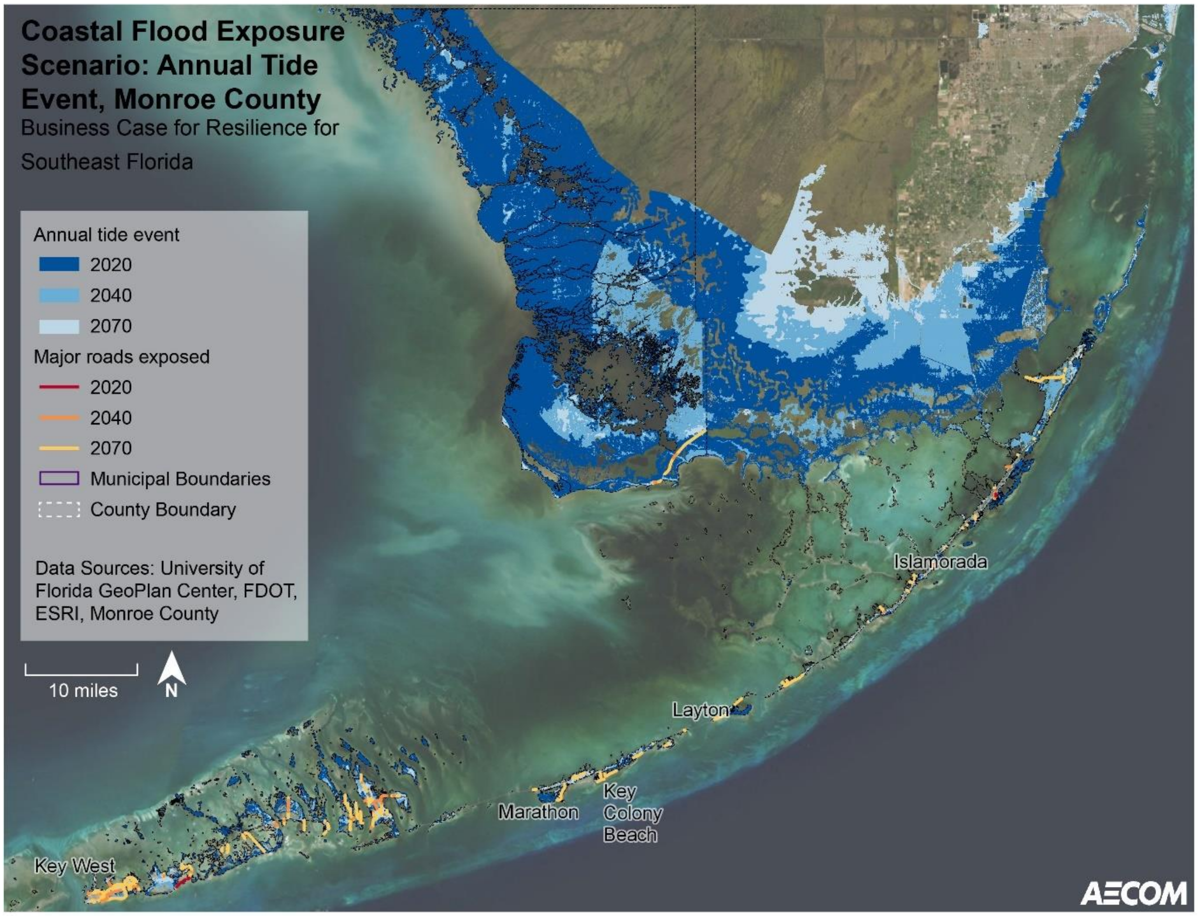


Figure 20. Monroe County Exposure to 10-Year Tide Event

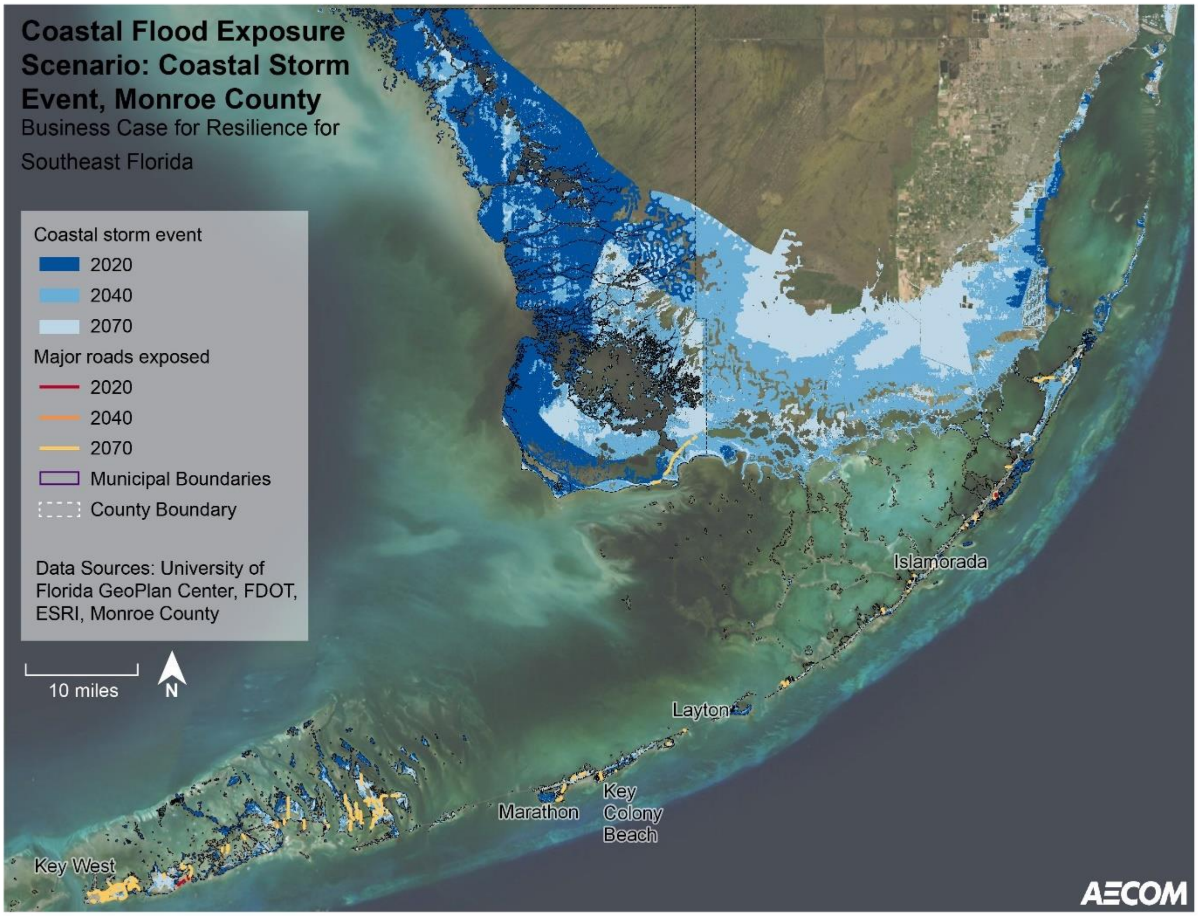


Figure 21. Palm Beach County Exposure to Average Daily High Tide (MHHW)

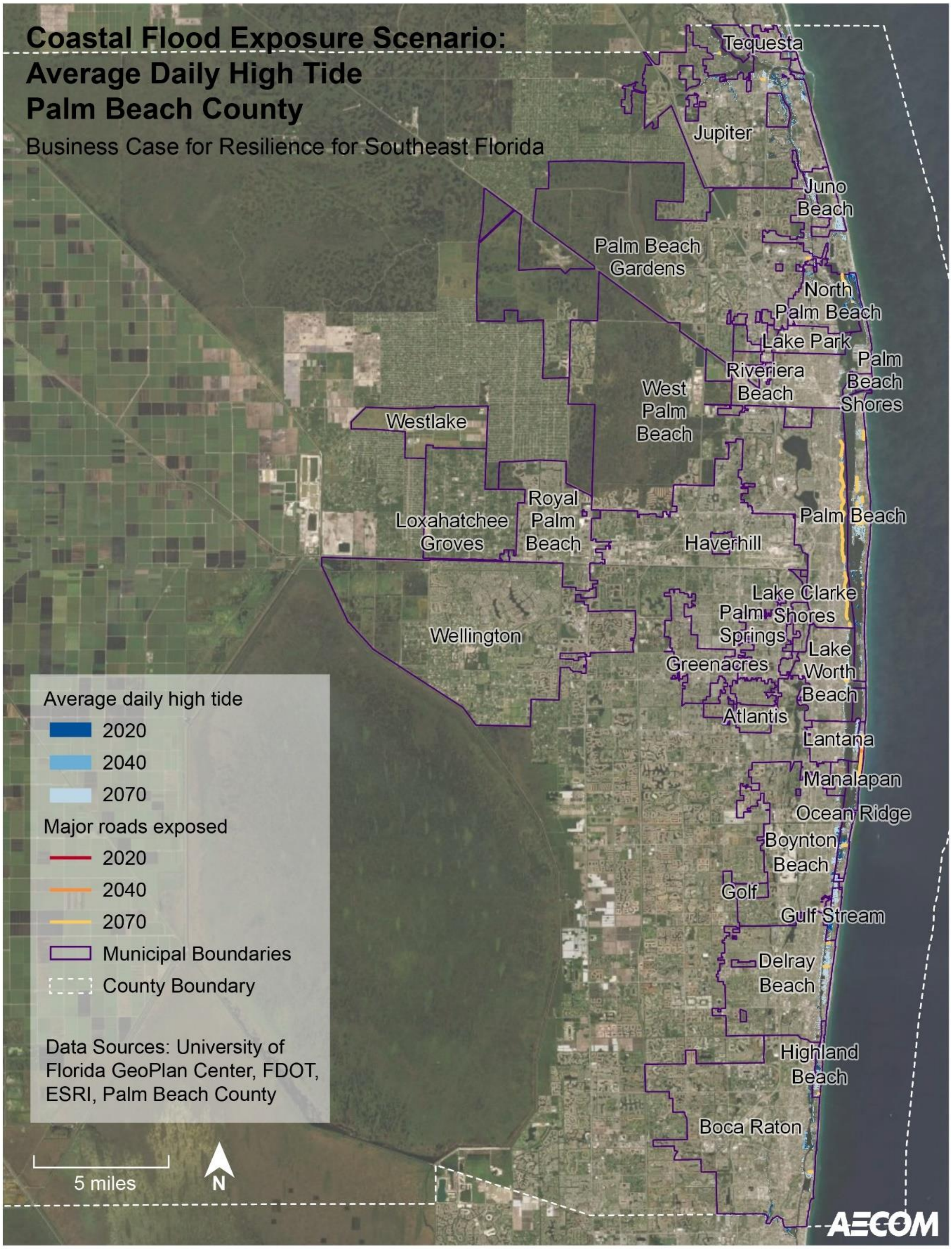


Figure 22. Palm Beach County Exposure to 1-Year Tide Event (King Tide)

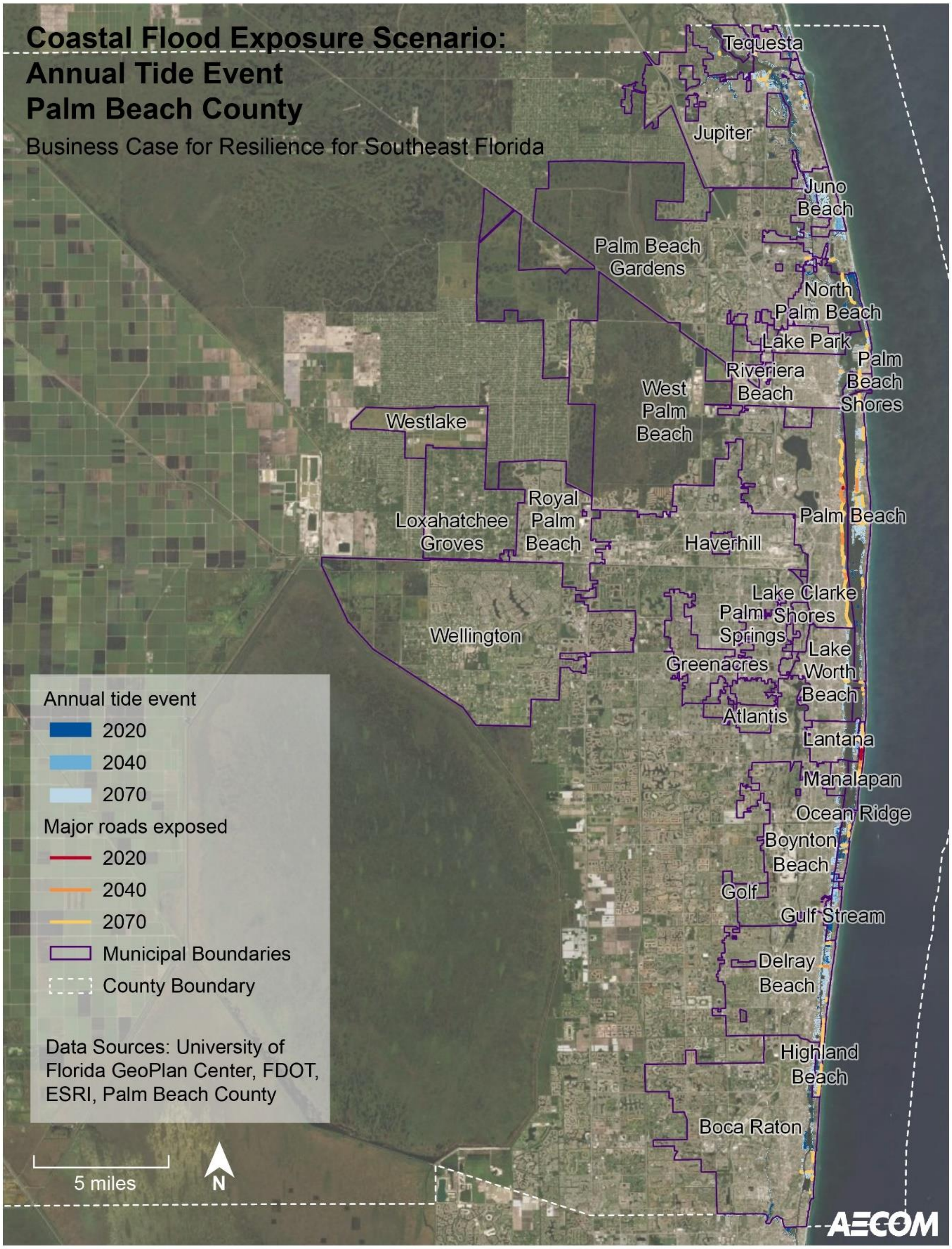
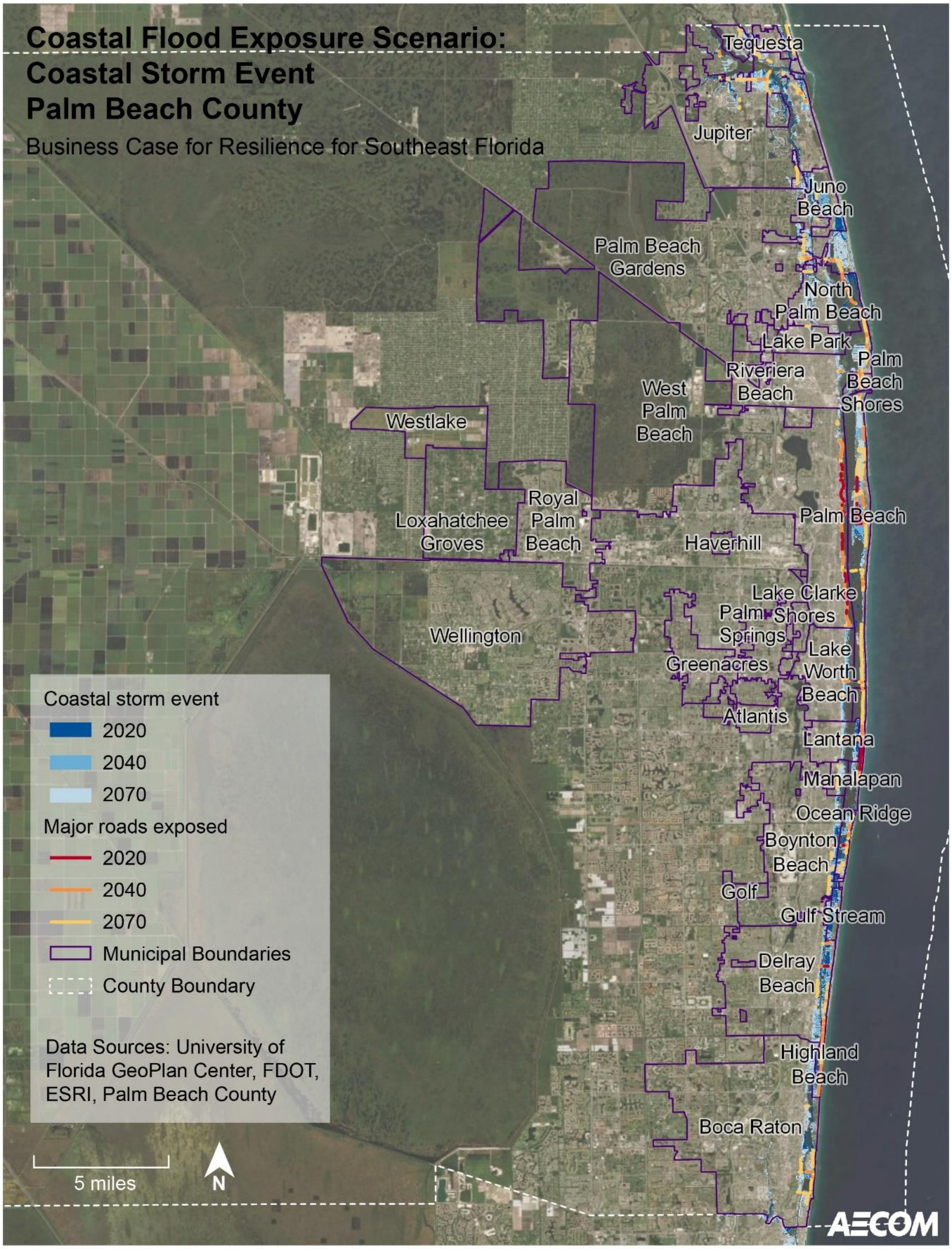


Figure 23. Palm Beach County Exposure to 10-Year Tide Event



Appendix C – Adaptation Strategy Modeling

This appendix summarizes the approach taken to modeling adaptation strategies were identified based on considerations of the project scope of work and feedback from County Compact partners.

