Hurricane Mitigation: Public Sector Mitigation and Adaptation Efforts, and the Florida Resident Perspectives

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EXECUTIVE SUMMARY

As a part of a reoccurring state grant for the study of hurricane-impact in Florida, this report provides insight into hurricane and sea level rise mitigation for the state, and provides the knowledge and analysis required for informed public sector decision makers. This study focuses on nine metropolitan coastal counties in Florida that exhibit heightened risk from hurricanes and sea level rise due to their growing populations and economic development: Duval, St Johns, Pasco, Hillsborough, Pinellas, Manatee, Palm Beach, Broward, and Miami-Dade Counties. These counties correspond with the major Florida metropolitan areas of Jacksonville, Tampa Bay, and South Florida. These three regions are major drivers in the Florida economy and are disproportionately threatened by hurricanes and sea level rise due to geography and geology. This report lays out a current overview of local, state, and national efforts to counter such threats in Florida, provides an organized matrix of public sector responses, as well as provides qualitative results from 30 surveyed public officials from across the state.

The overwhelming public sector trend nationwide towards hurricanes and sea level rise has been a post-disaster reactionary response, rather than a preemptive strategy to address threats before impacts are felt. This reactionary trend is exemplified through the revising of Florida construction codes following Hurricane Andrew, the expansion and upgrading of defensive barriers around New Orleans following Hurricane Katrina, and the new plans for building mitigation and resiliency in New York and New Jersey following Hurricane Sandy. This post-disaster mitigation is further evidenced through federal and state funding that is made available to areas only after a Presidential Declared Disaster, rather than funding projects and policies that could prevent or mitigate against such disasters before they occur. This trend has begun to be broken in Florida, where many municipalities and counties have decided to take a proactive approach by formulating a projected sea level rise and either accounting for it in future plans, or selecting locations within their jurisdiction to take more immediate action. These measures have focused on creating regional projected sea level rise with different heights dependent on the importance of the infrastructure and the designation of Adaptation Action Areas that are subject to programs and planning that are more drastic to mitigate against major losses. Some municipalities have also begun to implement specific interventions like new or larger pump stations, black flow valves, flood barriers, bioswales, and ecological defenses.

Other changes occurring both in Florida and nationwide include the governmental movement from exploratory 'strategies' to actionable 'plans' and a boom in innovative techniques and approaches. This shift from strategizing to planning has resulted in many communities, from the municipal level all the way up to the state level, moving from discussion to action. Examples of such concrete steps include the implementation of Adaptation Action Areas in Florida, the requirement of all projects receiving state dollars in New York to account for sea level rise and extreme weather events, and the improvements of stormwater systems across countless coastal municipalities to limit black flows and flooding. Recent years have also produced numerous examples of innovation across national and international public space, providing readily available sources of resiliency that are implementable in Florida. Through post-Sandy experimental funding, the US Department of Housing and Urban Development (HUD) has financed innovative projects through two competitions that have resulted in local attempts to mitigate from storms and sea level rise. Of these competition winners, projects utilize ecological structures to create green public space, sustainable barriers to storm surge, and environmentally friendly forms of collecting and controlling floodwaters. These same sustainable principles are demonstrated in further international examples, such as the Netherlands' Benthemplein square that collect neighborhood rainfall and the Chinese's' attempt to harvest citywide rainfall in futuristic 'Sponge Cities'.

As a product of this report, the authors attempted to create a comprehensive matrix on the public sector policies in mitigating hurricane and sea level rise impact. In **Table 1**, the policies are organized into five general categories that are then divided between a three sections on a policy's impact time. The table allows public officials to build a comprehensive and multidimensional plan for their community by combining policies from multiple categories. The Metropolitan Center also conducted 30 interviews with public officials across the state of Florida to gauge the public sector response to sea level rise. Roughly half of the respondents reported having standing committees that address sea level rise to some extent. Those respondents in South Florida or Tampa Bay regions were likely to have official sea level rise projections, with many also having a strategy or plan to mitigate its impact. There was a clear divergence in the policies from plans and strategies, those governments with plans were already implementing adaptations or capital improvements while those with strategies had little actionable policies. Finally, there was also a split in respondents with some governments viewing sea level rise in the lens of climate change and implementing 'green' policies, while other viewed in the lens of extreme weather and flooding.

Table 1. Public Sector Response Typology

	Governance	Zoning &	Transportatio	Hardening	Environmenta
Short-term	Budgetary Prioritization Public Awareness Campaign (threats, zoning, mitigation) Open Data/Documents	Improve Construction Codes Elevate Structures & Utilities	Raise Roads Pervious Concrete Damage Repair Planning & Asset Management	Flood-proofing buildings (flood doors/gates, relocate utilities, temporary barriers)	Beach Renourishment Dunes & Berms Green Public Space in Flood Zones
Mid-term	Master Plans & Vulnerability Studies Retrofitting & Resiliency Grants Insurance (de)Regulation	Development Regulations in Coastal Areas or Flooding Zones Flood & Storm Mapping	Account for SLR & Hurricane Projections in Future Infrastructure Optimize Public Transportation	Bioswales & Water Retention Sea Walls & Revetments Dredging & Leveeing	Barrier Islands, Breakwaters, & Coral Reefs Wetlands & Mangroves
Long-term	Comprehensive & Actionable Long-term Strategy Regional Commitments & Organizing (public & private)	Adaptation Action Areas Commercial or Residential Relocation	Construct Resilient Public Space Connectivity Reduce Infrastructure Usage & Reliance	Surge Barriers Large Hydrological Systems (networks of pumps, cisterns, & rerouting water flows)	Low-Impact Development Ecological Restoration Ecological Reclamation

I. SHORT HISTORY ON CYCLONE EVENTS IN FLORIDA

Florida has been hit by 22 tropical cyclones and hurricanes since 1990, with Hurricane Andrew in 1992, and the 2004 and 2005 seasons being the most destructive (Genovese & Greene, 2015). Recent research has put the economic impact of hurricanes in Florida since the early 20th Century at $450 billion, and "eight of the ten most expensive hurricanes ever to make landfall in U.S. history have had at least some effect on Florida, causing in excess of $60 billion (constant 2005 dollars) in insured losses" (Malmstadt, Scheitlin, & Elsner, 2009, p. 108). Since that report, two more storms have been added to the top ten as seen in **Table 2**: Hurricanes Sandy and Irene. Economic impacts from storms have dramatically increased in recent years due to the growth and development along the U.S. coast, evidenced by only one storm in the top ten not being in the 2000's. While Florida has not been directly hit by a hurricane in a decade, storms and projections operate on their own local returns and probabilities. Hence, the remarkable nature of January 2016's Hurricane Alex, only the fourth hurricane on record since 1851 to develop in the Atlantic basin in January, well outside of hurricane season (Martinez, Payne & Almasy, 2016).

Table 2. Top 10 Costliest Storms in US History

Storm	*States most Affected*	*Storm Category*	*Estimated Cost (unadjusted)*
Katrina (2005)	FL, LA, MS	3	$ 108 billion
Sandy (2012)	NC, Mid-Atlantic	3	$ 65 billion
Ike (2008)	TX, LA	2	$ 29.5 billion
Andrew (1992)	FL, LA	5	$ 26.5 billion
Wilma (2005)	FL	3	$ 21 billion
Ivan (2004)	AL, FL	3	$ 18.8 billion
Irene (2011)	NC, Mid-Atlantic	3	$ 15.8 billion
Charley (2004)	FL	4	$ 15.1 billion
Rita (2005)	LA, TX	3	$ 12 billion
Frances (2004)	FL	2	$ 9.5 billion

Source: Blake et al. (2011), Dolce (2013)

The development of tropical cyclones occurs in three stages. In the first stage, a collection of thunderstorms in the ocean combines for a sustained period with a constant wind speed at its center of 23-39 mph, at which point it is a tropical depression. The second stage of development is the intensification of the depression into a tropical storm with sustained winds of 39-73 mph; this is also the point at which a storm is named. The final stage is when the tropical storm becomes an outright hurricane, with sustained winds of 74 mph or higher. Hurricanes are similarly categorized by sustained wind strengths, ranking them from 1 to 5. As of the most recent revisions in 2012, the rankings are: 1) 74-95 mph, 2) 96-110 mph, 3) 111-129 mph, 4) 130-156 mph, and 5)

157 mph or higher (National Hurricane Center, 2012). The North Atlantic hurricane season stretches from June to November.

Colorado State University (CSU) makes forecasts for the season at three points, two before and one during the season, based upon a statistical analysis from 29 years of data. Researchers create projections using four predictors, or areas, in the Atlantic and Pacific basins and how conditions relate to prior hurricane seasons. As a result of this analysis, the 2016 season is forecast by Philip Klotzbach of CSU to be near-average with twelve projected named storms (Klotzbach, 2016). Klotzbach further predicts that of these twelve named storms five will be hurricanes and two major hurricanes. Florida's East Coast faces a 30 percent probability of at least one major hurricane making landfall while Florida's Gulf Coast faces a 29 percent probability (Klotzbach, 2016). In the event of a hurricane strike on Florida, **Figure 1** represents the anticipated economic phases by the Florida Office of Economic & Demographic Research.