Types of Adaptation

Two buckets of adaptation strategies were modelled that account for current and future water level conditions described in Appendix A. The selected adaptation strategies fall into two primary buckets: (1) *systemic adaptation strategies* that provide a primary form of defence at the shoreline to minimize coastal hazard impacts; and (2) *building-level adaptation strategies* that modify physical assets to lessen the consequences of coastal hazards. In general, systemic strategies are intended to provide mitigate impacts from both temporary coastal storms and permanent sea level rise to all landward assets while building-strategies are designed to mitigate impacts for individual assets that are exposed to temporary coastal storms and not permanent sea level rise. Table 62 below summarizes the proposed adaptation strategies.

Table 62. Adaptation Strategy Types Evaluated

Adaptation Type	Strategy	Description
Systemic Adaptation	• Beach nourishment/dune restoration • Seawall raising • Berm construction	This scenario involves a combination of soft and hard engineering investments at the shoreline, the application of which is dependent on open coast and intercoastal determinations.
Building-Level Adaptation	• Dry and wet floodproofing • Elevating structures	This scenario involves a combination of structural improvements to property, the application of which is dependent on building type and FEMA principles and procedures.

Adaptation Considerations – Systemic Strategies

During selection of the systemic adaptation strategies, simplifying assumptions, described thematically below, were made to allow for an adaptation approach that was generalized and repeatable across the large and varied geography in Southeast Florida.

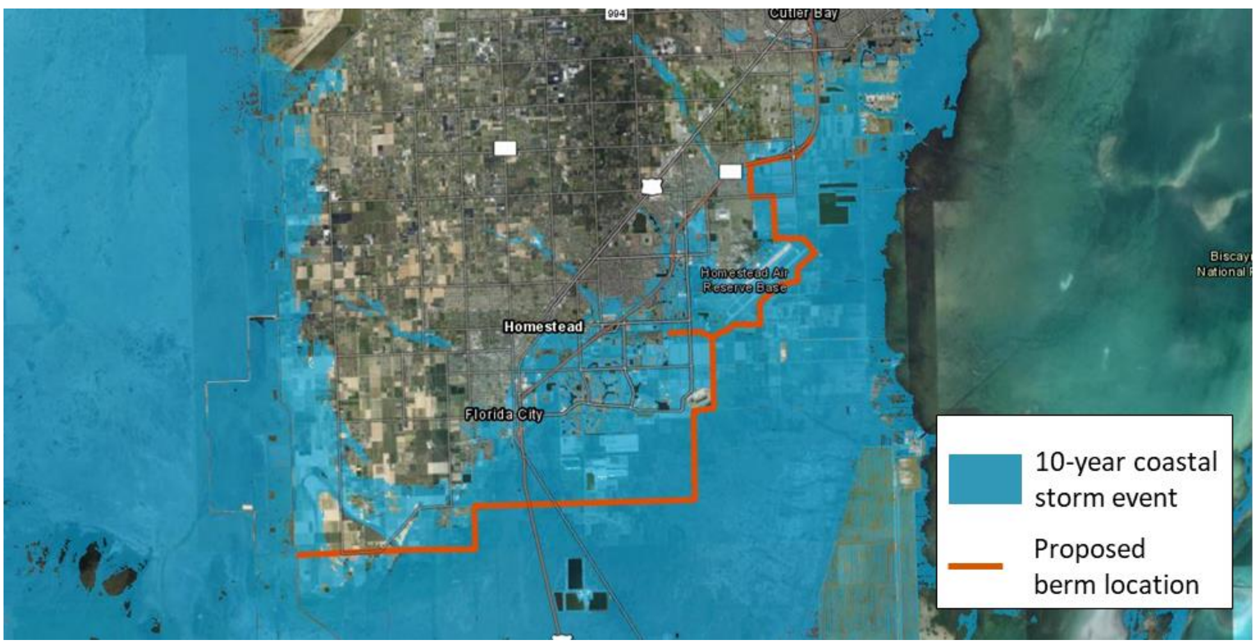
Shoreline Delineation*:* Applicable systemic adaptation strategies vary depending on if the shoreline is open coast or intercoastal. For example, open coast shorelines tend to be fronted by natural environments (e.g., beaches, wetlands, etc.) that may be more applicable for nature-based strategies (e.g., beach/dune nourishment). In contrast, intercoastal shorelines tend to be fixed with seawalls and bulkheads with development often extending to the water’s edge. These areas are better suited for elevating the hardened shoreline feature through time or elevating specific inland assets to accommodate future flood events. The shoreline for Southeast Florida counties was delineated as open coast or intercoastal in GIS by classifying segments of a readily-available digital shoreline file developed by GeoPlan as a part of the Sea Level Scenario Sketch Planning Tool inundation maps used in this study. Selection of appropriate adaptation strategies correspond to the open coast vs. intercoastal designation, as shown in Table 63 below.

Table 63. Systemic Strategy by Shoretype

Shoretype Designation	Applicable Systemic Strategy Type
Open Coast	Beach/Dune Nourishment
Intercoastal	Seawall Replacement or Raising
Inland	Berm Construction or Raising

The majority of Southeast Florida county shorelines corresponded to either open coast or intercoastal shoretype categories. However, much of the development in southern Miami-Dade County is landward of the Southern Glades, a low-lying mixed marsh and prairie conservation area. The study did not consider adaptation strategies to protect the shoreline of the Southern Glades, but a berm strategy was added to provide continuous flood protection of adjacent development, particularly near the City of Homestead (Figure 24). The rural setting of southern Miami-Dade County provides a more suitable condition for placement of a flood protection berm, rather than an elevated roadway, which is significantly more costly to implement and maintain over time.

Figure 24. Example Berm Location for a 2070 Coastal Storm Event



***Phased Approach to Elevated Shoreline Strategy Implementation**:* This project assumes that sea level rise will continue to occur over the next decades, through the coming century, and beyond. While Southeast Florida counties will have flood risks from high tides and coastal storm events, it is not necessary to adapt the entire shoreline at once. The shoreline was evaluated for the timing and extent of flood exposure for each water level condition (average daily high tide, annual tide event, 10-year event) considering all planning time horizons in the study. However, hard infrastructure adaptation strategies (i.e., seawalls and berms) were only applied to the length of shoreline exposed to the 10-year event at each planning time horizon to provide flood protection from high-frequency coastal storm events. Length of shoreline corresponding to average daily high tides and annual tide events was reported to provide information regarding the potential timing of exposure due to a range of future coastal conditions. Stretches of shoreline not exposed to future flooding were not included in the adaptation costs, as these areas are assumed to be of a sufficient elevation to provide continuous flood protection.

In addition to considering a phasing of shoreline lengths applicable for adaptation through time, the project also accounted for an incremental approach for structure replacement and raising. For example, intercoastal shorelines exposed by 2040 were recommended for immediate full replacement of seawalls to provide protection for 2040 conditions. However, upon replacement, it is recommended that the foundation of the structure account for future seawall capping to raise the structure's elevation in the year 2040 to provide continuous protection to the year 2070. Building in adaptive capacity to shoreline flood protection strategies will alleviate upfront construction costs and allow the counties to continue increasing the structure's elevation through time to align with observed changes in sea level.

Table 64 through Table 67 provide the lengths of elevated shoreline strategies for each county. The table highlights the timing of initial flood exposure of the existing shoreline structure, the recommended year for strategy implementation, and the protection level the structure should be designed to provide continuous flood defense for each of the study's planning time horizons.

Table 64. Length of Shoreline Adaptation, Broward County

Year Exposed	Cost Year (Implementation)	Protection Level	Broward Infrastructure Lengths (Linear Feet)	
			Length Replaced	Length Raised
2020	2020	2040	353,400	
2040	2020	2040	670,700	
2070	2040	2070	1,075,500	1,024,100

Table 65. Length of Shoreline Adaptation, Miami-Dade County

Year Exposed	Cost Year (Implementation)	Protection Level	Miami-Dade Infrastructure Lengths (Linear Feet)			
			Length Replaced	Length Raised	New Berm	Raised Berm
2020	2020	2040	174,000		56,200	
2040	2020	2040	239,200		24,400	
2070	2040	2070	277,500	413,200	25,100	80,500

Table 66. Length of Shoreline Adaptation, Monroe County

Year Exposed	Cost Year (Implementation)	Protection Level	Monroe Infrastructure Lengths (Linear Feet)	
			Length Replaced	Length Raised
2020	2020	2040	992,400	
2040	2020	2040	646,400	
2070	2040	2070	1,150,700	1,638,800

Table 67. Length of Shoreline Adaptation, Palm Beach County

Year Exposed	Cost Year (Implementation)	Protection Level	Palm Beach Infrastructure Lengths (Linear Feet)	
			Length Replaced	Length Raised
2020	2020	2040	363,700	
2040	2020	2040	338,900	
2070	2040	2070	460,500	702,600

***Beach Nourishment**:* Recognizing the importance of beaches and dunes as a protective buffer from coastal storms and high tide events, beach nourishment and dune restoration was considered as the primary adaptation strategy for the open coast of Southeast Florida counties. Future sediment needs to maintain the position and width of existing beaches and dunes was identified from the U.S. Army Corps of Engineers Southeast Florida Sediment Assessment and Needs Determination (SAND) Study (2013), which was completed to improve existing and future sediment needs and potential offshore sources for beach nourishment, storm damage reduction, and hurricane protection projects. The SAND Study also considered sea level rise impacts to exacerbated beach nourishment needs through the year 2062. It should be noted that, although the SAND Study represents the best-available quantification of sediment needs for beach nourishment in Southeast Florida, it is based on USACE Intermediate sea level rise projects, which are lower than the NOAA 2017 Intermediate-High projections used in this study. Therefore, future sediment needs may be higher.

To extend sediment needs to the 2070 planning time horizon, the sediment needs listed in the SAND Study for Palm Beach, Broward, and Miami-Dade Counties were extrapolated an additional 8 years. The SAND study did not include future projections of sediment needs for Monroe County, which performs beach nourishment on a much smaller scale than the other three Southeast Florida counties. A similar quantification of future sediment needs for Monroe County beaches was not available and therefore not included in this study.

Table 68 lists the Southeast Florida sediment needs based on rates from the SAND Study. The SAND study was completed in 2013 and it is assumed that nourishment activities for each of the counties have been performed to maintain beaches in the region. Therefore, the year 2020 is set as the starting year to represent existing beach conditions needed to sustain with nourishment activities.

Table 68. Southeast Florida Sediment Needs

County	Annual Sediment Need (cy/year)	2020 – 2040	2040 – 2070
Palm Beach	1,412,900	28,257,700	42,386,600
Broward	361,200	7,223,000	10,834,500
Miami-Dade	464,000	9,280,300	13,920,500
Monroe: Sediment needs not available as part of the USACE SAND study			

***Adaptation Costing**:* Adaptation strategies were not detailed in design, but rather, descriptive options to help illustrate the benefits conveyed by adaptation strategies considered in this study. As such, approximated and averaged unit costs were incorporated into the analysis, drawing from publicly available data from published reports that best reflect economic conditions in

Southeast Florida. Table 69 details the sources of adaptation costs considered for each strategy in the study.

Table 69. Direct Costs for Systemic Adaptation Strategies (2019 Dollars)

Type of Protection	Unit Measurement	Unit Cost
Seawall Replacement[9]	Linear foot	$1320
Seawall Raising[9]	Linear foot	$120
Berm Construction[10]	Linear foot	$110
Berm Raising[11]	Linear foot	$50
Beach Nourishment[12]	Cubic Yard	$50

Note: A 25 percent mark-up was applied to direct costs for Monroe County.

In addition to direct costs for materials, labor, equipment, etc., there are also a number of indirect costs and contingencies included in the estimated cost of adaptation. These additional cost components are described in Table 70.

Table 70. Additional Systemic Adaptation Cost Components

Cost Component	Description
Mobilization	This includes cost allowances for mobilization/demobilization to the project site, setup of temporary facilities and utilities. This is assumed to be 10% of the direct costs for all counties, with the exception of Monroe County, which is assumed to have a higher rate of 13% due to higher logistical costs.
Contractor’s Markup	This includes costs for site general conditions, job supervision, contractor’s office overhead, profit, and bonds. This is assumed to be 5% of the direct costs for all counties, with the exception of Monroe County, which is assumed to have a higher rate of 7% due to higher logistical costs.
Design Engineering and Permit Fees	The includes a 15% allowance for the engineering design fee and environmental permitting and clearance requirements.
Design Contingency	This includes a 25% allowance for project design and construction phases of the project as more current and updated information for the project and site conditions are obtained.
Construction Contingency	This includes a 10% allowance for changes during the construction phase of the project for possible unforeseen conditions, schedule delays, and project change orders.
Contract Administration	This includes a 30% allowance for contract administration and County staff time to oversee the design, permitting, and construction phases.

[9] Seawall replacement costs were taken as the average of new seawall costs listed in the 2018 Broward County Seawall Height Policy presentation ($450-2150). Seawall raising costs were selected based on the upper limit of the cost range ($60-120).

[10] Berm construction costs were assumed for an initial construction of 4 feet above the ground based on FEMA (2013) cost estimates for flood barriers.

[11] Berm raising costs were calculated as percentage of the difference between the cost of new berm construction and raising a berm as presented in Heberger et al. (2009). The percent cost difference was then applied to the $100/linear foot cost of berm construction to estimate an approximate unit cost of elevating.

[12] Beach nourishment costs were calculated as the average of project costs for nourishment projects completed in the state of Florida over the past decade based on information presented in the National Beach Nourishment Database (ASBPA 2017) plus one standard deviation to account for higher average costs in Southeast Florida projects.

Assumptions or Additional Considerations

Emphasis on Regional Flood Protection: Adaptation strategies evaluated for this study focused on high-level actions that are repeatable and able to provide regional scale protection from sea level rise and high frequency coastal storms. Although the strategies described offer several alternatives for regional flood protection, the study does not address potential flood pathways that may originate at a local scale, such as through individual jurisdiction stormwater networks. In general, stormwater systems represent a key vulnerability to sea level rise resilience because the network's capacity to collect, convey, and discharge flows will be reduced by higher sea levels. There is also often a lack of key data available (e.g., elevation of inlets and outfalls) and modeling capacity (e.g., dynamic modeling to show the interaction of stormwater conveyance and ocean water levels), making it difficult to fully understand the vulnerability of the stormwater system to future sea level conditions. Without action, sea level rise may partially or completely inundate stormwater outfalls, affecting the efficiency of stormwater drainage. Backflow of high tides into open outfalls may also cause surface flooding in low-lying areas that sit at elevations below the hydraulic grade line, even if shoreline protection systems are high enough to prevent overland flooding at the shoreline.