Figure 1. Economic Phases from Hurricanes

Phases	Defining Characteristics	Statewide Economic Consequences
Preparatory Phase *(Approximately 72 hours prior to hurricane landfall)*	• Purchase of Emergency Supplies (water, flashlights, food, etc.) • Evacuation Expenses (both in-state and out-of-state)	**Demand:** Localized increased demand on specific items in storm path and possible increase for lodging by evacuees **State Budget:** Shifting of resources to Emergency Management, overtime, and shelter costs **State Revenues:** Slight uptick, but largely undetectable
Crisis Phase *(Landfall to several weeks after event)*	• Rescue and relief efforts • Roads closed due to debris • Private structures and public infrastructure damaged • Utility disruptions • Businesses and non-essential parts of government closed • Temporary homelessness • Violence and looting	**Demand:** Localized decrease in overall demand dependent upon scale of event **State Budget:** Government agencies provide goods and services and incur new expenditures that may or may not be matched at a later time by the federal government **State Revenues:** Detectable downtick dependent upon scale of event
Recovery Phase *(Generally lasting up to two or three years after hurricane)*	• Increased spending related to deductibles, repair, and replacement (private savings, loans, state spending, FEMA, Federal spending, insurance) • Price increases due to competition for scarce resources (ex: construction workers and supplies)	**Demand:** Localized increase in overall demand with likely inflation **Employment:** Temporary increase in sectors related to recovery and relief **State Budget:** Reallocation of state and local government spending to affected areas **State Revenue:** Discernable and significant uptick
Displacement Phase *(Generally lasting two to six years after hurricane)*	• Reduction in normal purchasing behavior for items that were bought or replaced • Demographic and labor shifts related to dislocated households and economic centers	**Demand:** Localized decrease in overall demand, but undetectable at state level **State Revenues:** Slight downtick, but largely undetectable

Source: Recreated from Florida EDR (2015). 'Economic Evaluation of Florida's Investment in Beaches'

II. CHANGES IN TIDAL SURGE AND FLOODING EVENTS

One of the deadliest and most destructive aspects of tropical cyclones threatening coastal communities is the accompanying storm surge that has the potential to put cities and neighborhoods under many feet of fast moving and debris-ridden water. The National Hurricane Center defines storm surge as, "an abnormal rise in sea level accompanying a hurricane or other intense storm, and whose height is the difference between the observed level of the sea surface and the level that would have occurred in the absence of the cyclone." (Glossary, n.d.) The strength of storm surge is dependent upon many storm system factors: central pressure, wind speed, storm forward speed, angle of approach, local environmental features, and geographical and topographical features (National Oceanic and Atmospheric Association, n.d.).

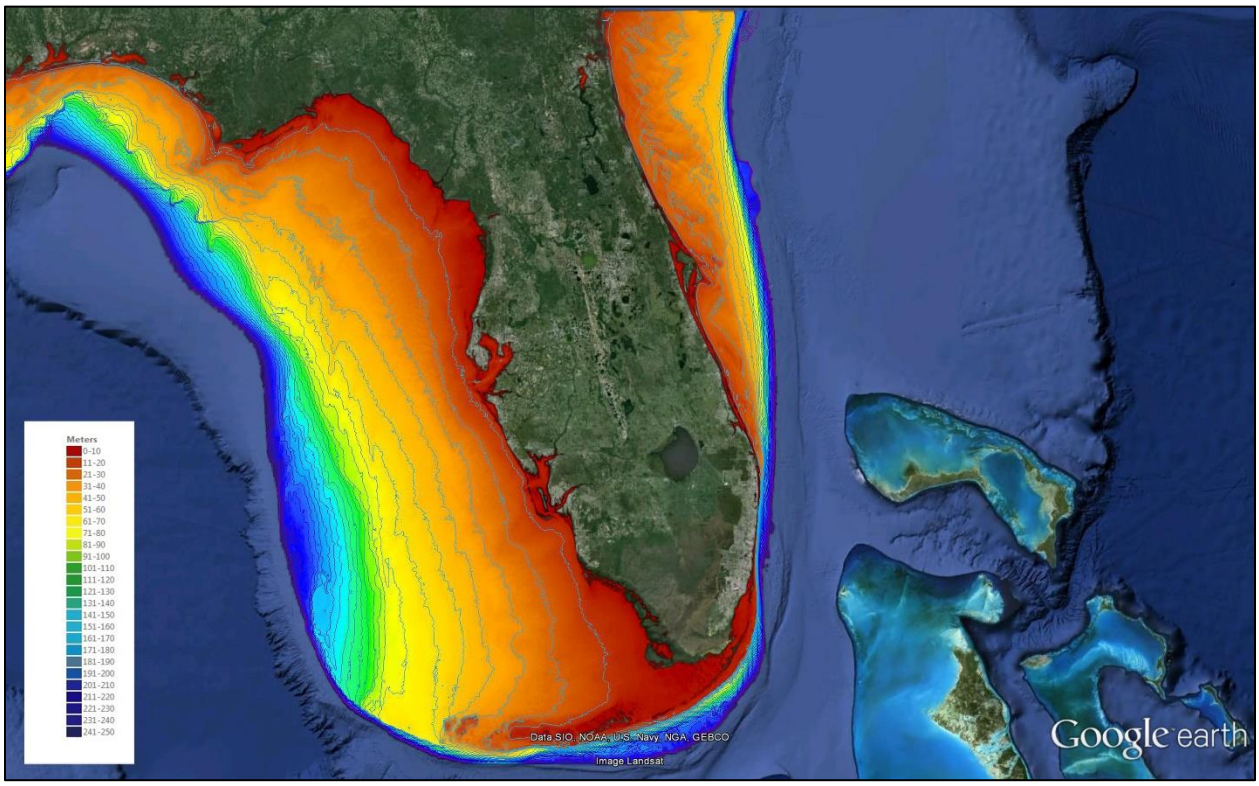


Image 1. Bathymetry of Florida from 0-250m depth of continental shelf. Source: USGS and Google Earth Pro

One of the most relevant of these factors for Florida Gulf coastal development is that of the sloping elevation of the continental shelf. As represented in **Image 1**, the Gulf Coast of Florida is at much higher risk of high storm surge with much of its offshore depth only reach 10-20 meters, while South Florida's Atlantic ridge plummets to depths past 250 meters just a few miles from

shore. Shallow coastlines along a continental shelf, exhibited by the Gulf Shelf that descends broadly and slowly, are at a higher risk of storm surge due to the gradual manner in which the surge that accompanies a storm's landfall will not be slowed by a rapid climb. In contrast, when the coastline has a steeper gradient, as the continental shelf off South Florida, a storm surge has an abrupt and sudden rise up the shelf that helps weaken the overall surge. **Image 1** illustrates the range of depth off the coasts of Florida, 0-10 meters in dark red to 250 meters in purple at its

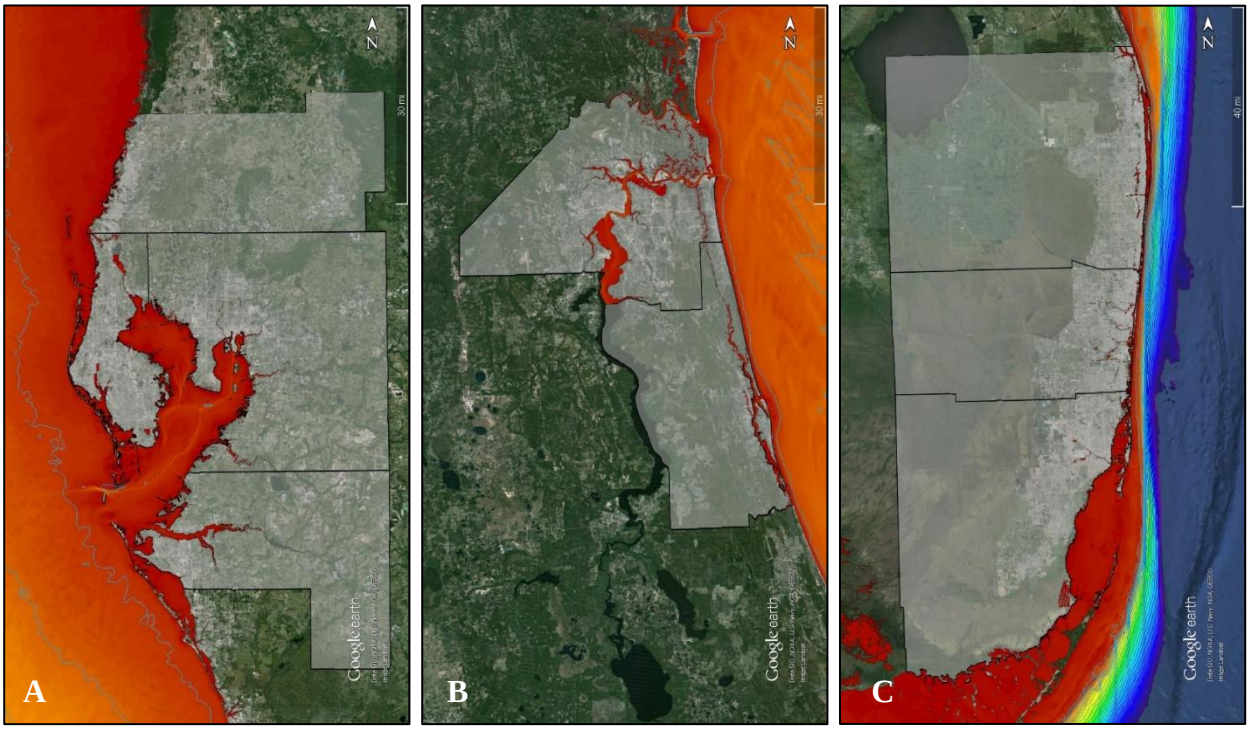


Image 2. Bathymetry Close-up of (a) Counties of the Tampa Bay MSA, (b) Counties of the Jacksonville MSA, and (c) Counties of the Miami MSA Source: USGS and Google Earth Pro

furthest extent, while **Image 2** provides a closer look at the coastal depth of the principle metro areas of this study. Much of the U.S. continental shelf in the Gulf of Mexico has gentle sloping sea floors, providing dangerous potential of storm surge. A recent article found the highest storm surge recorded in the Gulf was an astonishing 8.47 meters—or just under 28 feet tall—in Pass Christian, MS during the 2005 storm Hurricane Katrina (Needham and Keim, 2011). While South Florida is at lower risk for storm surge due to its steeper shelf, it is still one of the most statistically likely areas to be hit by a hurricane and has seen many of its own record heights. Due to the shallow depth of Biscayne Bay and the Florida Keys, the storm surge records of South Florida are 6.1 meters—20 feet—on Long Key in the 1935 Labor Day Hurricane and 4.57 meters—15 feet—in

Coconut Grove during the 1926 Great Miami Hurricane (Needham and Keim, 2011) (Masters, n.d.).

Given Florida's extensive coastline, continental shelf and beachfront development, the state and its cities are at the highest financial risk from storm surge in the country. CoreLogic, a property analysis company, revealed in their 2015 'Storm Surge Report' that of all coastal states, Florida had the highest potential reconstruction costs by modeled storm surge from various intensity hurricanes (Botts, Jeffery, Du, and Suhr, 2015). The authors, scaling from low risk properties that are only affected by a Category 5 storm up to an extreme risk property that is affected by just a Category 1 storm, reported that Florida has over 2.5 million properties at risk from hurricane-caused storm surge, reaching upwards of $491 billion in total reconstruction costs (Botts et al., 2015). It is important to point out that the group's projected costs are calculated under the assumption of complete destruction and that reconstruction values account for labor, materials, etc.