In addition to considering the regional flood protection strategies described in this study, Southeast Florida counties and cities may benefit from a developing a comprehensive adaptation plan that also considers the influence of stormwater networks on flood risk for the area. Costs of potential solutions to adapt stormwater infrastructure to accommodate future sea levels vary depending on the selected strategy and size of the flood area the strategy will mitigate. Table 71 lists several common approaches to stormwater adaptation with relative costs.

Table 71. Example Stormwater Adaptation Strategies

Potential Stormwater Strategy	Description	Relative Cost
Flap gate/backflow prevention	Installation of backflow prevention on coastal outfalls offers a low-cost, high result investment to reduce surge created during storm events from entering the stormwater system.	$
Pump stations	As sea levels continue to rise, it may be necessary to install pump stations at select outfalls to increase the efficiency of stormwater drainage against high tide and coastal storm conditions.	$$
Consolidate outfalls and pumping	Consolidation of outfalls may be considered to reduce the number of outfalls and thereby reduce the number of sources of backflow to inland areas.	$$$
Expanding stormwater system capacity	Stormwater systems that are already operating near or at capacity, may require modifications (e.g., increased storm drains, increasing pipe diameter, etc.) to increase the ability of the system to convey stormwater flows.	$$$

Adaptation Considerations – Building-Level Strategies

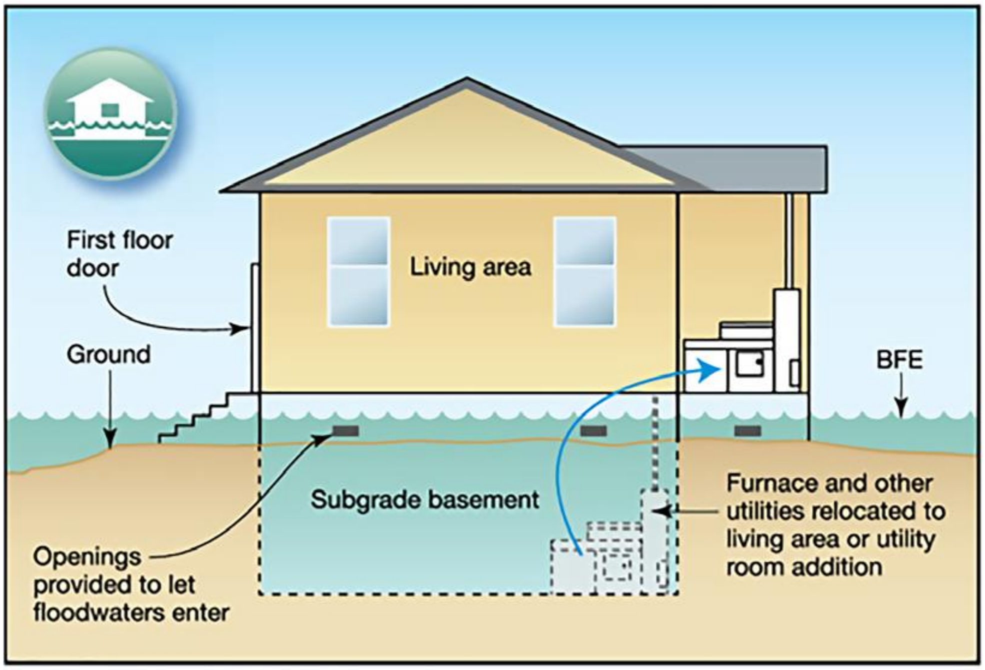
Building-level strategies, accounting for elevating or floodproofing structures were evaluated based on technical guidance and unit costs published by FEMA (2009, 2013), and further adapted by other researchers (Aerts et al. 2018). All building-level strategies were modelled to provide at least 1 foot of freeboard from the 100-year storm conditions for 2020 and 2040, a threshold that can affect flood insurance requirements and costs for properties subject to the National Flood Insurance Program.

The building-level strategies are assumed to be a phased approach, whereby the first phase provides a level of protection against the modeled storms through 2040 and the second phase provides a level of protection against the modeled storms through 2070. Note that the first investment phase protects properties subject to storm impacts in 2020, while the second investment phase protects properties subject to storm impacts in 2040. Costs were not developed for properties that are first subject to coastal storm impacts in 2070 because of the difficulty in estimating the actual year when these properties would first be subject to storm impacts, which is a necessary condition to be considered in the cumulative assessment of the costs and benefits of adaptation.

Elevating Structures: Elevation accounts for the entire structure being lifted, including the base floor. This would involve separating a structure from its foundation, raising it with temporary supports, and creating a new foundation or extending the foundation below. Foundation renovations would account for continuous walls, separate piers, posts, columns or piles. Elevation measures were evaluates using unit costs per square foot of building footprint, adjusted for the height of the intervention. Elevation was only applied to single family dwellings, manufactured housing, duplexes/triplexes/quadplexes and temporary lodging, per FEMA guidelines. Given the large study area and the challenges assigning which technology is most suitable and/or feasible for an individual structure, the unit costs for different construction types (e.g., frame, masonry) and foundation types (e.g., basement, crawlspace, slab on grade) were averaged and applied to all structures that were determined to be eligible for elevation. he national unit costs published by FEMA were adjusted to 2019 dollars using the Consumer Price Index and further adjusted for local economic conditions with RSMEANS regional construction cost indices.

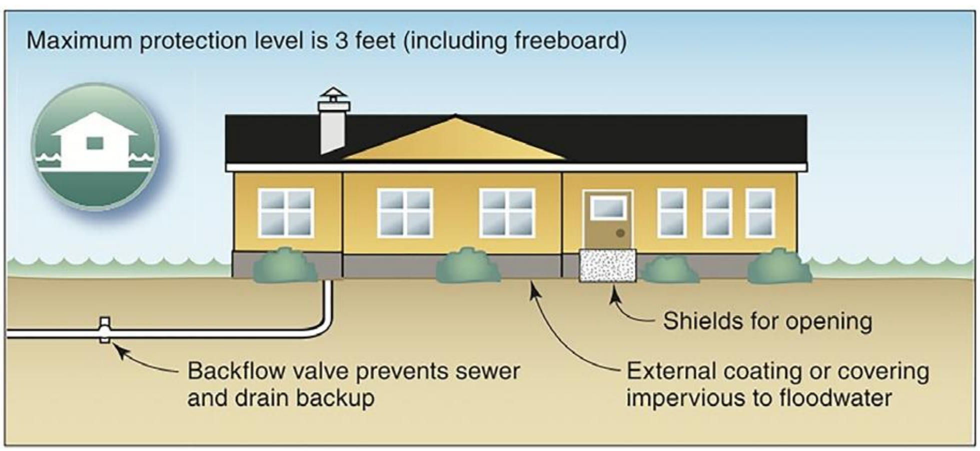
Floodproofing Structures: Both wet floodproofing and dry floodproofing measures were costed for the Southeast Florida Counties. Wet floodproofing allows for floodwaters to enter a structure, with investments made to minimize damages to the structure and its contents through raising utilities and assets of high-value above the flood grade as shown in Figure 25. Dry floodproofing attempts to make a structure watertight so that floodwaters are unable to enter as shown in Figure 26. Both floodproofing measures were evaluated using unit costs per square foot of building footprint, adjusted for the height of the intervention. Generally, only one of these floodproofing techniques would be used for an individual structure. However, given the large study area and the challenges assigning which technology is most suitable and/or feasible for an individual structure, the unit costs for different construction type (e.g., frame, masonry) and foundation type (e.g., basement, crawlspace, slab on grade) were averaged and applied to all structures that could not be elevated. The national unit costs published by FEMA were adjusted to 2019 dollars using the Consumer Price Index and further adjusted for local economic conditions with RSMEANS regional construction cost indices.

Figure 25. Example of Wet Floodproofing Measures



Source: FEMA 2009

Figure 26. Example of Dry Floodproofing Measures



Source: FEMA 2009

Table 72 shows the high-level national costs used to estimate the costs of implementing the building-level strategies. As noted, these costs were further to account for residential and commercial construction cost estimates for each of the Southeast Florida Counties.

Table 72. Order of Magnitude Costs to Implement Building-Level Strategies (2019 Dollars, $ per Square Foot of Building Footprint)

Scale of Intervention (Feet)	Floodproof	Elevate (1 Story Structure)	Elevate (+1 Story Structure)
1	$7.00	$75.00	$129.00
2	$7.00	$75.00	$129.00
3	$8.00	$77.00	$132.00
4	$10.00	$79.00	$135.00
5	$11.00	$80.00	$137.00
6	$15.00	$82.00	$140.00
7	$19.00	$83.00	$142.00
8	$22.00	$85.00	$145.00

Notes:

No information was identified to assign costs for the 1-foot scenario, resulting in the application of the 2-foot cost estimates. As shown in the table, the marginal costs for adding an additional foot or more for the measures are relatively insignificant.

Appendix D – Shoreline Typology Mapping Methods

To calculate the length of linear infrastructure require under each sea level rise/storm scenario, the project team identified a suitable shoreline delineation dataset, used parcel-level land use information from each county to identify shoreline near development, and overlaid this with polygons representing the inundated areas under each scenario to calculate the total length of shoreline overtopped in each county under each scenario. Major beaches were extracted manually, and their length was calculated separately.

Note that due to input data quality issues and the large study area, these calculations are imprecise and should be used for high level planning purposes only.

Detailed Methodology

A suitable shoreline delineation dataset was identified based on conversations with GIS specialists at the Florida GeoPlan Center who used it to develop the sea level rise inundation data used for this project. The dataset, available from the Florida Wildlife Research Institute was reasonably accurate compared to other candidates and had the added benefit of extending further inland up the canals than other datasets examined.

This shoreline dataset was actually a polygon dataset representing land area. Therefore, it was necessary to convert the polygons to linear data and remove all linework that did not represent actual shoreline. Then the shoreline was split by county.

It was determined that a calculation that assumed all overtopped shoreline would be armored would greatly overestimate the length of shoreline that would actually need to be armored to protect developed areas. To identify stretches of shoreline near development, land use codes from the Florida Department of Revenue were used. Note that while these land use codes represent the best available land use data for the area, and visual inspection to correct obvious issues was undertaken, inaccuracies in land use data are a potential source of error.

Once the dataset representing developed area within each county was developed, these polygons were buffered by 200 feet. This buffer was based on comparing shoreline data, satellite imagery, and inundation area in several representative locations.

This buffered area was used to clip the shoreline dataset in each county. Manual modifications based on satellite imagery to fix obvious omissions of shoreline that would need to be armored. For example, because the parcel layer in Miami-Dade County does not include road right-of-way's, shoreline near major highways had to be re-added.

Adding linework near development for areas where the actual shoreline is very far away, but the development would still clearly need protection due to gentle topography. This was especially prevalent in southern Miami-Dade County.

The result of this process was a dataset of shoreline areas that would require intervention if overtopped. To identify overtopped areas, the shoreline dataset was overlaid with each flooding and inundation scenario. However, many examples were identified where the shoreline linework was slightly seaward of the inundation polygons. This was caused by two reasons: (1) the inundation polygons developed by the Florida GeoPlan Center had been clipped to exclude areas that are currently open water; and (2) inaccuracies in the shoreline delineation resulted in the linework being located just offshore of the actual shoreline.

A simple overlay would miss these areas. To address this issue, a slight buffer of 40 feet was applied to the flooding and inundation polygons to make sure that they were counted. This distance was determined based on examining several representative problem areas and measuring the minimum buffer distance that would correct them.

The process applied is not expected to cause substantive overestimation of overtopped shoreline. Since the flooding and inundation polygons do not include open water, the polygons only extend where there is actual overtopping. Once overtopping is occurring, buffer distance inland will have little impact on the length of shoreline overtopped laterally.

Finally, the buffered inundation polygons were used to clip the shoreline layer and the length of shoreline within each clip was calculated.

Note that this calculation was not performed for the stretches of shoreline identified for beach nourishment. In these cases, the accuracy of the shoreline delineation was highly variable, in part due to large horizontal distance between high and low tide, so a suitable buffer could not be determined. It was assumed that all major beaches will require nourishment for all scenarios as beach nourishment is has historically been carried out on many of these beaches. Beaches were identified manually using satellite imagery for Miami-Dade, Broward, and Palm Beach counties. For Monroe County, critically eroded beaches were identified in the Strategic Beach Management Plan for the Florida Keys Region (DEP 2018) . It was assumed that critically eroded beaches near development would be nourished under all scenarios.

Appendix E – Primary Economic Consequence Methods

This economic and fiscal impact analysis draws from commonly used guidance outlined by the federal agencies such as the USACE and FEMA. The analysis also incorporates techniques from relevant academic and technical studies that address principles of accounting for economic and fiscal impacts in the natural hazard context. While standard economic methodologies underpin this analysis, effort was taken to ensure that model inputs reflected local—not national or regional—economic conditions where feasible to more accurately reflect on-the-ground conditions.

Note that different types of damages are expected from temporary storm-induced flooding compared to permanent progressive tidal inundation from sea level rise. Separate accounting methodologies were used to address these different types of impacts.

Temporary Coastal Storm Impacts

Direct Property Impacts

Storm-induced flooding can cause direct physical damage to structures and their contents as well as result in costs to clean up damaged property. In the context of this analysis, structural damage applies to real property while content damage applies to personal property.

Methodology

Standard procedures outlined by the USACE and FEMA were used to estimate damages to structures and contents. The primary steps of the analysis include:

1. Identify structures that are at risk to flooding.
2. Determine the depth of flooding for at-risk structures.
3. Estimate the replacement value of at-risk structures.
4. Estimate content replacement value within at-risk structures
5. Estimate the inventory replacement value within at-risk structures
6. Relate depth of flooding and structure and content replacement values to occupancy-specific depth damage functions (DDFs).[13]

Inputs

A variety of data sources were used to carry out this analysis. An inventory of parcel lot and structure characteristics was developed using data from the Florida Department of Revenue real property roll (Name – Address – Legal, or NAL); additional condominium property information

[13] DDFs account for the relationship between the depth of flooding within a structure and the extent of damage that could be expected, expressed as a percentage of the total building or content replacement value.

was brought in for Miami-Dade. Depth of flooding was determined by overlaying hazard maps developed by the USACE on the spatially-explicit parcel inventory. Impacts only account for parcels where 25 percent or more of the parcel footprint is exposed to the modeled coastal conditions. Structure replacement values were estimated by subtracting the parcel's land value from the just value. The DDFs and content to structure value ratios used in the analysis were developed by the USACE. For most land uses, the DDFs were based on USACE outputs developed from observed coastal storm damages along the Gulf Coast by the USACE, similar to the approach used by GEI Consultants, Inc. (2015). Additional USACE outputs were used for multi-family, condominium, and cooperative residential land uses based on DDFs produced post-Hurricane Sandy to be more representative of mid- to high-rise buildings in coastal areas. In the no action project alternative, first floor elevations were assumed to be one foot above grade.

Key Assumptions and Considerations

A number of data processing techniques were required to progress through the methodological steps outlined above. The land use or occupancy types of parcels recorded by the Assessor had to be mapped onto the classifications used to assign the most appropriate DDFs to each parcel and its structure(s). Square footage of the building was assumed to be the living / total usable area field from the Assessor data. Where there seemed to be information missing, such as when there was an estimated building value but no square footage, a value was estimated by applying the median value per square foot by land use. Story assumptions were made to better understand the square footage of the building's footprint and impacts to those who might be most impacted on the first floor. Story assumptions were based on land use, as well as a combination of the property's square footage and the parcel's area, estimated using both assessor land area and supporting GIS information.

Displacement Impacts

Storm-induced flooding resulting in property damage can displace people. Displacement can trigger a number of costs, such as one-time relocation costs and additional rental costs for the period of time that a property is being rehabilitated. In addition, businesses that are required to relocate can experience sales losses until they are back in operation at another location. Business and employment impacts are accounted for below separately from displacement. For this analysis, the displacement impacts were calculated only to be the one-time relocation expenses incurred by those living on the first floor of an impacted structure from storm damages.

Methodology

Standard procedures outlined by FEMA were used to estimate displacement and relocation costs. The primary steps of the analysis include:

1. Identify structures that are at risk to flooding.
2. Determine the depth of flooding for at-risk structures.

3. Relate the depth of flooding to the degree of structural damage that is expected.
4. Calculate one-time relocation cost based on land use and building square footage.