Table 3. Florida Property Threatened by Storm Surge

MSA	*Total Properties Potentially affected by all categories of Hurricane*	*Total Reconstruction Value*
Miami	564,913	$ 105,134,042,455
Tampa Bay	447,990	$ 78,191,384,320
Cape Coral	309,829	$ 62,437,286,236
Bradenton	229,889	$ 42,319,769,269
Naples	179,681	$ 42,336,358,876
Jacksonville	175,045	$ 36,595,996,688

Source: *CoreLogic*, 2015 CoreLogic Storm Surge Report, June 2015

As shown in **Table 3**, the group's data further assesses storm surge risk at the metropolitan level. According to CoreLogic, the Florida metro at greatest risk from storm surge is the Miami-Ft. Lauderdale-Palm Beach Metropolitan Statistical Area (MSA) with more than a half million properties that combine for $105 billion in potential reconstruction costs. Other major Florida metros are highlighted as well, projecting the Tampa-St. Petersburg MSA with just under half a million properties at risk with a $78 billion total reconstruction value, and the Jacksonville MSA with 175,000 properties with a $36.5 billion reconstruction cost.

In greater detail, the CoreLogic report provides the location of the at risk properties in Federal Emergency Management Agency (FEMA) Special Flood Hazard Area (SFHA)—high risk flood zones—and FEMA storm surge zones by metro area. As illustrated in **Table 4**, columns 2 and 4 are the properties identified by the report as at risk to storm surge, while column 3 is properties at risk from flooding due to elevation or other geographical and geological reasons.

Table 4. Florida Property Totals in FEMA SFHA and Surge Zones

MSA	*(1) Total Properties Exposed to Flood or Surge Inundation*	*(2) Total Properties in both a SFHA and a Surge Zone*	*% of Properties in both a SFHA and a Surge Zone*	*(3) Total Properties Located only in a SFHA Zone*	*% of Properties Located only in a SFHA Zone*	*(4) Total Properties Located only in a Surge Zone*	*% of Properties Located in a Surge Zone*
Miami - Ft. Lauderdale	848,023	317,353	37.4%	283,110	33.4%	247,560	29.2%
Tampa - St. Petersburg	477,765	198,296	41.5%	29,775	6.2%	249,694	52.3%
Cape Coral - Fort Myers	311,373	144,100	46.3%	1,544	0.5%	165,729	53.2%
Sarasota - Bradenton	232,675	84,173	36.2%	2,786	1.2%	145,716	62.6%
Jacksonville - St. Augustine	187,400	30,864	16.5%	12,355	6.6%	144,181	76.9%
Naples - Marco Island	182,645	106,033	58.1%	2,964	1.6%	73,648	40.3%
Daytona Beach - Ormond	108,756	20,533	18.9%	6,003	5.5%	82,220	75.6%

Source: *CoreLogic*, 2015 CoreLogic Storm Surge Report, June 2015

Accounting for both forms of flooding, fresh water and salt water, the Miami MSA nearly doubles its number of properties at risk, from 564,913 to 848,023.

Karen Clark & Company (KC & Co), a catastrophe risk group, released a report with a similar focus in which they modeled a 100-year storm along the Gulf and Atlantic Coasts and ranked the estimated losses from the storm surge. In the report, "Most Vulnerable U.S. Cities to Storm Surge Flooding" (2015), the group defined losses by the value of property, structural and content, and time elements. KC & Co found, differently than CoreLogic, that the Tampa Bay metropolitan area was at the highest risk in the U.S. by losses, with $175 billion (KC & Co., 2015). The report further found that Miami's losses were $80 billion, and Fort Myers' and Sarasota's were $70 billion and $50 billion respectively. While the two reports similarly found Florida as a state to be at the greatest risk from storm surge, the different rankings and monetized losses are likely in methodological differences. In metropolitan designations and loss definitions, the CoreLogic report utilizes Census MSA designations and only accounts for home reconstruction value, while KC & Co. use a more limited MSA and add the value of time elements such as lost income.

Table 5. City Loses from 100-year Storm

MSA	*Estimated Loses in $ Billion*
Tampa, FL	$175
New Orleans, LA	$130
New York City, NY	$100
Miami, FL	$80
Fort Myers, FL	$70
Galveston-Houston, TX	$55
Sarasota, FL	$50
Charleston, SC	$45

Source: *KC & Co.*, Most Vulnerable US Cities to Storm Surge Flooding, August 2015

Finally, Elisabetta Genovese and Colin Green (2015), of the Centre International de Recherche sur L'Environnement et le Développement and the Flood Hazard Research Centre of Middlesex University respectively, performed a study that examined the varying impacts of storm surge across all three counties of South Florida and projected potential diminished impacts if coastal barriers were erected. To project storm surge, the authors utilized Sea, Lake, and Overland Surges from Hurricanes (SLOSH) modeling from the NOAA's National Hurricane Center and applied percentage damage to buildings and contents by elevation, construction material, and insured rate. The resulting ranges—lowest for a Category 1 storm and highest for a Category 5 storm—were $32-71 billion for an eastern moving storm and $39-185 billion for a west-southwest moving storm (Genovese and Green, 2015, p. 418).

The authors then analyzed the results with theoretical coastal barriers, 2.1m and 3m in height, which could take the varied forms of sea walls, bulkheads, revetments, dikes, or levees. Under the scenario of a 2.1m barrier, the potential destruction from Category 1-3 storms falls to 0-20% residual damage, Category 4 storms to 43% residual damage, and Category 5 storms raise to 66.6% residual damage (Genovese and Green, 2015, p. 421). Under the scenario of a 3m barrier, the potential destruction from Category 1-3 storms falls to just 0-5% residual damage, Category 4 storms fall to 17.6% residual damage, and Category 5 storms have 33% residual damage (Genovese and Green, 2015, p. 421). Despite the effectiveness of various coastal barriers, political and economic limitations to their construction are evident: high costs, lack of space, destruction of beach and coastal real estate, and obstruction of waterfront industry.

Relationships between Climate Change and Hurricanes

The severe and catastrophic 2004 and 2005 seasons, with a combined twelve landfall hurricanes that killed 1,285 people and caused roughly $200 billion worth of damage (Blake et al., 2011),[1] raised new questions over the relation between tropical cyclones and climate change. The result was a contentious scientific debate with one side stressing the historical variability of hurricane seasons and the other focusing on the more recent hurricane frequency. Emblematic of this divide was an exchange in the academic review *Bulletin of the American Meteorological Society* in 2005 and 2006.

[1] Value in USD 2010 dollars, $195 billion adjusted and $210 billion normalized.

Arguing against drawing a significant connection between climate change and an increase in hurricane frequency or intensity, Pielke et al. (2005) made three major points that stressed a tempered assessment that relies on long-term statistical analysis of hurricane data. First, the authors argued that there was no established connection between greenhouse gas emissions and hurricane activity. Second, that the academic literature had reached a consensus that future changes in hurricane intensity will most likely be small in the context of historical trends. And third, that any future increase in destruction by this increase will pale in comparison to the dramatic upsurge in social vulnerability along U.S. coasts due to the rise of population and wealth density. While recognizing that a relationship between climate change and hurricane activity could not be drawn from the 2005 season alone, Anthes et tal. (2006) wrote a rebuttal that focused on recent phenomena. The authors wrote, "It is equally inappropriate to declare or imply that the current observed global changes and seasons with storms of unusually high frequency or intensity are not related to global warming and that there will not be a significant change in climate in the future." (p. 626) Anthes goes on to argue that climate change creates environmental factors like higher sea surface temperatures, warmer and moister air, and altered atmospheric and oceanic circulations that have the potential to strengthen tropical cyclone development and frequency.

This debate today shows greater nuance and complexity as improved research has met with a decade of quieter hurricane seasons. An analysis of hurricane strikes between 1900 and 2010 by Christopher Landsea of U.S. National Hurricane Center found no obvious anomaly in recent 21st Century storm trends (Lansea, 2015). Instead, Landsea notes that when a 110-year long record is used, "one can conclude that there has been no long-term century-scale increase in U.S. hurricane frequencies." (Landsea, 2015, p.1176) In contrast, a recent literature review of new modeling systems found that globally, average intensity of tropical cyclones will rise by 2-11 percent by 2100, and the overall frequency will decrease between 6-34 percent yet the rainfall at the center of the storms will rise by 20% (Knutson et al., 2010). Thus, accounting for the various factors of climate change, academic models of future hurricanes are projecting an interesting dynamic of lower frequency with higher intensity (Knutson et al., 2010).

Rise in 100yr Surge Events

The sudden attention on storm surge losses by nationally recognized catastrophe analytic firms and European scholars is due to the growing severity and regularity storm surge poses as sea

level rise's ecological repercussions become more impactful. As seas continue to rise, not only will the physical loss of Florida's coastline become a threat, but storm surge and tide impacts will reach further inland at higher levels. Analyzing a database of 50 years' worth of monthly and hourly records of 55 tidal gauges along the coastal U.S., researchers have projected a dramatic rise in storm surge due to sea level rise (Tebaldi, Strauss, and Zervas, 2012). The study found that many coastal areas will see a significant change in both the height and frequencies of annual high water levels. Of the most extreme of these gauges, today's century levels (having an annual 1% chance of occurring) will become decade events (a 10% chance of occurring).

As represented in **Table 6**, there is a diversity of projected outcomes in the state of Florida from sea level rise and its impact on storm surge. While no gauge can accurately represent the diverse geology surrounding the three metros and nine counties concerned in this study, the modeling provides general projections for the related areas. Despite not including a gauge for the Miami MSA, the two gauges in the Keys share moderately similar bathymetry and can still be illustrative of South Florida; all other major coastal population centers in the State are represented. Column 1 shows the average projected sea level rise for the eight Florida gauges calculated by the authors utilizing data from 19 separate models and depicts an across the board rise of 8-16 inches by 2050.

Table 6. Projections by FL Gauges in meters for 2050

Florida Gauges	*(1) Mean Estimate of 19 SLR models*	*(2) Maximum Estimate of 100yr Surge*	*(3) Average Estimate of Occurrence of 100yr Surge*
Fernandina Beach	0.3-0.4	0-1	1
Vaca Key	0.3-0.4	0-1	20
Key West	0.3-0.4	0-1	20
Naples	0.2-0.3	1-2	20
St. Petersburg	0.2-0.3	1-2	75
Clearwater Beach	0.2-0.3	1-2	75
Apalachicola	0.2-0.3	4-5	100
Pensacola	0.2-0.3	4-5	100

Source: Tebaldi, Strauss, and Zervas (2012)

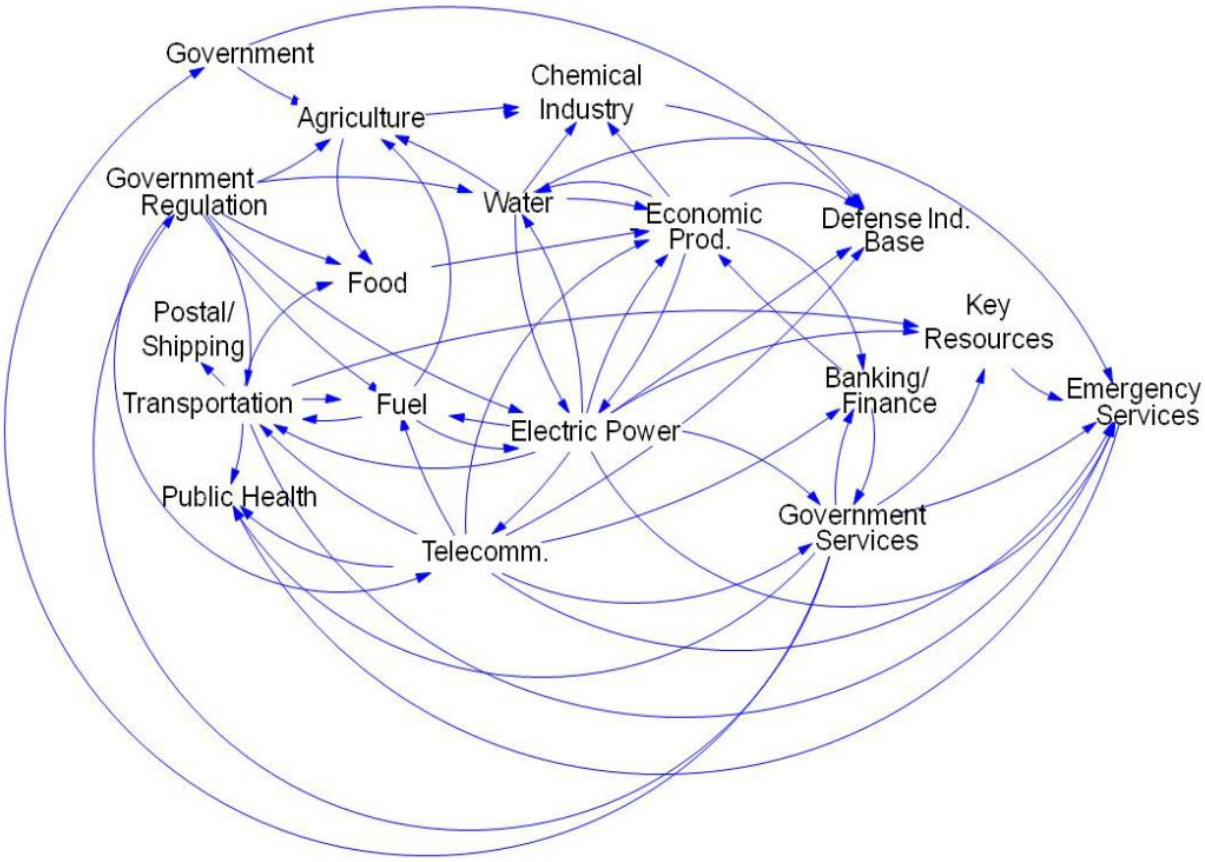
Column 2 shows the estimated high water level for a 100yr return period between 1983 and 2001. The range of surge between the Gulf Coast and the Keys illustrates the impact of steep bathymetry in, with 100yr surge only an upwards average of 1 meter in the Keys while the wide shallow shelf waters of the Panhandle have up to 5 meters. Finally, column 3 has the projections for the rise in frequency of current 100yr events by 2050, ranging from a '100' meaning no change to '1' meaning each year. Fernandina Beach, outside of Jacksonville, has the greatest change with prior 100yr events now becoming and annual possibility, while the Panhandle gauges' 100yr events will remain the same. Given that there is no Miami gauge provided in the study, the Florida Keys will

see the prior 100yr event becoming a 20yr possibility. More importantly, the correlation between the rise in sea level and rise in frequency of 100yr tidal events is apparent—the first three gauges projected to face the highest sea level rise also see the greater increase in events.

III. THE PUBLIC IMPACT OF SEA LEVEL RISE

Recent decades have witnessed a rapidly changing landscape in which public policy and planning have attempted to understand the complicated and interdependent nature of environmental threats facing Florida's communities. The varied public impacts from sea level rise and hurricanes go beyond just the loss of property and life, but have implications and ripple effects upon transportation infrastructure, public and private resources and services, local and regional economies, and quality of life. This variety of short and long-term impacts from environmental threats, when combined with numerous political and economic interests, have made the state of Florida a petri dish for studying vulnerabilities and mitigation.

Figure 2. An Illustration of Infrastructure Interdependencies



Source: Wilbanks et al. (2012, p. 17)

Much of the vulnerability that results from Florida's elevation and exposed coastal development is magnified by infrastructural interdependency. A dizzying, yet representative, example of the

interdependent nature of complex networks can be seen in **Figure 2**. The image illustrates the manner in which the impact on one segment of the infrastructure chain will reverberate into others. Applying this concept to a sample case of a hypothetical hurricane strike in 2030 in Miami-Dade County, the authors of a recent US Department of Energy technical report found varying 'strong' to 'low' relationships of impact between several segments in Miami's basic infrastructure (Wilbanks et al., 2012). The result can be seen in **Table 7**. Among other conclusions, the authors found that "Cascading system failures related to infrastructure interdependencies will increase threats to health and local economies in urban areas, especially in locations vulnerable to extreme weather events." (Wilbanks et al., 2012, p. 64)

Table 7. Example of Infrastructure Interdependency in Miami Following Hurricane

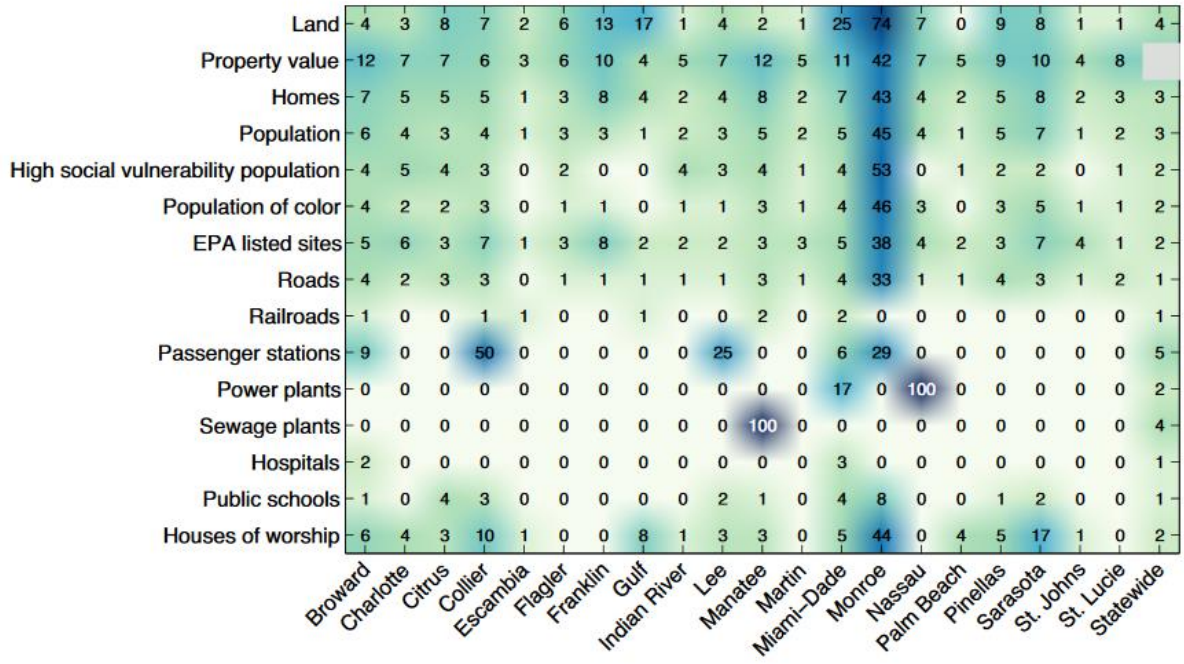
	Electric Power	*Natural Gas*	*Petroleum*	*Communication*	*Water Distribution*	*Transportation*	*Public Health & Sanitation*
Electric Power	N/A	Strong	Medium	Strong	Strong	Weak	Strong
Natural Gas	Strong	N/A	Low	Strong	Weak	Weak	Weak
Petroleum	Strong	Weak	N/A	Medium	Weak	Strong	Strong
Communication	Strong	Strong	Strong	N/A	Strong	Weak	Strong
Water Distribution	Strong	Weak	Weak	Strong	N/A	Medium	Strong
Transportation	Medium	Medium	Strong	Medium	Weak	N/A	Strong
Public Health & Sanitation	Strong	Weak	Medium	Strong	Strong	Strong	N/A

Source: Wilbanks et al. (2012, p. 57)

Beyond the vulnerability of interdependency from cascading impacts, individual vulnerabilities for community infrastructure can result from low elevation—sea level rise—and flood hazard zones—hurricanes. Given Florida's profile as a low lying state with considerable population density in flood zones and location along the path of more hurricanes than any other state, the need to recognize what current infrastructure is vulnerable to these threats is integral to building community resiliency. As seen in **Figure 3**, the research group Climate Central conducted a statewide analysis of infrastructure, people, and structures that sit below 3 feet of elevation (Strauss, Tebaldi & Kulp, 2014). The 20 coastal counties depicted in **Figure 3** are those at greatest risk from low elevation, with Monroe County standing out from even this group with significant portions of most categories affected. Indicative of the coastal development paradox—properties at greatest risk along the coast tend to also be more valuable due to location—property value is

consistently at a higher percentage below 3 feet of elevation then the total portion of the housing stock across all listed counties except Monroe County. Other notable results are Nassau and Manatee Counties' vulnerability to their sewage and power plants. While Climate Central's measure of vulnerable infrastructure is instructive for future threats from sea level rise, FEMA's tracking of 'critical facilities' in floodplains may be of more immediate concern.