Inputs

The land use or occupancy types of parcels recorded by the Assessor had to be mapped onto the classifications used to assign the most appropriate disruption cost estimates from FEMA technical guidance. Vacancy rates, when available, were estimated using real estate market studies (e.g., CoStar) for each county by major land use category and were applied so as to not include disruption of non-occupied space. Results from the Direct Property Impacts were used to determine which buildings suffer the degree of flooding that would trigger displacement.

Key Assumptions and Considerations

This analysis assumes that certain land uses, such as hotels and golf courses, cannot relocate and therefore do not incur one-time relocation expenses, though they do incur business losses as discussed below.

Business and Employment Impacts

Storm-induced flooding can damage structures and result in business losses during the time it takes for a building to be rehabilitated. If a business is closed, sales losses would be expected as well as the potential for lost employment and other associated fiscal impacts. Fiscal impacts that are related to temporary business closure are discussed separately below.

Methodology

Standard procedures outlined by FEMA were used to estimate business and employment impacts. The primary steps of the analysis include:

1. Determine the number of businesses in the study area and associate these businesses with the building data collected in the Direct Property Impact analysis.
2. Determine the annual sales, wages, and number of employees for identified vulnerable businesses.
3. Assign each business to an NAICS industry code to determine what percentage of sales and wages can be recaptured at a later date through increased productivity.
4. Using Direct Property Impact model outputs identify how many businesses will be impacted by structure damage and for how long they will experience an economic loss of function (LOF). Calculate the associated sales and wage losses that cannot be recaptured. For occupancy types where there are fewer substitute locations that could absorb operations, assign the LOF timeframe to the total number of days required for the structure to be rehabilitated.

Inputs

Several data sources were used to inform this analysis. ESRI's Business Analyst was used to collect business data for the study area including sales volume by business, number of employees, address, and the North American Industry Classification System (NAICS) code for all businesses. Sales volume estimates (in dollars) are for the full year 2019 for each business and are based on a model that assigns sales estimates per employee using NAICS codes when specific data is not available. Companies that typically do not generate sales (e.g. educational institutions, government offices) are not assigned sales volumes in the ESRI/Infogroup model. Recapture rates came from FEMA. All businesses were then associated with the Direct Property Impact information. Loss of function estimates were identified in FEMA technical documentation. Wage data was from the Quarterly Census of Employment and Wages and was downloaded for each county and applied by industry for all businesses based on number of employees.

Key Assumptions and Considerations

The economic loss of function (LOF) time is the amount of time a business is not capable of conducting its operations; it is shorter than the rehabilitation time of a damaged property as it assumes that businesses will rent alternative space during repairs and construction. LOF depends on the damage state, as determined by the percent of structure damage compared to the full building replacement value. It was assumed that businesses on the first floor would experience longer LOF timeframes than businesses located on upper stories. Since it is unknown what floor the businesses sit on, it was assumed that businesses were distributed throughout impacted buildings. Sales and wage losses are not summed together so as to avoid double counting of impacts. Only sales impacts are accounted for in the primary consequence impacts for the no action scenario cumulative impact calculations in Section 3.4.

Fiscal Impacts

Storm-induced flooding that damages property can result in fiscal impacts in the form of reduced sales tax and tourist development tax revenues. Sales tax and tourist development tax losses are a function of the amount of time a business is unable to operate, as well as considerations relating to the ability of a business to recapture some of these earnings at a later date, as described in the Business and Employment Impacts methodology discussed above.

Methodology

Standard fiscal impact methodologies were used to assess sales and tourist development tax losses. The primary steps of the analysis include:

Sales Taxes:

1. For taxable industries, apply local sales tax rate to sales losses as described in the Business and Employment Impacts methodology (discussed above).

Tourist Development Taxes:

1. For accommodation industries, apply local tourist development tax rates to sales losses as described in the Business and Employment Impacts methodology (discussed above).

Inputs

Tax rate data was identified from information published by the Florida Department of Revenue; rates were collected for each county and more specific for jurisdictions as applicable. Industries exempt from sales taxes were identified using the 2020 Florida Tax Handbook from the Florida Revenue Estimating Conference. Sales and tourist development tax rates were applied to the sales data provided by ESRI by business and NAICS industry code.

Key Assumptions and Considerations

The percent of total sales that are subject to sales taxes was estimated based on information published by the state regarding what industries are subject to sales taxes and what industries are exempt. It was assumed that sales associated with industries in the accommodation subsector were subject to the tourist development tax.

Permanent Sea Level Rise Impacts

Direct Property Impacts

Property that is vulnerable to tidal inundation from a rise in sea level is assumed to be an asset with limited to no market value and income producing potential.

Methodology

The primary steps of the analysis to calculate the market value of parcels at risk include:

1. Identify parcels that are vulnerable to tidal inundation (e.g., MHHW).
2. Determine market value of property using the Just Value from Assessor data.

Inputs

The core inputs are the Just Value from Assessor data.

Key Assumptions and Considerations

If a property is subject to tidal inundation following a rise in sea level, the market value of this property is assumed to be lost in addition to any future ability to generate income on that property (e.g., business impacts). Because coastal hazards will gradually increase, there would likely be a steady decline in the market value of properties that stand in the path of tidal inundation, rather than a one-time complete market loss. Impacts were only modeled at the discrete MHHW conditions of 2040 and 2070. Impacts were modeled for parcels where 25 percent or more of the parcel footprint is exposed to the modeled coastal conditions.

Business and Employment Impacts

Business properties that are vulnerable to tidal inundation from sea level rise are assumed to have limited or no potential to generate business and employment output.

Methodology

Standard procedures outlined by FEMA were used to estimate business impacts. The primary steps of the analysis include:

1. Identify what properties are vulnerable to tidal inundation and that are no longer considered functional assets based on damage thresholds being met as defined in the Direct Property Impacts methodology (described above).
2. Determine the annual sales, wages, and number of employees for identified vulnerable businesses.
3. Assign each business to a NAICS industry code to determine what percentage of sales can be recaptured at a later date through increased productivity.

Inputs

The core inputs for this analysis are the same as those used in the temporary storm Business and Employment Impacts methodology discussed above.

Key Assumptions and Considerations

The business and employment impacts are assumed to be equivalent to the annual sales and wages of the impacted business that are not recaptured. Job impacts are estimated based on wage losses. Sales and wage losses are not summed together so as to avoid double counting of impacts. Only sales impacts are accounted for in the primary consequence impacts for the no action scenario cumulative impact calculations in Section 3.4.

Fiscal Impacts

A business that is vulnerable to tidal inundation following a rise in sea level is assumed to be an asset with limited to no market value and income producing potential. When a property loses its market value and/or operating potential, fiscal impacts could occur in the form of lost sales tax, tourist development tax, and property tax. Sales and tourist occupancy tax losses are considered equivalent to the annual sales of a business that are subject to such taxes. Property tax losses are a result of property no longer being functional and having no assessed value.

Methodology

Standard fiscal impact methodologies were used to assess sales and tourist development tax losses. The primary steps of the analysis include:

Sales Taxes:

1. For applicable industries, apply local sales tax rate to annual lost sales of inundated businesses as described in the Business and Employment Impacts methodology (discussed above).

Tourist Development Taxes:

1. For accommodation industries, apply local tourist development tax rates to annual sales of inundated businesses as described in the Business and Employment Impacts methodology (discussed above).

Property Taxes:

1. Find the county wide ratio of taxable value to just value.
2. Find each county's property tax rate.
3. Calculate the taxable value of all property and multiply by each county's property tax rate for impacted properties.

Inputs

The core inputs to assess lost sales and tourist development taxes are the same as those used in the temporary event-based storm fiscal impact description above. Property tax rates for each county are from the Florida Department of Revenue. Property tax losses are based on the just value of the properties with an assumed taxable value ratio based on reports from the Florida Department of Revenue (2018).

Key Assumptions and Considerations

Property taxes are calculated as an additional fiscal impact only for permanently inundated properties and are not included in temporary fiscal impacts. Taxable value of inundated properties was estimated based on the Just Value using jurisdictional-level averages of the ratio of Taxable values to Just Values. The tax loss was estimated by county by applying county property tax rates. For sales taxes and tourist development taxes, the total annual sales subject to these taxes was incorporated into the analysis assuming recapture for impacted properties. Based on the methodology as described in Section 5.1, cumulative property tax losses were calculated over the period of analysis (i.e., 2020 to 2070).

Appendix F – Detailed Primary Economic Consequence Results

Property Impacts

Table 73. Direct Property Impacts by Land Use, 2020 Coastal Conditions, Broward County (2019 Dollars, $Millions)

Land Use	MHHW	1-Year Tide			10-Year Tide		
	Just Property Value	Structure Damages	Content Losses	Relocation Costs	Structure Damages	Content Losses	Relocation Costs
Agriculture	NA	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Centrally Assessed	NA	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Commercial	NA	$0.0	$0.0	$0.0	$3.7	$1.5	$0.1
Governmental	NA	$0.1	$0.0	$0.0	$4.9	$0.2	$0.1
Industrial	NA	$0.0	$0.0	$0.0	$0.1	$0.1	$0.0
Institutional	NA	$0.0	$0.0	$0.0	$2.9	$0.1	$0.1
Miscellaneous	NA	$0.0	$0.0	$0.0	$0.5	$0.0	$0.0
Non-Ag Acreage	NA	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Residential	NA	$0.6	$0.1	$0.0	$22.0	$9.3	$0.1
Total	**NA**	**$0.7**	**$0.1**	**$0.0**	**$34.1**	**$11.2**	**$0.5**

Notes:

Impacts only account for parcels where 25 percent or more of the parcel footprint is exposed to the modeled coastal conditions.

MHHW results account for one-time impacts equivalent to the just or market value of the parcel. Parcels impacted by MHHW conditions are excluded from 1-year and 10-year tide damages.

The 1-year and 10-year tide results account for the impacts of one storm event of these magnitudes occurring. The results are not adjusted to account for the probability of the modeled storm occurring.

Results are not adjusted to account for financial discounting.

Table 74. Direct Property Impacts by Land Use, 2040 Coastal Conditions, Broward County (2019 Dollars, $Millions)

Land Use	MHHW	1-Year Tide			10-Year Tide		
	Just Property Value	Structure Damages	Content Losses	Relocation Costs	Structure Damages	Content Losses	Relocation Costs
Agriculture	$2.4	$0.0	$0.0	$0.0	$2.8	$2.5	$0.0
Central Assessed	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Commercial	$16.8	$2.5	$0.5	$0.0	$50.1	$65.1	$1.1
Governmental	$153.5	$0.0	$0.0	$0.0	$15.9	$0.7	$0.5
Industrial	$0.5	$0.0	$0.0	$0.0	$1.5	$1.2	$0.1
Institutional	$0.0	$0.0	$0.0	$0.0	$11.0	$0.8	$0.6
Miscellaneous	$52.3	$0.0	$0.0	$0.0	$1.9	$0.1	$0.1

Land Use	MHHW	1-Year Tide			10-Year Tide		
	Just Property Value	Structure Damages	Content Losses	Relocation Costs	Structure Damages	Content Losses	Relocation Costs
Non-Ag Acreage	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Residential	$58.1	$4.4	$1.0	$0.0	$353.0	$188.0	$4.7
Total	**$283.6**	**$6.9**	**$1.5**	**$0.1**	**$436.2**	**$258.4**	**$7.2**

Notes:
Impacts only account for parcels where 25 percent or more of the parcel footprint is exposed to the modeled coastal conditions.

MHHW results account for one-time impacts equivalent to the just or market value of the parcel. Parcels impacted by MHHW conditions are excluded from 1-year and 10-year tide damages.

The 1-year and 10-year tide results account for the impacts of one storm event of these magnitudes occurring. The results are not adjusted to account for the probability of the modeled storm occurring.

Results are not adjusted to account for financial discounting.

Table 75. Direct Property Impacts by Land Use, 2070 Coastal Conditions, Broward County (2019 Dollars, $Millions)

Land Use	MHHW	1-Year Tide			10-Year Tide		
	Just Property Value	Structure Damages	Content Losses	Relocation Costs	Structure Damages	Content Losses	Relocation Costs
Agriculture	$14.7	$5.2	$4.2	$0.0	$32.0	$32.5	$0.1
Central Assessed	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Commercial	$1,078.2	$9.5	$38.9	$0.5	$640.5	$1,286.6	$10.8
Governmental	$506.0	$9.1	$0.4	$0.3	$304.4	$10.9	$13.4
Industrial	$38.5	$6.3	$5.4	$0.3	$193.2	$160.4	$13.2
Institutional	$155.7	$3.0	$0.2	$0.3	$114.1	$7.9	$8.1
Miscellaneous	$124.1	$0.0	$0.0	$0.0	$3.1	$0.1	$0.4
Non-Ag Acreage	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Residential	$8,091.8	$101.1	$45.5	$0.8	$2,222.4	$1,228.3	$37.5
Total	**$10,009.0**	**$134.2**	**$94.6**	**$2.2**	**$3,509.7**	**$2,726.7**	**$83.5**

Notes:
Impacts only account for parcels where 25 percent or more of the parcel footprint is exposed to the modeled coastal conditions.

MHHW results account for one-time impacts equivalent to the just or market value of the parcel. Parcels impacted by MHHW conditions are excluded from 1-year and 10-year tide damages.

The 1-year and 10-year tide results account for the impacts of one storm event of these magnitudes occurring. The results are not adjusted to account for the probability of the modeled storm occurring.

Results are not adjusted to account for financial discounting.

Table 76. Direct Property Impacts by Land Use, 2020 Coastal Conditions, Miami-Dade County (2019 Dollars, $Millions)

Land Use	MHHW	1-Year Tide			10-Year Tide		
	Just Property Value	Structure Damages	Content Losses	Relocation Costs	Structure Damages	Content Losses	Relocation Costs
Agriculture	NA	$0.0	$0.0	$0.0	$4.7	$3.6	$0.1

Land Use	MHHW	1-Year Tide			10-Year Tide		
	Just Property Value	Structure Damages	Content Losses	Relocation Costs	Structure Damages	Content Losses	Relocation Costs
Central Assessed	NA	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Commercial	NA	$0.0	$0.5	$0.0	$6.6	$9.5	$0.0
Governmental	NA	$0.0	$0.0	$0.0	$22.0	$0.8	$1.6
Industrial	NA	$0.0	$0.0	$0.0	$0.5	$0.3	$0.0
Institutional	NA	$0.0	$0.0	$0.0	$0.3	$0.0	$0.0
Miscellaneous	NA	$0.0	$0.0	$0.0	$12.7	$0.5	$0.4
Non-Ag Acreage	NA	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Residential	NA	$189.7	$8.8	$0.0	$311.7	$32.8	$0.8
Total	**NA**	**$189.7**	**$9.3**	**$0.0**	**$358.5**	**$47.5**	**$3.0**

Notes:
Impacts only account for parcels where 25 percent or more of the parcel footprint is exposed to the modeled coastal conditions.

MHHW results account for one-time impacts equivalent to the just or market value of the parcel. Parcels impacted by MHHW conditions are excluded from 1-year and 10-year tide damages.

The 1-year and 10-year tide results account for the impacts of one storm event of these magnitudes occurring. The results are not adjusted to account for the probability of the modeled storm occurring.

Results are not adjusted to account for financial discounting.

Table 77. Direct Property Impacts by Land Use, 2040 Coastal Conditions, Miami-Dade County (2019 Dollars, $Millions)

Land Use	MHHW	1-Year Tide			10-Year Tide		
	Just Property Value	Structure Damages	Content Losses	Relocation Costs	Structure Damages	Content Losses	Relocation Costs
Agriculture	$28.2	$0.0	$0.0	$0.0	$21.7	$20.0	$0.4
Central Assessed	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Commercial	$60.2	$1.2	$0.8	$0.0	$56.8	$79.2	$0.8
Governmental	$276.3	$0.2	$0.0	$0.0	$24.2	$1.0	$1.5
Industrial	$2.9	$0.0	$0.0	$0.0	$1.9	$1.5	$0.1
Institutional	$0.1	$0.0	$0.0	$0.0	$5.6	$0.2	$0.2
Miscellaneous	$55.0	$0.0	$0.0	$0.0	$1.5	$0.0	$0.0
Non-Ag Acreage	$23.5	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Residential	$2,639.4	$34.4	$3.4	$0.0	$1,216.7	$145.1	$3.6
Total	**$3,085.6**	**$35.8**	**$4.2**	**$0.1**	**$1,328.4**	**$247.0**	**$6.8**

Notes:
Impacts only account for parcels where 25 percent or more of the parcel footprint is exposed to the modeled coastal conditions.