Figure 3. County and State Percentage below 3ft. Elevation



Source: Strauss, Tebaldi & Kulp (2014, p. 23)

FEMA provides an ongoing list of critical facilities in coastal counties in relation to their floodplains, or areas with high and frequent occurences of flooding. FEMA designates critical facilities as those that provide some of the most basic services of health and security to a community, i.e. public schools, police stations, fire stations, and medical facilities. **Table 8** illustrates the concerning level of critical facilities in floodplains in this study's nine Florida counties of focus. Of notable concern are St Johns and Miami-Dade Counties' facility percentage in a floodplain, each with over a quarter of their total facilities at risk to frequent flooding. Miami-Dade County had the dismal distinction of having the most critical facilities for each category in a FEMA floodplain. All cells in **Table 8** marked in red highlight percentages 20 percent and over. Consistent across most counties is the placement of fire stations within the floodplain, concerning

because many fire departments double as emergency management units during environmental events.

Table 8. Critical Facilities in FEMA Floodplain

	Schools	*Police Stations*	*Fire Stations*	*Medical Facilities*	*Total*
Duval	2%	0%	3%	0%	2%
St Johns	**28%**	**27%**	**24%**	0%	**27%**
Pasco	8%	0%	**25%**	**20%**	11%
Pinellas	16%	**25%**	**30%**	12%	19%
Hillsborough	8%	12%	13%	16%	9%
Manatee	10%	**38%**	**24%**	**25%**	16%
Palm Beach	8%	16%	10%	16%	9%
Broward	17%	13%	19%	3%	17%
Miami-Dade	**34%**	**40%**	**34%**	**31%**	**34%**
Total	17%	**23%**	**20%**	15%	18%

Source: NOAA Coastal County Snapshot, as of Aug. 1, 2016

Rounding out the various important structures and facilities in Florida that are vulnerable to sea level rise and flooding from hurricanes, a group named the Union of Concerned Scientists (UCS) released a report in 2016 that analyzed 18 US Military facilities they felt represented strategically important and representative of coastal bases along the Eastern seaboard (UCS, 2016b). Moreover, they selected the East Coast and Gulf Coast due to their higher projected rise in sea levels over the coming century. On this shortlist or vulnerable sites is three facilities in Florida: Naval Air Station Key West, Naval Station Mayport, and Eglin Air Force Base. Of these three installations, the Naval Air Station of Key West is the most at risk, and is moreover nationally one of the greatest impacted by sea level rise. Using a tiered system, the medium and high levels of projections will have 70 and 95 percent, respectively, of the Naval Air Station in Key West under of water during high tide (UCS, 2016b). Naval Station Mayport, located just east of Jacksonville, is representative of the middle road of impact from rising waters. Through the same source of projections, the UCS found that about 35 to 55 percent of the installation will be under high tides by 2100 (UCS, 2016b). In contrast, the Eglin Air Force Base in Florida's panhandle will see little land loss from sea level rise, but will still see a greater amount of flooding and tidal surge risk due to the base's general loss of elevation (UCS, 2016b). The significance of encroaching seas upon our military's facilities is not just a threat to our national security and domestic emergency response capabilities, but it is also an economic threat. The Eglin Air Force Base alone supports 192,000 jobs and has a replacement value of $4.7 billion dollars. Military bases provide a rich resource for local and regional economies in providing local jobs and federal money, all of which

will be threatened as installations begin to lose viability due to land loss and increased flooding from sea level rise.

IV. FLORIDA MITIGATION AND ADAPTATION EFFORTS

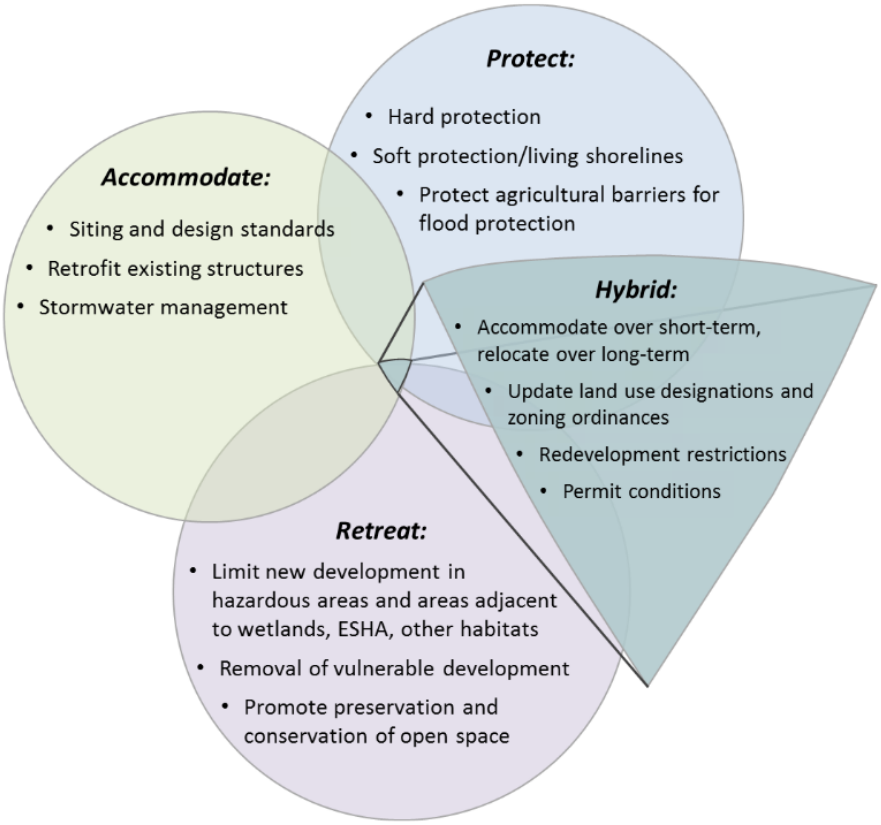
Much of Florida's most effective response to these environmental threats has been a regional approach that has taken the form of regional planning councils, intercounty compacts, and regional sea level rise assessments. The earliest of such intergovernmental collaborations was the regional planning council, or RPC. The RPC was developed in the mid-20th Century across the US as way to provide a centralized source of planning and grant funding. One of the most important functions of the RPC's in Florida has become the reoccurring regional Evacuation Studies. Systematically updated by House Bills 1721 and 1359 in 2006, the Statewide Regional Evacuation Study Program was funded by a FEMA Hazard Mitigation Grant and contracted to RPC's to create regional evacuation plans that incorporated updated demographic and LiDAR data, as well as improved SLOSH, inundation, behavioral, and transportation modeling (SFRC, 2016). Over the last seven years, local RPC's have continued to update the regional evacuation plans as new data and models have been made available. These evacuation studies, because they use SLOSH models that do not incorporate sea level rise, are meant to be used in short-term planning and are utilized by county and municipal emergency management officials.

Beyond RPC's, County and municipal governments have collaborated at the regional level across Florida to address the threat of sea level rise. The most significant of these locally fostered groups is the Southeast Florida Regional Climate Change Compact (further referred to as Compact), formed by Palm Beach, Broward, Miami-Dade, and Monroe Counties in 2010. The Compact, though led by Counties, has numerous municipal partners and has created a list of 110 recommendations to make the region more resilient, and has formulated a unified sea level rise projection to be applied to future development and infrastructure planning. While participation and policy enactment are on a voluntary basis, the compact's position creates a larger regional voice that can influence broader mitigation that can be too easily influenced by local political prerogatives. Outside of Southeast Florida, there have been few major efforts to create such broad coalitions to create regional solutions.

Similar regional efforts have begun in the other two regions of this study, Tampa Bay and Jacksonville, but with the major omission of direct involvement by counties and local governments. The first such product, the regional action plan to address sea level rise by the

Regional Community Institute of Northeast Florida, was a product requested by the local RPC. While not a compact or having any formal commitment to the document's findings, the action plan develops a categorized list of recommendations to be taken by local entities. The second such product was the regional sea level rise projection, similar to that conducted by the Southeast Florida Compact, by the Tampa Bay Climate Science Advisory Panel. The self-described "ad hoc network of scientists and resource managers working in the Tampa Bay region" (TBCSAP, 2015, p. 1) was formed to assess sea level rise's impact in the bay area and develop recommendations to local governments. Like the Northeast Florida group, the Panel is not a compact like in Southeast Florida, yet the Panel holds great potential because it has the largest coalition of involvement. While the Compact was primarily made up of county and local government officials, the Panel involves a wide spectrum of regional, state and national agencies, municipal and county governments, and academic institutions, fostering a far broader group of participants.

Figure 4. County and State Percentage below 3ft. Elevation



Source: Strauss, Tebaldi & Kulp (2014, p. 23)

Led by Southeast Florida's Compact, one adaptation policy that many stakeholders see as holding potential for use across the state are Adaptation Action Areas. Adaptation Action Areas, created by the Community Planning Act of 2011, are defined through Florida Statute 163.3164 (1) as "a designation in the coastal management element of a local government's comprehensive plan which identifies one or more areas that experience coastal flooding due to extreme high tides and storm

surge, and that are vulnerable to the related impacts of rising sea levels for the purpose of prioritizing funding for infrastructure needs and adaptation planning." (2011) These adaptation areas are meant to be designated by local governments as a way to provide a middle road that incorporates the three traditional pillars of adaptation: protection, accommodation, and retreat, as illustrated in **Figure 4**. Adaptation areas are utilized in various Florida communities, including Ft. Lauderdale, Satellite Beach, and Pinecrest.

State Coastal Mitigation

Beyond Florida's reliance on its beaches and marine resources as an economic lifeline, they are also a vital defense to tropical cyclones and sea level rise. Yet shorelines are battered every year from this same combination of human activity, storms and sea level rise, which impedes natural sediment build-up. Storms and sea level rise erode and shift shorelines by moving sand from through wave action and depositing it elsewhere. In order to prevent major coastal erosion, governments have enacted various actionable policies that include both hard structures and soft structures. Hard structures aim to limit and prevent wave effect and include constructing seawalls, breakwaters and groins. Soft structures are primarily the replenishing of beaches and dunes through adding sand. Adding sand can be quite complicated due to sourcing, which range from inland quarrying and trucking to offshore dredging from harbors, rivers, inlets or deeper waters.

Table 9. Erosion of Florida Beaches in Miles

Counties	*Critical Beach*	*Non-Critical Beach*
Duval	10.4	0
Saint Johns	13.7	0.5
Pasco	0.2	0
Pinellas	21.4	4.4
Hillsborough	1.6	0
Manatee	13	0
Palm Beach	33.6	0.9
Broward	21.3	0
Miami-Dade	17	1.4
Total Atlantic Shoreline	***210.8***	***23.9***
Total Gulf Shoreline	***188.9***	***68.4***
Monroe	10.2	1.6
Total All Florida Shoreline	***409.9***	***93.9***

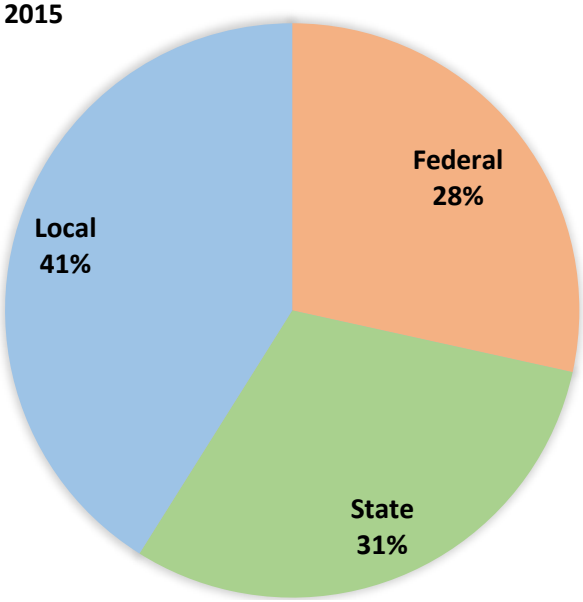
Source: Department of Water Resource Management, Florida Department of Environmental Protection (2015, June)

Florida diligently monitors and maintains its beaches, at both a state and local level, of which the state government maintains a database of beaches threatened by erosion. The state classifies beach erosion as 'critical' and 'non-critical', though both are threatened by erosion. 'Critical beach' is designated by the State as shoreline threatened by natural or human processes that threaten physical interests, be they

economic or environmental. In contrast, 'non-critical beach' is similarly eroding shoreline, yet not to the degree of threatening public or private interests. As seen in **Table 9**, Florida has over 500 miles of shoreline threatened by coastal erosion (Florida Department of Environmental Protection [DEP], 2015). Of the counties focused on in this study, Palm Beach has the most miles of critical beaches at 33.6 miles, with Pinellas and Broward just behind with slightly over 21 miles of critical beaches. In their latest update, the Florida Department of Environmental Protection (DEP) highlighted the impact of beach erosion by storms. Following the catastrophic 2005 hurricane season, the updated 2006 assessment found a 5.5 percent increase in critically eroded shoreline, adding 20.2 miles to the critically beaches (Florida DEP, 2015). Since the first study in 1989, more than 190 miles have been added to the list, nearly doubling the total miles of critical erosion in two and half decades.

Beach renourishment projects are funded and planned at all levels of government dependent upon the project type and jurisdictional control of the beach itself. Nationwide, the federal government pays up to 65 percent of beach renourishment projects, while state and local governments make up the rest (Ludden, 2013). In Florida, however, with local economies so dependent upon tourist dollars and with coastlines so susceptible to erosion, local governments foot a far larger portion of the bill at roughly 41 percent as seen in **Figure 5** (Florida EDR, 2015). In a recent study by the Florida EDR, the state found that over 25 percent of its annual visitors come for Florida's beaches, and in relation to the costs of nourishment projects, the state has a 5.4 positive return on investment (Florida EDR, 2015). In more concrete terms, at the time of review, the state invested $44 million into their Beach Management Restoration Program with a reported average annual increase in GDP of $2.4 billion (Florida EDR, 2015).

Figure 5. Approximate Beach Restoration Expenditures in Florida 2015



Source: Florida Office of Economic & Demographic Research (2015)

With human activity now focused on the maintenance of beach size due to prior development and hurricane impact inconsistent by nature, sea level rise is one of the greatest threats facing every coastal community in Florida in the coming decades. To this point, the U.S. Army Corps of Engineers has projected that "Miami-Dade County will need 23 million cubic yards of beach renourishment over the next 50 years to sustain its beaches." (Tompkins & DeConcini, 2014) However, recent research has also shown that since the mid-1800s, the Florida Atlantic Coast has actually recorded an average shoreline advance, despite the projection models forecasting a net loss of shoreline even with nourishment (Houston & Dean, 2014). The authors venture, "Onshore transport hypothesized by Dean (1987) appears to be the only possible source of sand that can account for the average advance of the Florida east coast shoreline, especially given significant reductions in sand in the littoral zone as a result of offshore disposal of sand and ebb shoal growth from cutting new inlets." (Houston & Dean, 2014, p. 655) This finding should be taken in the context of diminishing offshore sand deposits and rising sea levels that limit the lifetime of both soft and hard structures.

As of 2013, Miami-Dade County's offshore sand deposits have been exhausted while Broward's and Palm Beach's were quickly following course. The result is a looming confrontation as South Florida looks north to Martin and St. Lucie Counties as sources of sand for future beach renourishment (Alvarez, 2013). With much of South Florida's deposits already depleted, and sources off St. Lucie and Martin Counties only projected to have 50 years' worth of sand, there have been calls by some to loosen Federal regulation that prevents sourcing sand from foreign countries—Cuba and the Bahamas both being far closer than many potential northern or inland sources (TC Palm, 2013). This situation immediately brings into question the sustainability of any such offshore sourcing of sand for soft structures along Florida's coasts.

Tasked with the nation's civil and environmental engineering since America's founding, the U.S. Army Corps of Engineers (USACE) "supports an integrated approach to reducing coastal risks and increasing human and ecosystem community resilience through the full array of natural, nature based, nonstructural, and structural measures" (USACE, 2013, p. 8). The USACE has raised emphasis in recent years to incorporating natural barriers as a form of weather mitigation and resilience, and in concert and combination with existing structural and nonstructural features. The USACE categorizes the following as natural and nature-based features to enhance: 1) dunes and

beaches, 2) vegetated features, 3) oyster and coral reefs, 4) barrier islands, and 5) maritime forests and shrub communities (USACE, 2013). The USACE further categorizes nonstructural features as: 1) floodplain policy and management, 2) flood-proofing and impact reduction, 3) flood warning and preparedness, and 4) relocation; similarly they categorize structural features as: 1) levees, 2) storm surge barriers, 3) seawalls and revetments, 4) groins, and 5) detached breakwaters (USACE, 2013). Given that federal, state, and local entities already utilize the nonstructural features, and because there is only limited possibility for structural features due to the extent of coastal development in Florida, the natural features mentioned above are being given ever-greater attention for mitigation potential by all levels of government.

While much of governmental soft structure efforts have focused on beach and dune renourishment, one of the most important forms of natural mitigation for Florida are its mangroves. Due to urban development and population growth, at least 23 percent of Florida's 20th Century mangrove forests were eradicated by 1982, limiting potential mitigation benefits from storms for those same urban populations (Shafer & Roberts, 2007). While almost a quarter of total mangrove habitat loss is significant at the state level, some areas saw far more catastrophic losses during the same period. Tampa Bay had a reported 44 percent loss of mangrove habitat, while Miami's Biscayne Bay had an astounding 82 percent habitat loss (Shafer & Roberts, 2007). Mangroves provide numerous benefits in mitigating sea level rise, coastal erosion, storm surge and storm winds. Mangroves show moderate abilities to mitigate sea level rise through natural processes of accretion and elevation. Mangrove forests have been shown to retain up to 80 percent of sediment carried from tides, catch debris, aid in benthic mat development, and provide their own decomposition, all contributing to moderate elevation change (Krauss et al., 2014). In mitigation against storms, recent research found that "The decay rates of surge amplitudes are about 20-50 cm/km across mangroves. Without the mangrove zone, surge amplitudes would decrease gradually landward in almost linear fashion with rates of 6-10 cm/km." (Zhang et al., 2012) Following the passing of the *1996 Mangrove Trimming & Preservation Act*, the Florida state government has taken major strides to preserve and protect this important resource, with elevated legal status against development and a highly regulated process over even the tree's pruning.

The Federal government provides aid in local mitigation through two forms, thought leadership and project funding. One such form of thought leadership that guides the national

dialogue and development of disaster education, research, and standards is the recently created National Windstorm Impact Reduction Program (NWIRP). The NWIRP was established by the US Congress in 2004 to coordinate Federal agencies to decrease the loss of life and property from windstorms. The NWIRP is made up of the Federal Emergency Management Agency (FEMA), the National Oceanic and Atmospheric Administration (NOAA), the National Science Foundation (NSF), the Office of Science and Technology Policy (OSTP), and the National Institute of Standards and Technology (NIST), which is the lead agency. The network of agencies have "focused on facilitating improvements in forecast models, warning systems, evacuation planning, structural design, and community preparedness to meet this goal." (NSTC, 2015, p. 6) The results from the NWIRP's research and outreach extend to all levels of government and business, improving resiliency for communities impacted by storms all across the country.

The primary means of Federal mitigation efforts in Florida are through the various FEMA grant programs that fund projects from the state level down to individual towns and organizations. A review of all FEMA grant mitigation funding can be view in **Table 10**. The various programs include the Hazard Mitigation Grant Program (HMGP), the Repetitive Flood Claims (RFC), the Severe Repetitive Loss (SRL), the Flood Mitigation Assistance (FMA), and the Pre-Disaster Mitigation (PDM). The purpose of the HMGP is to reduce future loss of life and property from future disasters during reconstruction following an event. The RFC is a grant program for individual properties that have had one or more claims from flood insurance to create greater savings for the National Flood Insurance Fund. The SRL provides funding to reduce flood damage to residential properties that have experienced severe repetitive losses with flood insurance, with the objective of greater savings for the National Flood Insurance Fund. The FMA program's purpose is to reduce or eliminate future claims under the National Flood Insurance Program (NFIP). The PDM program is designed to assist States, Territories, Indian Tribal governments, and local communities to reduce overall risk to lives and property from future disasters and reduce the need for Federal funding from future events. These five grant programs combine to form the Unified Hazard Mitigation Assistance Grant Programs with a common goal of minimizing the loss of life and property from natural disasters. Given the different objectives of each grant program, they similarly have different cost-sharing structures between the programs. The HMGP, PDM, FMA, and SRL have a 75/25 percent cost-sharing structure between federal and non-federal funding while the RFC has a 100 percent coverage of the project. Moreover, when the sub-grantee

or Tribe is a small impoverished community under the PDM program, cost-sharing shifts to 90/10, and when properties qualify under FEMA's Repetitive Loss Strategy, the FMA and SRL cost-sharing similarly shifts to 90/10.