MHHW results account for one-time impacts equivalent to the just or market value of the parcel. Parcels impacted by MHHW conditions are excluded from 1-year and 10-year tide damages.

The 1-year and 10-year tide results account for the impacts of one storm event of these magnitudes occurring. The results are not adjusted to account for the probability of the modeled storm occurring.

Results are not adjusted to account for financial discounting.

Table 78. Direct Property Impacts by Land Use, 2070 Coastal Conditions, Miami-Dade County (2019 Dollars, $Millions)

Land Use	MHHW	1-Year Tide			10-Year Tide		
	Just Property Value	Structure Damages	Content Losses	Relocation Costs	Structure Damages	Content Losses	Relocation Costs
Agriculture	$246.4	$1.8	$1.5	$0.0	$23.1	$27.0	$0.3
Central Assessed	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Commercial	$3,309.2	$3.2	$4.2	$0.0	$705.8	$2,448.7	$9.4
Governmental	$1,544.7	$3.2	$0.1	$0.0	$223.6	$13.3	$10.5
Industrial	$102.6	$2.1	$1.7	$0.0	$25.6	$21.4	$2.5
Institutional	$261.9	$1.1	$0.0	$0.0	$75.1	$6.0	$3.3
Miscellaneous	$110.4	$0.3	$0.0	$0.0	$10.8	$0.5	$0.5
Non-Ag Acreage	$156.3	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Residential	$17,752.1	$750.2	$60.4	$1.1	$3,575.1	$831.1	$35.3
Total	**$23,483.6**	**$761.9**	**$67.9**	**$1.3**	**$4,639.1**	**$3,348.0**	**$61.7**

Notes:
Impacts only account for parcels where 25 percent or more of the parcel footprint is exposed to the modeled coastal conditions.

MHHW results account for one-time impacts equivalent to the just or market value of the parcel. Parcels impacted by MHHW conditions are excluded from 1-year and 10-year tide damages.

The 1-year and 10-year tide results account for the impacts of one storm event of these magnitudes occurring. The results are not adjusted to account for the probability of the modeled storm occurring.

Results are not adjusted to account for financial discounting.

Table 79. Direct Property Impacts by Land Use, 2020 Coastal Conditions, Monroe County (2019 Dollars, $Millions)

Land Use	MHHW	1-Year Tide			10-Year Tide		
	Just Property Value	Structure Damages	Content Losses	Relocation Costs	Structure Damages	Content Losses	Relocation Costs
Agriculture	NA	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Central Assessed	NA	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Commercial	NA	$0.0	$0.0	$0.0	$0.3	$0.1	$0.0
Governmental	NA	$0.0	$0.0	$0.0	$1.3	$0.0	$0.0
Industrial	NA	$0.0	$0.0	$0.0	$0.3	$0.2	$0.0
Institutional	NA	$0.0	$0.0	$0.0	$0.1	$0.0	$0.0
Miscellaneous	NA	$0.0	$0.0	$0.0	$0.1	$0.0	$0.0
Non-Ag Acreage	NA	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Residential	NA	$0.6	$0.1	$0.0	$22.0	$10.6	$0.2
Total	**NA**	**$0.6**	**$0.1**	**$0.0**	**$24.1**	**$10.9**	**$0.3**

Notes:
Impacts only account for parcels where 25 percent or more of the parcel footprint is exposed to the modeled coastal conditions.

MHHW results account for one-time impacts equivalent to the just or market value of the parcel. Parcels impacted by MHHW conditions are excluded from 1-year and 10-year tide damages.

The 1-year and 10-year tide results account for the impacts of one storm event of these magnitudes occurring. The results are not adjusted to account for the probability of the modeled storm occurring.

Results are not adjusted to account for financial discounting.

Table 80. Direct Property Impacts by Land Use, 2040 Coastal Conditions, Monroe County (2019 Dollars, $Millions)

Land Use	MHHW	1-Year Tide			10-Year Tide		
	Just Property Value	Structure Damages	Content Losses	Relocation Costs	Structure Damages	Content Losses	Relocation Costs
Agriculture	$0.2	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Central Assessed	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Commercial	$19.0	$0.2	$0.1	$0.0	$1.9	$0.7	$0.0
Governmental	$249.7	$0.9	$0.0	$0.0	$10.0	$0.3	$0.4
Industrial	$3.8	$0.1	$0.1	$0.0	$0.8	$0.6	$0.1
Institutional	$13.7	$0.0	$0.0	$0.0	$1.1	$1.0	$0.0
Miscellaneous	$3.5	$0.0	$0.0	$0.0	$0.1	$0.0	$0.0
Non-Ag Acreage	$1.3	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Residential	$348.0	$11.3	$4.2	$0.0	$59.6	$26.4	$0.4
Total	**$639.2**	**$12.5**	**$4.4**	**$0.1**	**$73.5**	**$29.0**	**$0.9**

Notes:

Impacts only account for parcels where 25 percent or more of the parcel footprint is exposed to the modeled coastal conditions.

MHHW results account for one-time impacts equivalent to the just or market value of the parcel. Parcels impacted by MHHW conditions are excluded from 1-year and 10-year tide damages.

The 1-year and 10-year tide results account for the impacts of one storm event of these magnitudes occurring. The results are not adjusted to account for the probability of the modeled storm occurring.

Results are not adjusted to account for financial discounting.

Table 81. Direct Property Impacts by Land Use, 2070 Coastal Conditions, Monroe County (2019 Dollars, $Millions)

Land Use	MHHW	1-Year Tide			10-Year Tide		
	Just Property Value	Structure Damages	Content Losses	Relocation Costs	Structure Damages	Content Losses	Relocation Costs
Agriculture	$0.2	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Central Assessed	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Commercial	$1,776.3	$2.3	$14.4	$0.2	$37.7	$50.3	$0.4
Governmental	$1,546.3	$54.9	$1.6	$0.2	$75.5	$2.2	$0.3
Industrial	$77.2	$0.5	$0.4	$0.0	$1.3	$1.1	$0.1
Institutional	$131.6	$0.1	$0.1	$0.0	$1.3	$1.0	$0.0
Miscellaneous	$59.9	$0.1	$0.0	$0.0	$1.5	$0.0	$0.1
Non-Ag Acreage	$2.9	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Residential	$9,907.0	$56.5	$23.2	$0.4	$252.5	$136.4	$4.2

Land Use	MHHW	1-Year Tide			10-Year Tide		
	Just Property Value	Structure Damages	Content Losses	Relocation Costs	Structure Damages	Content Losses	Relocation Costs
Total	**$13,501.4**	**$114.4**	**$39.7**	**$0.9**	**$369.8**	**$191.0**	**$5.1**

Notes:
Impacts only account for parcels where 25 percent or more of the parcel footprint is exposed to the modeled coastal conditions.
MHHW results account for one-time impacts equivalent to the just or market value of the parcel. Parcels impacted by MHHW conditions are excluded from 1-year and 10-year tide damages.
The 1-year and 10-year tide results account for the impacts of one storm event of these magnitudes occurring. The results are not adjusted to account for the probability of the modeled storm occurring.
Results are not adjusted to account for financial discounting.

Table 82. Direct Property Impacts by Land Use, 2020 Coastal Conditions, Palm Beach County (2019 Dollars, $Millions)

Land Use	MHHW	1-Year Tide			10-Year Tide		
	Just Property Value	Structure Damages	Content Losses	Relocation Costs	Structure Damages	Content Losses	Relocation Costs
Agriculture	NA	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Central Assessed	NA	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Commercial	NA	$0.0	$0.0	$0.0	$1.4	$1.8	$0.0
Governmental	NA	$0.0	$0.0	$0.0	$0.8	$0.0	$0.0
Industrial	NA	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Institutional	NA	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Miscellaneous	NA	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Non-Ag Acreage	NA	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Residential	NA	$1.0	$0.5	$0.0	$22.1	$11.5	$0.2
Total	**NA**	**$1.0**	**$0.5**	**$0.0**	**$24.3**	**$13.3**	**$0.2**

Notes:
Impacts only account for parcels where 25 percent or more of the parcel footprint is exposed to the modeled coastal conditions.
MHHW results account for one-time impacts equivalent to the just or market value of the parcel. Parcels impacted by MHHW conditions are excluded from 1-year and 10-year tide damages.
The 1-year and 10-year tide results account for the impacts of one storm event of these magnitudes occurring. The results are not adjusted to account for the probability of the modeled storm occurring.
Results are not adjusted to account for financial discounting.

Table 83. Direct Property Impacts by Land Use, 2040 Coastal Conditions, Palm Beach County (2019 Dollars, $Millions)

Land Use	MHHW	1-Year Tide			10-Year Tide		
	Just Property Value	Structure Damages	Content Losses	Relocation Costs	Structure Damages	Content Losses	Relocation Costs
Agriculture	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Central Assessed	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0

Land Use	MHHW	1-Year Tide			10-Year Tide		
	Just Property Value	Structure Damages	Content Losses	Relocation Costs	Structure Damages	Content Losses	Relocation Costs
Commercial	$11.8	$0.0	$0.0	$0.0	$90.2	$150.3	$1.0
Governmental	$31.4	$0.1	$0.0	$0.0	$4.0	$0.5	$0.1
Industrial	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Institutional	$0.0	$0.0	$0.0	$0.0	$20.7	$9.1	$0.2
Miscellaneous	$2.9	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Non-Ag Acreage	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Residential	$117.3	$6.3	$3.1	$0.0	$359.3	$230.8	$4.8
Total	**$163.4**	**$6.4**	**$3.1**	**$0.0**	**$474.2**	**$390.7**	**$6.1**

Notes:

Impacts only account for parcels where 25 percent or more of the parcel footprint is exposed to the modeled coastal conditions.

MHHW results account for one-time impacts equivalent to the just or market value of the parcel. Parcels impacted by MHHW conditions are excluded from 1-year and 10-year tide damages.

The 1-year and 10-year tide results account for the impacts of one storm event of these magnitudes occurring. The results are not adjusted to account for the probability of the modeled storm occurring.

Results are not adjusted to account for financial discounting.

Table 84. Direct Property Impacts by Land Use, 2070 Coastal Conditions, Palm Beach County (2019 Dollars, $Millions)

Land Use	MHHW	1-Year Tide			10-Year Tide		
	Just Property Value	Structure Damages	Content Losses	Relocation Costs	Structure Damages	Content Losses	Relocation Costs
Agriculture	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Central Assessed	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Commercial	$793.2	$15.0	$2.8	$0.0	$131.4	$157.7	$1.3
Governmental	$305.5	$0.3	$0.0	$0.0	$5.2	$0.2	$0.2
Industrial	$0.2	$0.0	$0.0	$0.0	$1.2	$1.0	$0.2
Institutional	$264.4	$2.1	$0.1	$0.1	$29.4	$9.2	$0.6
Miscellaneous	$17.3	$0.0	$0.0	$0.0	$0.9	$0.0	$0.1
Non-Ag Acreage	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Residential	$5,259.9	$92.0	$46.8	$0.7	$852.1	$482.2	$12.8
Total	**$6,640.5**	**$109.4**	**$49.7**	**$0.8**	**$1,020.2**	**$650.3**	**$15.2**

Notes:

Impacts only account for parcels where 25 percent or more of the parcel footprint is exposed to the modeled coastal conditions.

MHHW results account for one-time impacts equivalent to the just or market value of the parcel. Parcels impacted by MHHW conditions are excluded from 1-year and 10-year tide damages.

The 1-year and 10-year tide results account for the impacts of one storm event of these magnitudes occurring. The results are not adjusted to account for the probability of the modeled storm occurring.

Results are not adjusted to account for financial discounting.

Business and Employment Impacts

Table 85. Business and Employment Impacts by Industry, 2020 Coastal Conditions, Broward County (2019 Dollars, $Millions)

NAICS Industry	MHHW			1-Year Tide			10-Year Tide		
	Sales Output Loss	Income Loss	Job Loss	Sales Output Loss	Income Loss	Job Loss	Sales Output Loss	Income Loss	Job Loss
Agriculture, forestry, fishing and hunting	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Mining, quarrying, and oil and gas extraction	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Utilities	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Construction	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Manufacturing	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Wholesale trade	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Retail trade	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Transportation and warehousing	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Information	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Finance and insurance	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Real estate and rental and leasing	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Professional and technical services	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Management of companies and enterprises	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Administrative and waste services	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Educational services	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Health care and social assistance	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Arts, entertainment, and recreation	NA	NA	NA	$0.0	$0.0	0	$0.2	$0.1	0
Accommodation and food services	NA	NA	NA	$0.0	$0.0	0	$0.2	$0.1	0
Other services, except public administration	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.2	10
Public administration	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.3	0
Unclassified	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Total	**NA**	**NA**	**NA**	**$0.0**	**$0.0**	**0**	**$0.4**	**$0.7**	**20**

Notes:

Impacts only account for parcels where 25 percent or more of the parcel footprint is exposed to the modeled coastal conditions.

MHHW results account for one year of impacts. These impacts would recur, annually. Businesses impacted by MHHW conditions are excluded from 1-year and 10-year tide damages.

The 1-year and 10-year tide results account for the impacts of one storm event of these magnitudes occurring. The results are not adjusted to account for the probability of the modeled storm occurring.

Results account for recapture as discussed in Appendix E.

Jobs rounded to nearest 10.

Results are not adjusted to account for financial discounting.

Table 86. Business and Employment Impacts by Industry, 2040 Coastal Conditions, Broward County (2019 Dollars, $Millions)

NAICS Industry	MHHW			1-Year Tide			10-Year Tide		
	Sales Output Loss	Income Loss	Job Loss	Sales Output Loss	Income Loss	Job Loss	Sales Output Loss	Income Loss	Job Loss
Agriculture, forestry, fishing and hunting	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Mining, quarrying, and oil and gas extraction	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Utilities	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Construction	$0.1	$0.0	0	$0.0	$0.0	0	$0.2	$0.0	0
Manufacturing	$0.0	$0.0	0	$0.0	$0.0	0	$0.1	$0.0	0
Wholesale trade	$0.9	$0.1	0	$0.0	$0.0	0	$0.6	$0.0	0
Retail trade	$0.0	$0.0	0	$0.0	$0.0	0	$1.2	$0.1	0
Transportation and warehousing	$0.0	$0.0	0	$0.0	$0.0	0	$1.1	$0.5	10
Information	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Finance and insurance	$0.0	$0.0	0	$0.0	$0.0	0	$0.2	$0.0	0
Real estate and rental and leasing	$0.0	$0.0	0	$0.0	$0.0	0	$0.2	$0.1	0
Professional and technical services	$0.5	$0.1	0	$0.0	$0.0	0	$01.0	$0.5	10
Management of companies and enterprises	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Administrative and waste services	$0.0	$0.0	0	$0.0	$0.0	0	$0.1	$0.0	0
Educational services	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Health care and social assistance	$0.0	$0.0	0	$0.0	$0.0	0	$0.1	$0.4	10
Arts, entertainment, and recreation	$1.1	$0.4	10	$0.0	$0.0	0	$10.5	$2.0	60
Accommodation and food services	$0.2	$0.1	0	$0.0	$0.0	0	$1.8	$0.8	30
Other services, except public administration	$0.0	$0.9	40	$0.0	$0.0	0	$0.2	$0.3	10
Public administration	$0.0	$4.2	50	$0.0	$0.0	0	$0.0	$0.1	0
Unclassified	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Total	**$2.8**	**$5.7**	**110**	**$0.0**	**$0.0**	**0**	**$17.2**	**$5.0**	**130**

Notes:

Impacts only account for parcels where 25 percent or more of the parcel footprint is exposed to the modeled coastal conditions.

MHHW results account for one year of impacts. These impacts would recur, annually. Businesses impacted by MHHW conditions are excluded from 1-year and 10-year tide damages.

The 1-year and 10-year tide results account for the impacts of one storm event of these magnitudes occurring. The results are not adjusted to account for the probability of the modeled storm occurring.

Results account for recapture as discussed in Appendix E.

Jobs rounded to nearest 10.

Results are not adjusted to account for financial discounting.

Table 87. Business and Employment Impacts by Industry, 2070 Coastal Conditions, Broward County (2019 Dollars, $Millions)

NAICS Industry	MHHW			1-Year Tide			10-Year Tide		
	Sales Output Loss	Income Loss	Job Loss	Sales Output Loss	Income Loss	Job Loss	Sales Output Loss	Income Loss	Job Loss
Agriculture, forestry, fishing and hunting	$0.2	$0.1	0	$0.0	$0.0	0	$0.1	$0.0	0
Mining, quarrying, and oil and gas extraction	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Utilities	$0.0	$0.0	0	$0.0	$0.0	0	$0.1	$0.0	0
Construction	$4.5	$1.2	20	$0.1	$0.0	0	$1.7	$0.5	10
Manufacturing	$1.9	$0.4	10	$0.1	$0.1	0	$0.7	$0.2	0
Wholesale trade	$68.3	$2.6	40	$0.1	$0.0	0	$12.7	$0.7	10
Retail trade	$64.2	$7.5	150	$0.2	$0.0	0	$13.7	$1.7	40
Transportation and warehousing	$22.6	$8.9	160	$0.5	$0.2	0	$4.3	$1.4	30
Information	$7.8	$2.8	30	$0.0	$0.0	0	$1.7	$0.7	10
Finance and insurance	$30.6	$6.9	70	$0.0	$0.0	0	$2.3	$0.8	10
Real estate and rental and leasing	$19.9	$7.5	140	$0.1	$0.0	0	$1.8	$0.7	10
Professional and technical services	$50.2	$31.3	380	$0.0	$0.0	0	$2.1	$1.3	20
Management of companies and enterprises	$3.5	$0.7	10	$0.0	$0.0	0	$0.3	$0.1	0
Administrative and waste services	$75.1	$29.0	570	$0.1	$0.0	0	$1.2	$0.5	10
Educational services	$1.7	$12.5	270	$0.0	$0.0	0	$0.3	$1.5	40
Health care and social assistance	$25.7	$16.3	340	$0.1	$0.0	0	$5.8	$3.6	60
Arts, entertainment, and recreation	$73.6	$14.1	400	$0.1	$0.0	0	$8.7	$1.7	50
Accommodation and food services	$52.9	$18.7	680	$0.0	$0.0	0	$10.2	$3.8	150
Other services, except public administration	$9.9	$11.0	330	$0.1	$0.0	0	$3.1	$3.4	90
Public administration	$0.0	$11.8	160	$0.0	$0.0	0	$0.0	$2.6	40
Unclassified	$0.0	$0.7	10	$0.0	$0.0	0	$0.0	$0.1	0
Total	**$512.6**	**$184.0**	**3,780**	**$1.4**	**$0.5**	**10**	**$70.6**	**$25.0**	**580**

Notes:

Impacts only account for parcels where 25 percent or more of the parcel footprint is exposed to the modeled coastal conditions.

MHHW results account for one year of impacts. These impacts would recur, annually. Businesses impacted by MHHW conditions are excluded from 1-year and 10-year tide damages.

The 1-year and 10-year tide results account for the impacts of one storm event of these magnitudes occurring. The results are not adjusted to account for the probability of the modeled storm occurring.

Results account for recapture as discussed in Appendix E.

Jobs rounded to nearest 10.

Results are not adjusted to account for financial discounting.

Table 88. Business and Employment Impacts by Industry, 2020 Coastal Conditions, Miami-Dade County (2019 Dollars, $Millions)

NAICS Industry	MHHW			1-Year Tide			10-Year Tide		
	Sales Output Loss	Income Loss	Job Loss	Sales Output Loss	Income Loss	Job Loss	Sales Output Loss	Income Loss	Job Loss
Agriculture, forestry, fishing and hunting	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Mining, quarrying, and oil and gas extraction	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Utilities	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Construction	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Manufacturing	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Wholesale trade	NA	NA	NA	$0.0	$0.0	0	$0.4	$0.0	0
Retail trade	NA	NA	NA	$0.0	$0.0	0	$1.9	$0.3	10
Transportation and warehousing	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Information	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Finance and insurance	NA	NA	NA	$0.0	$0.0	0	$0.1	$0.0	0
Real estate and rental and leasing	NA	NA	NA	$0.0	$0.0	0	$0.2	$0.1	0
Professional and technical services	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Management of companies and enterprises	NA	NA	NA	$0.0	$0.0	0	$0.1	$0.0	0
Administrative and waste services	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Educational services	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.1	0
Health care and social assistance	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Arts, entertainment, and recreation	NA	NA	NA	$0.0	$0.0	0	$0.1	$0.0	0
Accommodation and food services	NA	NA	NA	$0.3	$0.1	0	$2.6	$0.9	30
Other services, except public administration	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.2	0
Public administration	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Unclassified	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Total	NA	NA	NA	**$0.4**	**$0.1**	**0**	**$5.5**	**$1.7**	**50**

Notes:

Impacts only account for parcels where 25 percent or more of the parcel footprint is exposed to the modeled coastal conditions.

MHHW results account for one year of impacts. These impacts would recur, annually. Businesses impacted by MHHW conditions are excluded from 1-year and 10-year tide damages.

The 1-year and 10-year tide results account for the impacts of one storm event of these magnitudes occurring. The results are not adjusted to account for the probability of the modeled storm occurring.

Results account for recapture as discussed in Appendix E.

Jobs rounded to nearest 10.

Results are not adjusted to account for financial discounting.

Table 89. Business and Employment Impacts by Industry, 2040 Coastal Conditions, Miami-Dade County (2019 Dollars, $Millions)

NAICS Industry	MHHW			1-Year Tide			10-Year Tide		
	Sales Output Loss	Income Loss	Job Loss	Sales Output Loss	Income Loss	Job Loss	Sales Output Loss	Income Loss	Job Loss
Agriculture, forestry, fishing and hunting	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Mining, quarrying, and oil and gas extraction	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Utilities	$1.4	$0.2	0	$0.0	$0.0	0	$0.0	$0.0	0
Construction	$0.1	$0.0	0	$0.0	$0.0	0	$0.1	$0.0	0
Manufacturing	$0.1	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Wholesale trade	$1.2	$0.1	0	$0.0	$0.0	0	$0.7	$0.0	0
Retail trade	$2.2	$0.4	10	$0.0	$0.0	0	$3.0	$0.4	10
Transportation and warehousing	$1.0	$0.4	10	$0.0	$0.0	0	$0.5	$0.2	0
Information	$0.0	$0.1	0	$0.0	$0.0	0	$0.2	$0.0	0
Finance and insurance	$1.5	$0.3	0	$0.1	$0.0	0	$0.3	$0.1	0
Real estate and rental and leasing	$1.8	$0.6	10	$0.0	$0.0	0	$0.8	$0.3	0
Professional and technical services	$1.0	$0.6	10	$0.0	$0.0	0	$0.2	$0.1	0
Management of companies and enterprises	$0.6	$0.2	0	$0.1	$0.0	0	$0.2	$0.1	0
Administrative and waste services	$0.2	$0.1	0	$0.0	$0.0	0	$0.1	$0.1	0
Educational services	$0.1	$6.0	140	$0.0	$0.0	0	$0.1	$0.1	0
Health care and social assistance	$2.1	$0.9	20	$0.0	$0.0	0	$0.5	$0.2	0
Arts, entertainment, and recreation	$4.6	$2.9	70	$0.0	$0.0	0	$2.1	$0.7	10
Accommodation and food services	$9.9	$3.6	90	$0.1	$0.0	0	$5.1	$2.2	70
Other services, except public administration	$0.4	$1.1	20	$0.0	$0.0	0	$0.3	$0.5	10
Public administration	$0.0	$1.2	20	$0.0	$0.0	0	$0.0	$0.1	0
Unclassified	$0.0	$0.1	0	$0.0	$0.0	0	$0.0	$0.0	0
Total	**$28.1**	**$18.9**	**420**	**$0.3**	**$0.1**	**0**	**$14.2**	**$5.0**	**130**

Notes:

Impacts only account for parcels where 25 percent or more of the parcel footprint is exposed to the modeled coastal conditions.

MHHW results account for one year of impacts. These impacts would recur, annually. Businesses impacted by MHHW conditions are excluded from 1-year and 10-year tide damages.

The 1-year and 10-year tide results account for the impacts of one storm event of these magnitudes occurring. The results are not adjusted to account for the probability of the modeled storm occurring.

Results account for recapture as discussed in Appendix E.

Jobs rounded to nearest 10.

Results are not adjusted to account for financial discounting.

Table 90. Business and Employment Impacts by Industry, 2070 Coastal Conditions, Miami-Dade County (2019 Dollars, $Millions)

NAICS Industry	MHHW			1-Year Tide			10-Year Tide		
	Sales Output Loss	Income Loss	Job Loss	Sales Output Loss	Income Loss	Job Loss	Sales Output Loss	Income Loss	Job Loss
Agriculture, forestry, fishing and hunting	$0.5	$0.2	10	$0.0	$0.0	0	$0.2	$0.0	0
Mining, quarrying, and oil and gas extraction	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Utilities	$1.8	$0.3	0	$0.0	$0.0	0	$0.2	$0.0	0
Construction	$8.5	$2.2	40	$0.0	$0.0	0	$0.8	$0.2	0
Manufacturing	$1.2	$0.4	10	$0.0	$0.0	0	$0.2	$0.1	0
Wholesale trade	$51.5	$2.3	40	$0.4	$0.0	0	$12.2	$0.6	10
Retail trade	$123.2	$17.0	540	$0.5	$0.1	0	$5.5	$0.7	20
Transportation and warehousing	$26.4	$9.7	230	$0.3	$0.1	0	$2.3	$1.0	20
Information	$12.9	$3.3	40	$0.1	$0.0	0	$1.3	$0.4	10
Finance and insurance	$30.6	$8.7	80	$0.3	$0.1	0	$3.7	$1.0	10
Real estate and rental and leasing	$57.2	$22.8	380	$0.5	$0.2	0	$2.7	$01.0	20
Professional and technical services	$40.4	$16.0	260	$0.1	$0.1	0	$2.3	$1.3	20
Management of companies and enterprises	$15.6	$5.0	30	$0.1	$0.1	0	$0.8	$0.3	0
Administrative and waste services	$9.8	$4.8	100	$0.0	$0.0	0	$0.6	$0.3	10
Educational services	$3.5	$16.6	410	$0.0	$0.0	0	$0.4	$0.6	20
Health care and social assistance	$66.2	$29.6	570	$0.2	$0.1	0	$6.1	$3.0	60
Arts, entertainment, and recreation	$68.9	$35.2	740	$1.9	$0.4	10	$5.9	$1.7	30
Accommodation and food services	$172.4	$71.9	2,220	$0.8	$0.4	10	$18.6	$7.8	260
Other services, except public administration	$29.7	$32.0	870	$0.1	$0.1	0	$1.7	$1.7	50
Public administration	$0.0	$26.9	340	$0.0	$0.0	0	$0.0	$0.5	10
Unclassified	$0.0	$1.2	30	$0.0	$0.0	0	$0.0	$0.1	0
Total	**$720.4**	**$306.0**	**6,920**	**$5.3**	**$1.6**	**40**	**$65.5**	**$22.3**	**540**

Notes:

Impacts only account for parcels where 25 percent or more of the parcel footprint is exposed to the modeled coastal conditions.

MHHW results account for one year of impacts. These impacts would recur, annually. Businesses impacted by MHHW conditions are excluded from 1-year and 10-year tide damages.

The 1-year and 10-year tide results account for the impacts of one storm event of these magnitudes occurring. The results are not adjusted to account for the probability of the modeled storm occurring.

Results account for recapture as discussed in Appendix E.

Jobs rounded to nearest 10.

Results are not adjusted to account for financial discounting.

Table 91. Business and Employment Impacts by Industry, 2020 Coastal Conditions, Monroe County (2019 Dollars, $Millions)

NAICS Industry	MHHW			1-Year Tide			10-Year Tide		
	Sales Output Loss	Income Loss	Job Loss	Sales Output Loss	Income Loss	Job Loss	Sales Output Loss	Income Loss	Job Loss
Agriculture, forestry, fishing and hunting	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Mining, quarrying, and oil and gas extraction	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Utilities	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Construction	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Manufacturing	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Wholesale trade	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Retail trade	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Transportation and warehousing	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Information	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Finance and insurance	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Real estate and rental and leasing	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Professional and technical services	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Management of companies and enterprises	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Administrative and waste services	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Educational services	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Health care and social assistance	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Arts, entertainment, and recreation	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Accommodation and food services	NA	NA	NA	$0.0	$0.0	0	$0.1	$0.0	0
Other services, except public administration	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Public administration	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Unclassified	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Total	**NA**	**NA**	**NA**	**$0.0**	**$0.0**	**0**	**$0.1**	**$0.0**	**0**

Notes:
Impacts only account for parcels where 25 percent or more of the parcel footprint is exposed to the modeled coastal conditions.

MHHW results account for one year of impacts. These impacts would recur, annually. Businesses impacted by MHHW conditions are excluded from 1-year and 10-year tide damages.

The 1-year and 10-year tide results account for the impacts of one storm event of these magnitudes occurring. The results are not adjusted to account for the probability of the modeled storm occurring.

Results account for recapture as discussed in Appendix E.

Jobs rounded to nearest 10.

Results are not adjusted to account for financial discounting.

Table 92. Business and Employment Impacts by Industry, 2040 Coastal Conditions, Monroe County (2019 Dollars, $Millions)

NAICS Industry	MHHW			1-Year Tide			10-Year Tide		
	Sales Output Loss	Income Loss	Job Loss	Sales Output Loss	Income Loss	Job Loss	Sales Output Loss	Income Loss	Job Loss
Agriculture, forestry, fishing and hunting	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Mining, quarrying, and oil and gas extraction	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Utilities	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Construction	$0.2	$0.1	0	$0.0	$0.0	0	$0.0	$0.0	0
Manufacturing	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Wholesale trade	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Retail trade	$0.3	$0.1	0	$0.0	$0.0	0	$0.0	$0.0	0
Transportation and warehousing	$0.6	$0.2	0	$0.0	$0.0	0	$0.0	$0.0	0
Information	$1.0	$0.1	0	$0.0	$0.0	0	$0.0	$0.0	0
Finance and insurance	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Real estate and rental and leasing	$0.1	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Professional and technical services	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Management of companies and enterprises	$0.0	$0.0	0	$0.0	$0.0	0	$0.1	$0.0	0
Administrative and waste services	$0.1	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Educational services	$0.2	$1.7	40	$0.0	$0.0	0	$0.0	$0.1	0
Health care and social assistance	$0.5	$0.3	0	$0.0	$0.0	0	$0.0	$0.0	0
Arts, entertainment, and recreation	$0.0	$0.3	0	$0.0	$0.0	0	$0.1	$0.0	0
Accommodation and food services	$1.2	$0.8	30	$0.0	$0.0	0	$0.1	$0.0	0
Other services, except public administration	$0.6	$0.5	10	$0.0	$0.0	0	$0.0	$0.0	0
Public administration	$0.0	$7.8	80	$0.0	$0.0	0	$0.0	$0.2	0
Unclassified	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Total	**$4.9**	**$11.8**	**180**	**$0.0**	**$0.0**	**0**	**$0.3**	**$0.3**	**10**

Notes:

Impacts only account for parcels where 25 percent or more of the parcel footprint is exposed to the modeled coastal conditions.

MHHW results account for one year of impacts. These impacts would recur, annually. Businesses impacted by MHHW conditions are excluded from 1-year and 10-year tide damages.

The 1-year and 10-year tide results account for the impacts of one storm event of these magnitudes occurring. The results are not adjusted to account for the probability of the modeled storm occurring.

Results account for recapture as discussed in Appendix E.

Jobs rounded to nearest 10.

Results are not adjusted to account for financial discounting.