At the state level, a number of recent mitigation efforts are worth mentioning, these include the development of more rigorous statewide and local building codes, regional evacuation studies, and the creation of a new statewide alarm system. Florida's building codes are considered some of the strongest in the country, recently receiving a 94 out of 100 rating by the Insurance Institute for Business & Home Safety (IIBHS, 2015). The state's building codes were dramatically changed following the total destruction of residential structures from Hurricane Andrew in 1992. The change came in 1998 under House Bill 4181, creating Florida's first statewide building code, with the most recent fifth Edition released in 2014. The creation of a standardized code has allowed for significant improvements in structural integrity during storms, and a responsiveness to make changes statewide following experiences in other parts of the state.

Table 10. FEMA Grants since 1997

	HMGP		RFC		SRL		FMA		PDM		Total	
	#	$*	#	$*	#	$*	#	$*	#	$*	#	$*
Duval	23	$6,597,357	5	$1,665,198	11	$4,476,646	11	$4,586,673	0	$0	50	$17,325,875
Saint Johns	6	$1,774,601	0	$0	0	$0	1	$6,325,000	0	$0	7	$8,099,601
Pasco	31	$6,756,785	1	$494,079	1	$237,841	35	$6,897,194	0	$0	68	$14,385,899
Pinellas	26	$2,439,338	1	$405,000	2	$489,350	70	$15,730,204	5	$3,618,742	104	$22,682,634
Hillsborough	14	$18,428,228	0	$0	1	$175,585	5	$655,704	1	$870,201	21	$20,129,718
Manatee	26	$1,238,840	0	$0	4	$2,553,959	14	$2,705,924	0	$0	44	$6,498,723
Palm Beach	59	$44,302,969	0	$0	0	$0	2	$80,118	3	$588,333	64	$44,971,420
Broward	72	$102,045,504	0	$0	1	$244,177	4	$719,453	20	$15,798,170	97	$118,807,305
Miami-Dade	209	$181,151,385	0	$0	1	$496,140	2	$1,235,405	38	$41,877,572	250	$224,760,502
Florida**	201	$248,033,511	4	$774,547	5	$1,703,964	79	$10,888,084	0	$0	289	$261,400,107

* This is total project costs, FEMA on average pays 75% of total

** The state of Florida as a grantee, not a total of recipients in the state

Source: FEMA data-feeds

After the 2004-2005 seasons, a state effort to reexamine disaster preparedness led to the passing of *House Bills 1721* and *1359* which tasked the government with improving hurricane evacuation and redefining coastal high hazard areas. The result was 11 separate evacuation studies completed by regional planning councils that analyzed and enhanced county level evacuation procedures. A further realization was the lack of a central warning system. A similarly timed and commissioned state study found that "Florida currently has an extensive, but independent

collection of notification systems administered by cities, counties, schools, colleges, businesses, and others. However, the current independent system structure is costly, has multiple redundancies, and could benefit from transferring to an integrated system structure." (Carter-Jones, Dixon, & Dumas, 2012, p. i) On April 20, 2016, the Florida Division of Emergency Management announced the awarding of contract to the company Everbridge to create a statewide emergency notification system named 'AlertFlorida.' The warning system will provide the first standardized statewide event-specific warnings based upon recipient locations via mobile devices and social media.

To address coastal resilience and provide a universal projection for sea level rise, the South Florida Climate Change Regional Compact released a unified projection for all member counties in 2015. The report discussed three different models that they present as providing a projection for low, medium, and high sea level rise, viewable in **Table 11** from left to right. The Compact designed the range as a means of planning and prioritizing construction in South Florida, dependent upon the intended lifetime of the project and the importance of it to the public in the event of high sea level rise or a hurricane. To this point, the authors argue that all future critical infrastructure should be built with the highest projections in mind, with examples of such infrastructure including power plants, waste treatment plants, levees, airports, seaports, railroads, and bridges and roads along evacuation routes (Compact, 2015).

Table 11. Unified Sea Level Rise Projection

Year	*IPCC AR5 Median (inches)*	*USACE High (inches)*	*NOAA High (inches)*
2030	6	10	12
2060	14	26	34
2100	31	61	81

Source: Compact (2015, October)

A similar attempt to prepare for the effects from climate change and sea level rise to Florida's hydrological features was prepared through joint studies by the Florida State University System. Of greatest change will be Florida's access to freshwater. The final study found that, in 2005, 90 percent of Florida's residential freshwater came from groundwater aquifers, which are at growing risk to saline intrusion, while 56 percent of freshwater withdrawals for agricultural and power generation came from surface waters (Koch-Rose, Mitsova-Boneva & Root, 2011). Those at greatest risk to salination are the communities of South Florida that utilize the Biscayne Aquifer, which already shows progressive saline intrusion in many wells. Cities and towns mentioned in the report that are already effected by saline intrusion and elevated chloride levels include

Hallandale Beach, Dania Beach, Lantana, Lake Worth, Ft. Lauderdale, Florida City, Homestead, the Florida Keys, and even Miami International Airport (Koch-Rose, Mitsova-Boneva & Root,

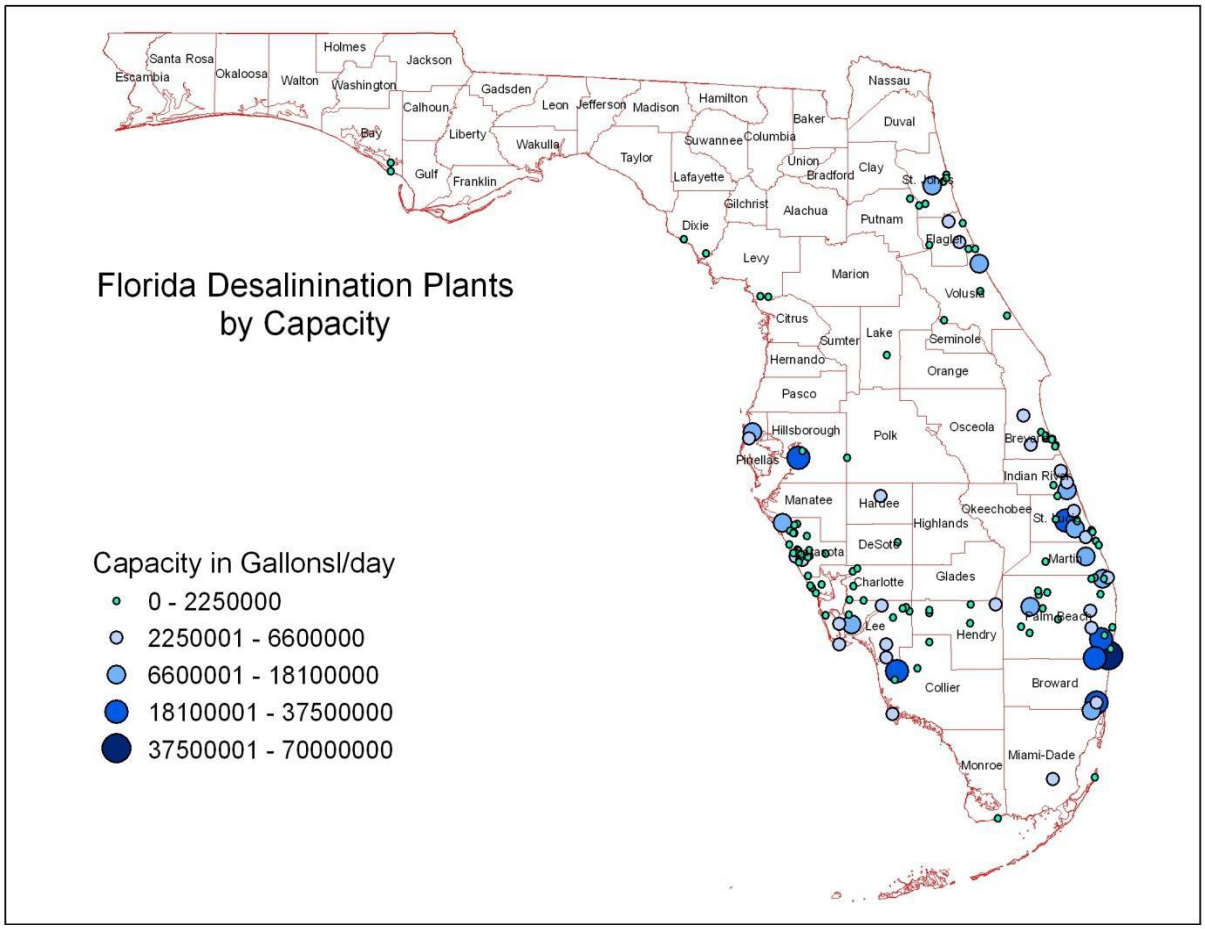


Image 3. Existing Florida Desalination Infrastructure Source: (Koch-Rose, Mitsova-Boneva & Root, 2011, 2011).

The response, however, will be difficult, as salt-water intrusion will require finding alternative sources and methods that will rise costs and negatively affect the environment. Desalination has become cost-effective in many Florida communities, as the improvements in technology have coincided with the rising costs and difficulties of freshwater sourcing and transport. As illustrated in the image above, Florida already operates with considerable levels of desalination as a source of potable water—Florida leads the country in desalination, with over 140 facilities and roughly 515 million gallons daily (FDEP, 2010). However, desalination has its market limits. Existing desalination infrastructure is utilized for brackish water, while desalinating seawater would cost 50 percent more and creates higher levels of salinity in residual ocean water by 2.5 times (Koch-Rose, Mitsova-Boneva & Root, 2011). Moreover, as Florida begins relying for

greater desalinated water, the resulting infrastructure will become far more vulnerable to post-storm resiliency in the event of severe damage.