Table 93. Business and Employment Impacts by Industry, 2070 Coastal Conditions, Monroe County (2019 Dollars, $Millions)

NAICS Industry	MHHW			1-Year Tide			10-Year Tide		
	Sales Output Loss	Income Loss	Job Loss	Sales Output Loss	Income Loss	Job Loss	Sales Output Loss	Income Loss	Job Loss
Agriculture, forestry, fishing and hunting	$2.41	$0.7	18	$0.0	$0.0	0	$0.0	$0.0	0
Mining, quarrying, and oil and gas extraction	$0.6	$0.2	0	$0.0	$0.0	0	$0.0	$0.0	0
Utilities	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Construction	$190.8	$19.4	240	$0.0	$0.0	0	$0.0	$0.0	0
Manufacturing	$8.9	$2.1	40	$0.0	$0.0	0	$0.0	$0.0	0
Wholesale trade	$0.5	$0.6	10	$0.0	$0.0	0	$0.2	$0.0	0
Retail trade	$92.0	$2.7	40	$0.2	$0.0	0	$0.6	$0.1	0
Transportation and warehousing	$111.8	$10.9	330	$0.0	$0.0	0	$0.3	$0.2	0
Information	$19.6	$8.7	200	$0.0	$0.0	0	$0.0	$0.0	0
Finance and insurance	$7.0	$0.9	20	$0.0	$0.0	0	$0.1	$0.0	0
Real estate and rental and leasing	$6.8	$2.1	20	$0.0	$0.0	0	$0.0	$0.0	0
Professional and technical services	$10.6	$3.0	70	$0.0	$0.0	0	$0.0	$0.0	0
Management of companies and enterprises	$7.6	$4.6	70	$0.0	$0.0	0	$0.0	$0.0	0
Administrative and waste services	$1.0	$0.1	0	$0.0	$0.0	0	$0.1	$0.0	0
Educational services	$13.2	$3.6	100	$0.0	$0.0	0	$0.0	$0.0	0
Health care and social assistance	$2.3	$5.6	140	$0.1	$0.0	0	$0.3	$0.1	0
Arts, entertainment, and recreation	$56.9	$23.7	400	$0.0	$0.0	0	$0.3	$0.1	0
Accommodation and food services	$45.2	$12.6	280	$0.0	$0.0	0	$5.1	$0.9	30
Other services, except public administration	$200.9	$57.6	1,780	$0.0	$0.0	0	$0.2	$0.0	0
Public administration	$16.6	$18.3	680	$0.0	$0.0	0	$0.0	$0.2	0
Unclassified	$0.0	$63.7	910	$0.0	$0.0	0	$0.0	$0.0	0
Total	**$792.4**	**$240.6**	**5,340**	**$0.4**	**$0.1**	**0**	**$7.2**	**$1.6**	**40**

Notes:

Impacts only account for parcels where 25 percent or more of the parcel footprint is exposed to the modeled coastal conditions.

MHHW results account for one year of impacts. These impacts would recur, annually. Businesses impacted by MHHW conditions are excluded from 1-year and 10-year tide damages.

The 1-year and 10-year tide results account for the impacts of one storm event of these magnitudes occurring. The results are not adjusted to account for the probability of the modeled storm occurring.

Results account for recapture as discussed in Appendix E.

Jobs rounded to nearest 10.

Results are not adjusted to account for financial discounting.

Table 94. Business and Employment Impacts by Industry, 2020 Coastal Conditions, Palm Beach County (2019 Dollars, $Millions)

NAICS Industry	MHHW			1-Year Tide			10-Year Tide		
	Sales Output Loss	Income Loss	Job Loss	Sales Output Loss	Income Loss	Job Loss	Sales Output Loss	Income Loss	Job Loss
Agriculture, forestry, fishing and hunting	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Mining, quarrying, and oil and gas extraction	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Utilities	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Construction	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Manufacturing	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Wholesale trade	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Retail trade	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Transportation and warehousing	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Information	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Finance and insurance	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Real estate and rental and leasing	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Professional and technical services	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Management of companies and enterprises	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Administrative and waste services	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Educational services	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Health care and social assistance	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Arts, entertainment, and recreation	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Accommodation and food services	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Other services, except public administration	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Public administration	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Unclassified	NA	NA	NA	$0.0	$0.0	0	$0.0	$0.0	0
Total	**NA**	**NA**	**NA**	**$0.0**	**$0.0**	**0**	**$0.1**	**$0.0**	**0**

Notes:

Impacts only account for parcels where 25 percent or more of the parcel footprint is exposed to the modeled coastal conditions.

MHHW results account for one year of impacts. These impacts would recur, annually. Businesses impacted by MHHW conditions are excluded from 1-year and 10-year tide damages.

The 1-year and 10-year tide results account for the impacts of one storm event of these magnitudes occurring. The results are not adjusted to account for the probability of the modeled storm occurring.

Results account for recapture as discussed in Appendix E.

Jobs rounded to nearest 10.

Results are not adjusted to account for financial discounting.

Table 95. Business and Employment Impacts by Industry, 2040 Coastal Conditions, Palm Beach County (2019 Dollars, $Millions)

NAICS Industry	MHHW			1-Year Tide			10-Year Tide		
	Sales Output Loss	Income Loss	Job Loss	Sales Output Loss	Income Loss	Job Loss	Sales Output Loss	Income Loss	Job Loss
Agriculture, forestry, fishing and hunting	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Mining, quarrying, and oil and gas extraction	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Utilities	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Construction	$0.0	$0.0	0	$0.0	$0.0	0	$0.1	$0.0	0
Manufacturing	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Wholesale trade	$0.0	$0.0	0	$0.0	$0.0	0	$0.3	$0.0	0
Retail trade	$0.0	$0.0	0	$0.0	$0.0	0	$0.4	$0.1	0
Transportation and warehousing	$0.0	$0.0	0	$0.0	$0.0	0	$0.2	$0.1	0
Information	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Finance and insurance	$0.0	$0.0	0	$0.0	$0.0	0	$0.4	$0.1	0
Real estate and rental and leasing	$0.2	$0.1	0	$0.0	$0.0	0	$0.1	$0.1	0
Professional and technical services	$0.0	$0.0	0	$0.0	$0.0	0	$0.4	$0.2	0
Management of companies and enterprises	$0.0	$0.0	0	$0.0	$0.0	0	$0.1	$0.0	0
Administrative and waste services	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Educational services	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Health care and social assistance	$0.0	$0.0	0	$0.0	$0.0	0	$0.4	$0.3	0
Arts, entertainment, and recreation	$0.0	$0.4	10	$0.0	$0.0	0	$1.9	$0.9	20
Accommodation and food services	$0.0	$0.0	0	$0.0	$0.0	0	$3.5	$1.4	50
Other services, except public administration	$0.0	$0.0	0	$0.0	$0.0	0	$0.1	$0.4	10
Public administration	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Unclassified	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Total	**$0.2**	**$0.5**	**10**	**$0.0**	**$0.0**	**0**	**$8.0**	**$3.6**	**90**

Notes:

Impacts only account for parcels where 25 percent or more of the parcel footprint is exposed to the modeled coastal conditions.

MHHW results account for one year of impacts. These impacts would recur, annually. Businesses impacted by MHHW conditions are excluded from 1-year and 10-year tide damages.

The 1-year and 10-year tide results account for the impacts of one storm event of these magnitudes occurring. The results are not adjusted to account for the probability of the modeled storm occurring.

Results account for recapture as discussed in Appendix E.

Jobs rounded to nearest 10.

Results are not adjusted to account for financial discounting.

Table 96. Business and Employment Impacts by Industry, 2070 Coastal Conditions, Palm Beach County (2019 Dollars, $Millions)

NAICS Industry	MHHW			1-Year Tide			10-Year Tide		
	Sales Output Loss	Income Loss	Job Loss	Sales Output Loss	Income Loss	Job Loss	Sales Output Loss	Income Loss	Job Loss
Agriculture, forestry, fishing and hunting	$0.7	$0.3	10	$0.0	$0.0	0	$0.0	$0.0	0
Mining, quarrying, and oil and gas extraction	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Utilities	$0.0	$0.0	0	$0.0	$0.0	0	$0.0	$0.0	0
Construction	$2.0	$0.5	10	$0.0	$0.0	0	$0.1	$0.0	0
Manufacturing	$0.4	$0.1	0	$0.0	$0.0	0	$0.0	$0.0	0
Wholesale trade	$18.4	$1.4	10	$0.0	$0.0	0	$0.6	$0.0	0
Retail trade	$19.0	$2.8	90	$0.1	$0.0	0	$1.3	$0.2	0
Transportation and warehousing	$3.7	$1.1	20	$0.0	$0.0	0	$0.2	$0.1	0
Information	$2.0	$0.7	10	$0.0	$0.0	0	$0.1	$0.0	0
Finance and insurance	$14.6	$6.4	50	$0.2	$0.1	0	$0.5	$0.1	0
Real estate and rental and leasing	$9.1	$4.8	70	$0.0	$0.0	0	$0.3	$0.2	0
Professional and technical services	$13.0	$6.3	70	$0.0	$0.0	0	$0.3	$0.1	0
Management of companies and enterprises	$1.9	$0.5	0	$0.0	$0.0	0	$0.0	$0.0	0
Administrative and waste services	$1.8	$01.0	10	$0.0	$0.0	0	$0.1	$0.0	0
Educational services	$0.2	$1.1	30	$0.0	$0.0	0	$0.0	$0.0	0
Health care and social assistance	$32.6	$15.1	240	$0.0	$0.0	0	$0.4	$0.2	0
Arts, entertainment, and recreation	$26.5	$6.5	150	$0.0	$0.3	10	$1.8	$0.6	10
Accommodation and food services	$49.3	$21.7	760	$0.2	$0.1	0	$4.8	$1.8	60
Other services, except public administration	$4.4	$8.4	200	$0.2	$0.1	0	$0.4	$0.6	20
Public administration	$0.0	$3.7	30	$0.0	$0.0	0	$0.0	$0.1	0
Unclassified	$0.0	$0.4	10	$0.0	$0.0	0	$0.0	$0.0	0
Total	**$199.4**	**$82.6**	**1,770**	**$0.7**	**$0.5**	**10**	**$11.0**	**$4.2**	**110**

Notes:

Impacts only account for parcels where 25 percent or more of the parcel footprint is exposed to the modeled coastal conditions.

MHHW results account for one year of impacts. These impacts would recur, annually. Businesses impacted by MHHW conditions are excluded from 1-year and 10-year tide damages.

The 1-year and 10-year tide results account for the impacts of one storm event of these magnitudes occurring. The results are not adjusted to account for the probability of the modeled storm occurring.

Results account for recapture as discussed in Appendix E.

Jobs rounded to nearest 10.

Results are not adjusted to account for financial discounting.

Appendix G – Detailed Secondary Economic Job Consequence Results (REMI)

No Action Scenario

Table 97 shows employment impacts by industry for the temporary event-based storm models.

Table 97. Employment Impacts by Industry for Event-Based Storms

REMI Aggregated Industries	2020 10-Year Tide Jobs relative to Baseline	2040 10-Year Tide Jobs relative to Baseline	2070 10-Year Tide Jobs relative to Baseline
Broward County			
All Industries	**-590**	**-2,250**	**-15,410**
Natural Resources	0	0	-30
Construction	-60	-130	-780
Manufacturing	-10	-20	-200
Retail and Wholesale	-40	-210	-2,720
Transportation and Public Utilities	-10	-70	-640
Finance, Insurance & Real Estate	-230	-480	-1,510
Services	-230	-1,270	-9,080
Government	-20	-70	-440
Farm	0	0	0
Miami-Dade County			
All Industries	**-1,490**	**-1,750**	**-16,120**
Natural Resources	0	0	-40
Construction	-100	150	-390
Manufacturing	-30	-20	-230
Retail and Wholesale	-260	-270	-2,320
Transportation and Public Utilities	-50	-80	-740
Finance, Insurance & Real Estate	-400	-390	-1,700
Services	-590	-1,070	-10,350
Government	-60	-60	-360
Farm	0	0	0
Monroe County			
All Industries	**-20**	**-70**	**-680**
Natural Resources	0	0	-30
Construction	0	10	10
Manufacturing	0	0	0
Retail and Wholesale	0	-10	-70
Transportation and Public Utilities	0	0	-20
Finance, Insurance & Real Estate	0	0	-30
Services	-20	-60	-520
Government	0	0	-20
Farm	0	0	0
Palm Beach County			
All Industries	**-240**	**-2,450**	**-3,310**
Natural Resources	0	-10	-10

REMI Aggregated Industries	2020 10-Year Tide Jobs relative to Baseline	2040 10-Year Tide Jobs relative to Baseline	2070 10-Year Tide Jobs relative to Baseline
Construction	-40	-200	-180
Manufacturing	0	-20	-50
Retail and Wholesale	-20	-220	-320
Transportation and Public Utilities	0	-60	-80
Finance, Insurance & Real Estate	-90	-350	-460
Services	-80	-1,550	-2,140
Government	-10	-60	-60
Farm	0	0	0
Rest of Florida			
All Industries	**-190**	**-510**	**-2,650**
Natural Resources	0	-10	-40
Construction	-20	-50	-280
Manufacturing	-10	-20	-100
Retail and Wholesale	-20	-60	-410
Transportation and Public Utilities	-10	-20	-150
Finance, Insurance & Real Estate	-90	-160	-390
Services	-50	-200	-1,240
Government	0	-10	-50
Farm	0	0	0

Notes:

Jobs are rounded to nearest 10.

Systemic Adaptation Scenario

Table 98 shows employment impacts by industry for the systemic adaptation scenario. Employment is shown as job years over the two phases of investment. Job years is one year of work for one person – for example: a new construction job that lasts the duration of the investment phase of five years will equate to five job years.

Table 98. Employment Impacts from Systemic Adaptation Scenario Shown in Two Phases (Shown in Job Years)

REMI Aggregated Industries	Investments in 2020 Job Years *Combined Difference from Baseline*	Investments in 2040 Job Years *Combined Difference from Baseline*
Broward County		
All Industries	**6,780**	**5,280**
Natural Resources	0	0
Construction	18,910	16,290
Manufacturing	140	30
Retail and Wholesale	-1,420	-1,230
Transportation and Public Utilities	-290	-260
Finance, Insurance & Real Estate	-1,600	-1,370
Services	-5,140	-5,140
Government	-3,820	-3,040

REMI Aggregated Industries	Investments in 2020	Investments in 2040
	Job Years *Combined Difference from Baseline*	Job Years *Combined Difference from Baseline*
Farm	0	0
Miami-Dade County		
All Industries	**15,200**	**9,550**
Natural Resources	0	0
Construction	13,450	8,900
Manufacturing	440	200
Retail and Wholesale	2,250	1,640
Transportation and Public Utilities	190	130
Finance, Insurance & Real Estate	240	90
Services	1,970	1,180
Government	-3,340	-2,590
Farm	0	0
Monroe County		
All Industries	**19,370**	**9,230**
Natural Resources	-210	-170
Construction	34,830	20,370
Manufacturing	-170	-150
Retail and Wholesale	-1,820	-1,650
Transportation and Public Utilities	-320	-240
Finance, Insurance & Real Estate	-1,760	-1,490
Services	-6,420	-5,180
Government	-4,760	-2,250
Farm	0	0
Palm Beach County		
All Industries	**9,470**	**9,910**
Natural Resources	-20	-10
Construction	17,430	14,300
Manufacturing	220	140
Retail and Wholesale	-450	310
Transportation and Public Utilities	-130	-30
Finance, Insurance & Real Estate	-1,060	-390
Services	-2,680	-780
Government	-3,830	-3,630
Farm	0	0
Rest of Florida		
All Industries	**-15,050**	**-11,320**
Natural Resources	0	0
Construction	-1,080	-670
Manufacturing	120	50
Retail and Wholesale	-1,060	-720
Transportation and Public Utilities	-210	-150
Finance, Insurance & Real Estate	-920	-620
Services	-3,720	-3,020
Government	-8,190	-6,190

REMI Aggregated Industries	Investments in 2020 Job Years *Combined Difference from Baseline*	Investments in 2040 Job Years *Combined Difference from Baseline*
Farm	0	0

Notes:

Jobs are rounded to nearest 10.

Building-Level Adaptation Scenario

Table 99 shows employment impacts by industry for the building-level adaptation scenario. Employment is shown as job years over the two phases of investment. Job years is one year of work for one person – for example: a new construction job that lasts the duration of the investment phase of five years will equate to five job years.

Table 99. Employment Impacts from Build-Level Adaptation Scenario Shown in Two Phases (Shown in Job Years)

REMI Aggregated Industries	Investments in 2020 Job Years *Combined Difference from Baseline*	Investments in 2040 Job Years *Combined Difference from Baseline*
Broward County		
All Industries	**2,530**	**15,010**
Natural Resources	0	20
Construction	2,330	13,480
Manufacturing	50	160
Retail and Wholesale	60	520
Transportation and Public Utilities	30	190
Finance, Insurance & Real Estate	-40	-90
Services	60	410
Government	30	320
Farm	0	0
Miami-Dade County		
All Industries	**3,190**	**18,470**
Natural Resources	0	20
Construction	2,460	14,860
Manufacturing	80	290
Retail and Wholesale	240	1,250
Transportation and Public Utilities	60	310
Finance, Insurance & Real Estate	30	80
Services	230	1,120
Government	90	540
Farm	0	0
Monroe County		
All Industries	**2,560**	**5,600**
Natural Resources	0	0

REMI Aggregated Industries	Investments in 2020	Investments in 2040
	Job Years *Combined Difference from Baseline*	Job Years *Combined Difference from Baseline*
Construction	2,440	5,230
Manufacturing	0	0
Retail and Wholesale	20	120
Transportation and Public Utilities	10	20
Finance, Insurance & Real Estate	-10	-10
Services	10	70
Government	90	180
Farm	0	0
Palm Beach County		
All Industries	**1,270**	**7,020**
Natural Resources	0	10
Construction	980	5,490
Manufacturing	30	100
Retail and Wholesale	60	370
Transportation and Public Utilities	10	70
Finance, Insurance & Real Estate	20	90
Services	120	680
Government	50	220
Farm	0	0
Rest of Florida		
All Industries	**300**	**1,130**
Natural Resources	10	20
Construction	40	140
Manufacturing	40	140
Retail and Wholesale	60	250
Transportation and Public Utilities	30	130
Finance, Insurance & Real Estate	20	80
Services	80	340
Government	10	50
Farm	0	0

Notes:

Jobs are rounded to nearest 10.

Appendix H – REMI Model Framework

REMI provided the following narrative and figures to AECOM.

The following core framework applies to all REMI model builds. The model integrates input-output, computable general equilibrium, econometric and economic geography methodologies. The model is dynamic, with forecasts and simulations generated on an annual basis and behavioral responses to compensation, price, and other economic factors.

The model consists of thousands of simultaneous equations with a structure that is relatively straightforward. The exact number of equations used varies depending on the extent of industry, demographic, demand, and other detail in the specific model being used. The overall structure of the model can be summarized in five major blocks: (1) Output and Demand, (2) Labor and Capital Demand, (3) Population and Labor Supply, (4) Compensation, Prices, and Costs, and (5) Market Shares. The blocks and their key interactions are shown in Figure 27 and Figure 28.

Figure 27. REMI Model Linkages

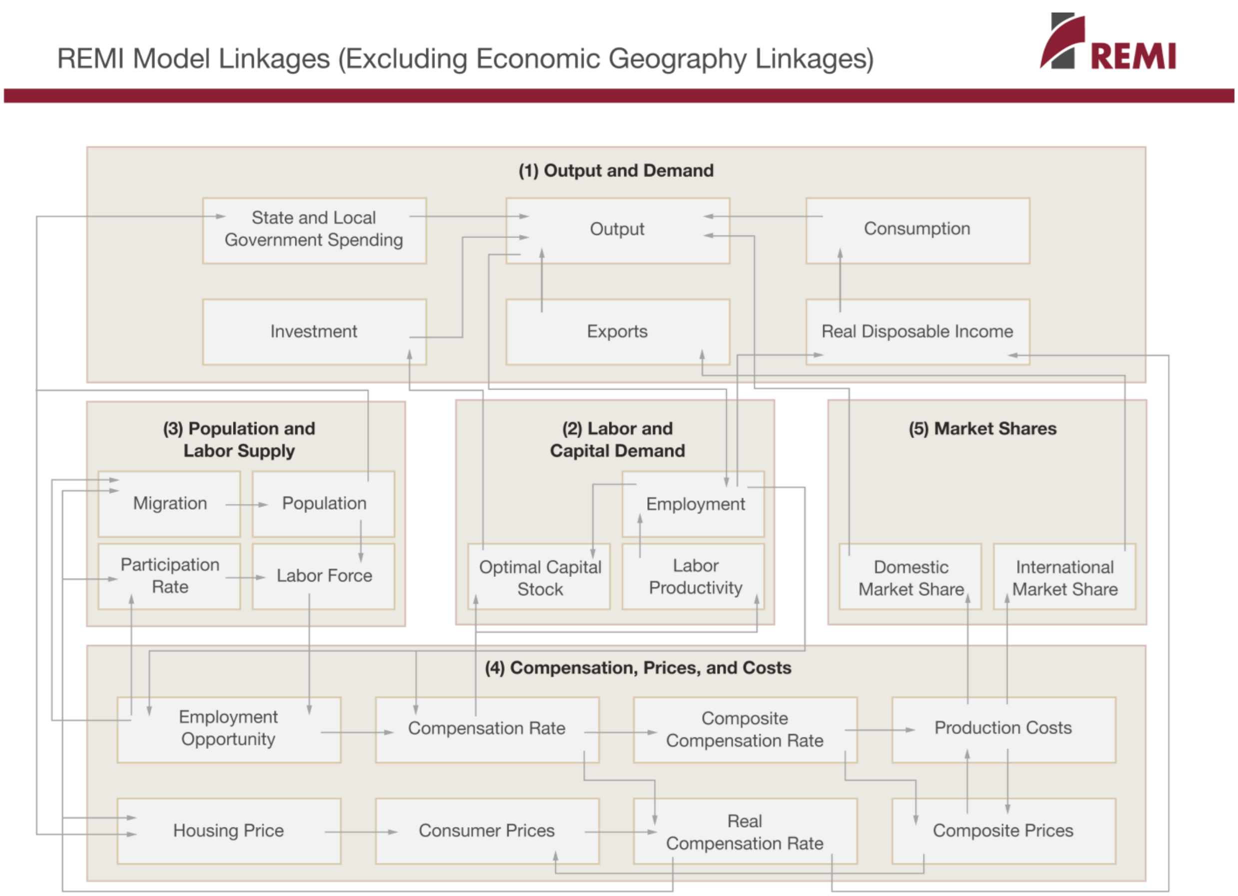
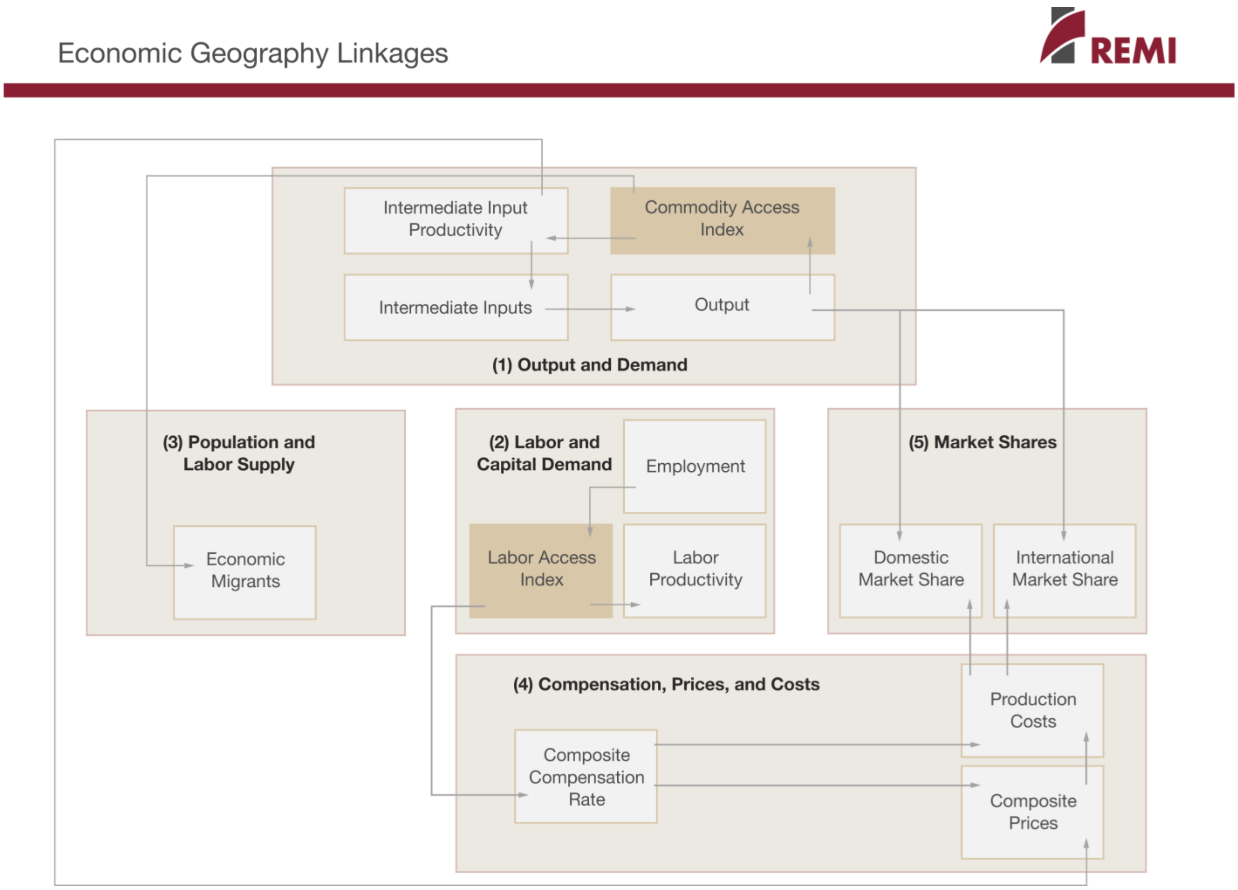


Figure 28. Economic Geography Linkages



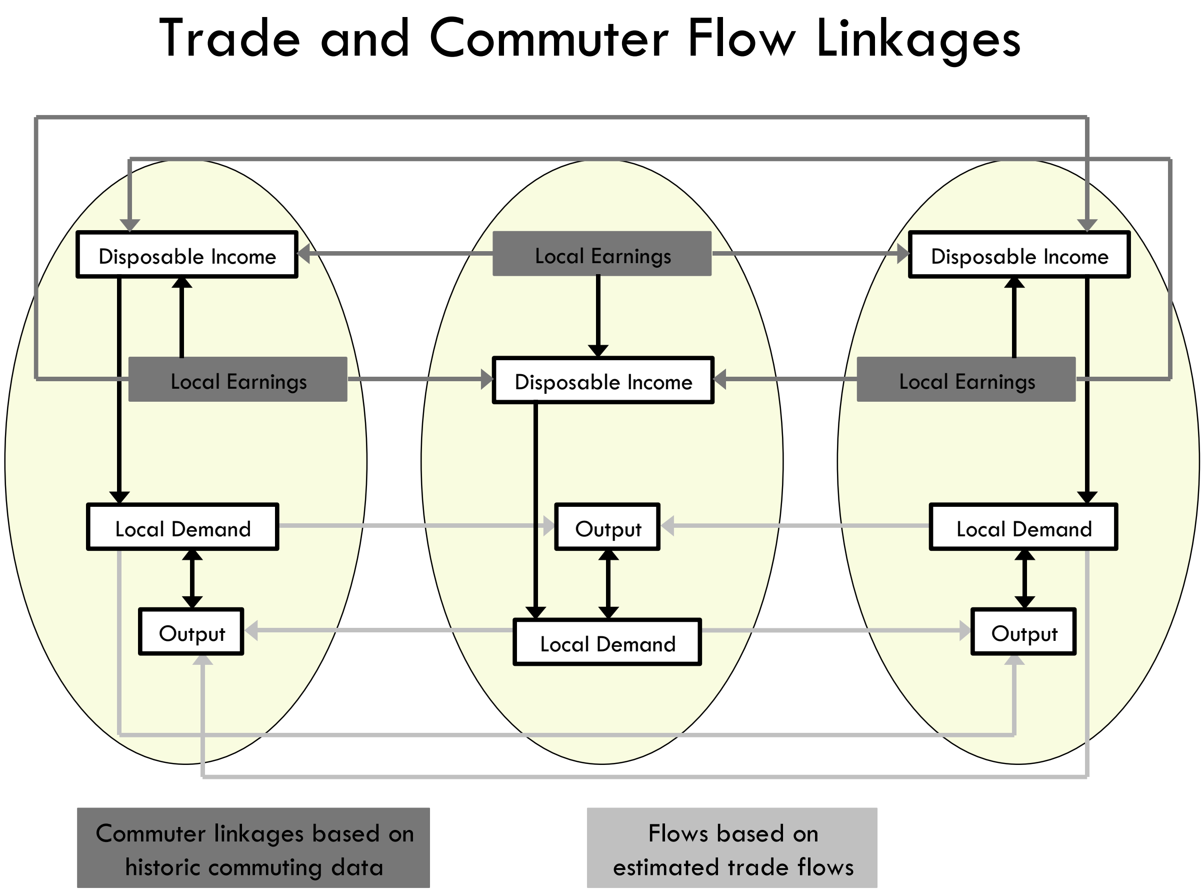
The Output and Demand block consists of output, demand, consumption, investment, government spending, exports, and imports, as well as feedback from output change due to the change in the productivity of intermediate inputs. The Labor and Capital Demand block includes labor intensity and productivity as well as demand for labor and capital. Labor force participation rate and migration equations are in the Population and Labor Supply block. The Compensation, Prices, and Costs block includes composite prices, determinants of production costs, the consumption price deflator, housing prices, and the compensation equations. The proportion of local, inter-regional, and export markets captured by each region is included in the Market Shares block.

Models can be built as single region, multi-region, or multi-region national models. A region is defined broadly as a sub-national area, and could consist of a state, province, county, or city, or any combination of sub-national areas.

Single-region models consist of an individual region, called the home region. The rest of the nation is also represented in the model. However, since the home region is only a small part of the total nation, the changes in the region do not have an endogenous effect on the variables in the rest of the nation.

Multi-regional models have interactions among regions, such as trade and commuting flows. These interactions include trade flows from each region to each of the other regions. These flows are illustrated for a three-region model in Figure 29.

Figure 29. Trade and Commuter Flow Linkages



Multiregional national models also include a central bank monetary response that constrains labor markets. Models that only encompass a relatively small portion of a nation are not endogenously constrained by changes in exchange rates or monetary responses.

Block 1. Output and Demand

This block includes output, demand, consumption, investment, government spending, import, commodity access, and export concepts. Output for each industry in the home region is determined by industry demand in all regions in the nation, the home region's share of each market, and international exports from the region.

For each industry, demand is determined by the amount of output, consumption, investment, and capital demand on that industry. Consumption depends on real disposable income per capita, relative prices, differential income elasticities, and population. Input productivity depends on access to inputs because a larger choice set of inputs means it is more likely that the input with the specific characteristics required for the job will be found. In the capital stock adjustment process, investment occurs to fill the difference between optimal and actual capital stock for residential, non-residential, and equipment investment. Government spending changes are determined by changes in the population.

Block 2. Labor and Capital Demand

The Labor and Capital Demand block includes the determination of labor productivity, labor intensity, and the optimal capital stocks. Industry-specific labor productivity depends on the availability of workers with differentiated skills for the occupations used in each industry. The occupational labor supply and commuting costs determine firms' access to a specialized labor force.

Labor intensity is determined by the cost of labor relative to the other factor inputs, capital and fuel. Demand for capital is driven by the optimal capital stock equation for both non-residential capital and equipment. Optimal capital stock for each industry depends on the relative cost of labor and capital, and the employment weighted by capital use for each industry. Employment in private industries is determined by the value added and employment per unit of value added in each industry.

Block 3. Population and Labor Supply

The Population and Labor Supply block includes detailed demographic information about the region. Population data is given for age, gender, and race, with birth and survival rates for each group. The size and labor force participation rate of each group determines the labor supply. These participation rates respond to changes in employment relative to the potential labor force and to changes in the real after-tax compensation rate. Migration includes retirement, military, international, and economic migration. Economic migration is determined by the relative real after-tax compensation rate, relative employment opportunity, and consumer access to variety.

Block 4. Compensation, Prices and Costs

This block includes delivered prices, production costs, equipment cost, the consumption deflator, consumer prices, the price of housing, and the compensation equation. Economic geography concepts account for the productivity and price effects of access to specialized labor, goods, and services.

These prices measure the price of the industry output, considering the access to production locations. This access is important due to the specialization of production that takes place within each industry, and because transportation and transaction costs of distance are significant. Composite prices for each industry are then calculated based on the production costs of supplying regions, the effective distance to these regions, and the index of access to the variety of outputs in the industry relative to the access by other uses of the product.

The cost of production for each industry is determined by the cost of labor, capital, fuel, and intermediate inputs. Labor costs reflect a productivity adjustment to account for access to specialized labor, as well as underlying compensation rates. Capital costs include costs of non-residential structures and equipment, while fuel costs incorporate electricity, natural gas, and residual fuels.

The consumption deflator converts industry prices to prices for consumption commodities. For potential migrants, the consumer price is additionally calculated to include housing prices. Housing prices change from their initial level depending on changes in income and population density.

Compensation changes are due to changes in labor demand and supply conditions and changes in the national compensation rate. Changes in employment opportunities relative to the labor force and occupational demand change determine compensation rates by industry.

Block 5. Market Shares

The market shares equations measure the proportion of local and export markets that are captured by each industry. These depend on relative production costs, the estimated price elasticity of demand, and the effective distance between the home region and each of the other regions. The change in share of a specific area in any region depends on changes in its delivered price and the quantity it produces compared with the same factors for competitors in that market. The share of local and external markets then drives the exports from and imports to the home economy.