Florida Counties and Cities

The Southeast Florida Regional Climate Change Compact remains one of the most influential parties in Florida in driving mitigation, adaptation, and resiliency strategies. Through the Compact's efforts, they have enlisted 29 municipalities in their four counties to participate in their 110 action items, as well as providing examples of policy and planning steps to be taken across other regional and local bodies in Florida. Such influence can be seen in the codifying of Adaptation Action Areas into State Statute, tracking municipal implementation of action items, and being the first regional Florida body to implement a unified sea level rise projection tied to future infrastructure and development. While the Compact's contributions have been integral in spurring action across the state, many other counties and municipalities have taken laudable steps in addressing their local situation. The following sections briefly discuss many of these local efforts to build resiliency into their communities.

Miami-Dade County

Miami-Dade County has taken a number of credible steps in the past decade to mitigate the long-term impact of sea level rise. Milestones have included their participation in the Climate Change Regional Compact, their most recent Sea Level Rise Taskforce, and the creation of a Chief Resiliency Officer position in charge of an Office of Resilience. These three notable steps have shown the government's commitment to meaningful efforts in mitigation and planning. Moreover, the County's efforts have resulted in national recognition and collaboration, ranging from overtures from the Federal governments, to partnerships with the Nature Conservancy and the Rockefeller Foundation.

While the County first formed a Climate Change Advisory Taskforce (CCASTF) in 2006, by 2013, there had been sufficient political momentum due to the recent formation and success of the Climate Change Regional Compact to create a Sea Level Rise Taskforce for the County (Staletovich, 2014). The Taskforce was charged with providing "a realistic assessment of the likely impacts of sea level rise and storm surge over time" and making "recommendations relative to the Comprehensive Development Plan (CDMP), Capital Facilities Planning and other priorities." (Ruvin et al., 2014, p. 3) The report found that the most important recommendation was the need to move the adaptation planning process forward quickly by finding the expertise needed to

formulate a comprehensive capital improvements plan to incorporate projected sea levels and salinity intrusions on existing and future infrastructure, while ensuring accountability with measureable impact. Other recommendations stressed the need to follow through on CCASTF recommendations, the implementation of AAA's, and increase environmental restoration and conservation efforts. A significant step in mitigation efforts has resulted with the County's Water and Sewer Department, which now incorporates sea level rise into all of its projects and plans.

The impact of the Taskforce and the County's involvement in the Regional Compact have resulted in a number of studies, programs, and policies. Studies included the implementation of various new modeling and vulnerabilities studies that identified infrastructure in need of adaptation measures, areas that would see greatest impact, as well as a general improvement of existing geographical data for the County. Various County staff member also carried out a series of information gathering meetings with experienced staff and subject matter experts from cities like New York City, San Francisco and Seattle, the USACE, and a number of insurance and reinsurance companies. The County also began collaboration in two local mitigation projects with the Nature Conservancy to introduce environmental soft structures to show the effectiveness of mangroves and wetlands. Finally, the County formally created a Chief Resiliency Officer position, which was filled by former SFRPC Executive Director James Murley, and then officially joined the Rockefeller Foundation's 100 Resilient Cities, a group that provides financial and logistical support for cities in preparing and implementing a resiliency strategy.

Miami

The City of Miami convened its first Sea Level Rise Committee in October 2015, following its establishment earlier in the year by the City Commission to study the phenomenon, hold public hearings, create a report on the subject, and provide advice and recommendation as needed to the City. The Committee's overall impact has resulted in greater visibility for the threat of sea level rise in a community that is already being affected by it. Since its inception, the Committee has been a source of discussion and analysis of programs and policies under consideration by the City. Such reviews that have commenced under the Committee include reviews of improved mapping for vulnerabilities, the impact of sea level rise on insurance rates, and existing and proposed planning and zoning code. More concretely, the City is in an exploratory phase to incorporate sea

level rise projections in their major plans, including their Comprehensive Neighborhood Plan and their Stormwater Master Plan (City of Miami, personal communication, June, 2016).

As previously mentioned, the City of Miami has also been a member of a number of important regional collaborations on mitigation and resiliency. The most recent of these collaborations was the joint grant application with the City of Miami Beach and Miami-Dade County for the 100 Resilient Cities. The collaborative application and the growing national prominence of South Florida's vulnerability were key to the entry's success. Moreover, while both Miami-Dade County and Miami Beach each already had an existing Chief Resilience Officer in their administrations, the City of Miami may benefit the most by having the grant fund such a position for the first time. At the press conference announcing the applicants' selection, Peter Madoma, the Chief Operation Officer of the Rockefeller Foundation—the funder and organizer of 100 Resilient Cities—said of the selection, "Miami is ground zero for some of the most common and pressing challenges facing cities in the 21st Century. A dynamic, holistic strategy for moving Miami forward should address the city's aging infrastructure, housing stock, and public transportation system – all in addition to fast-emerging threats as a result of climate change." (City of Miami, 2016)

Miami Beach

Miami Beach's most significant efforts in combatting sea level rise's impact on its island has been through its Stormwater Management Master Plan (SWMMP) and ongoing infrastructural improvements. The City's comprehensive approach began with the approval of the SWMMP in 2012 with a recommended $200 million in capital improvements, and has most recently risen to $500 million for a 5-year capital improvement plan (City of Miami Beach, personal communication, June, 2016). This effort is being executed under the Department of Public Works and primarily focuses on installing new pumps at greater height with newer technology, but the City's plans also include raising roads, raising sea walls, and restoring dunes and mangroves. To help fund these projects, the City has issued bonds and raised residents' stormwater fees between $9 and $16 a month (UCS, 2016a).

Beyond the SWMMP, the City has taken a number of other steps to promote resiliency and sustainability. One such step towards resiliency has been its preparation for greater physical

damage from sea level rise and hurricanes. For example, the City's Environmental Resources Management Division now accounts for greater projected damage from storms in its annual budget. Like many other regional governments, Miami Beach has pertinent committees to examine this and other policies and efforts that can be undertaken by the Mayor and Commission. To this effect, Miami Beach has a Sustainability and Resiliency Committee, formerly their Flooding Mitigation Committee. The Committee meets once a month to discuss proposed polices, review commissioned studies, and follow-up on implemented programs and policies.

Coral Gables

The City of Coral Gables has made progressive efforts in addressing sea level rise in its community through educating and informing its residents on the area's vulnerability and incorporating a number of policy and planning processes in its governments. On the education front, the City has dedicated a central webpage for residents to source information, both local and national, in understanding the larger phenomenon and its local impact. Listed in the site's resources are a number of federal agency sites, the policies under review by the city, and prior public forums on sea level where the City's public officials and local experts discussed the issue. One such public forum was an official Coral Gables 'Sea Level Rise Discussion Series' held on April 13, 2016 in conjunction with Florida International University to review vulnerabilities, strategies, and possible policies.

In recent years, the mayor and commission have generated a wide variety of sustainability and resiliency programs that coincide with sea level rise mitigation. Included are the creation of committees like the Sustainability Advisory Board and the Transportation Advisory Board, and becoming a signatory of the Southeast Florida Climate Change Regional Compact as a municipal partner. The City has taken concrete steps towards resiliency and mitigation through the appropriation of $200,000 for a city-wide sea level rise vulnerability assessment, the ongoing writing of a 10-year Sustainability Master Plan, and the raising of stormwater fees from $8.80 to $11.89 per equivalent residential unit per year to fund future capital improvements (City of Coral Gables, personal communication, June, 2016). In an effort to create both beautification and sustainability, the City is enacting their $3 million Tree Succession Project, which will plant 3,000 trees to replace dead, dying, or absent trees across the city.

Broward County

Broward County has been a national leader on government action in mitigating against sea level rise. Along with being a founding member of the Southeast Florida Climate Change Regional Compact, one of Broward's most meaningful impact has been its partnership with the City of Fort Lauderdale in early implementation of Adaptation Action Areas. The partnership was initiated by the Department of Economic Opportunity (DEO) to ensure broader regional support and the successfully implemented pilot program is now recognized as a model to be replicated elsewhere in Florida. The beginnings of Broward County's proactive policy began in 2008 with the formation of a Climate Change Task Force through Resolution 2008-442, a group that ultimately produced a 2010 Action Plan with 126 recommended actions (Task Force, 2010). This Action Plan was updated in 2015 to 96 recommended actions, with an extra emphasis on environmental sustainability, alternative energy, and water supply protection (Task Force, 2015). Adding to this library of resiliency literature for the County, Broward also has a Climate Change Element integration framework, Renewable Energy Action Plan, a Community Energy Strategic Plan, and the Broward Metropolitan Planning Organization Climate Study. As a result, the County has created a wealth of knowledge available to the public and public official alike, including projections, vulnerability studies, updated flooding and elevation mapping, strategies and plans, and climate change educational material.

Fort Lauderdale

The City of Fort Lauderdale shares a similar history of mitigation as Broward County due to their partnerships in both establishing the Adaptation Action Area (AAA) pilot program for the city, as well as their cooperation on the Regional Compact. Fort Lauderdale's commitment to utilizing AAA's for mitigation was solidified in 2015 when the City's Community Investment Plan officially designated 16 AAA's and listed 38 projects meant to help the areas adapt to future sea level rise. Many such projects included stormwater improvements, seawall enhancements, and streetscaping. Two projects of note are the use of pavers on city properties to improve drainage and the creation of a stormwater preserve in the River Oaks neighborhood to alleviate frequent flooding. Similar to previously mentioned cities, Fort Lauderdale also has a Sustainability Advisory Board that has issued a Sustainability Action plan, first in 2010, and then updated in 2011. The Board created a Progress Report in 2015, in which they document the considerable

advancement made with 42% of the recommended actions completed and another 29% in progress (City of Fort Lauderdale, 2015). The steps taken between 2010 and 2014 have resulted in a citywide reduction of water demand by 7% and electricity by 4.4% (City of Fort Lauderdale, 2015).

Palm Beach County

As a signatory of the Regional Compact, Palm Beach County has taken a number of steps to address sea level rise beyond its regional commitment. Notable among these are its creation of a County Climate Change and Sustainability Coordinator, the addition of climate change policy to the County Comprehensive Plan, and their coastal environmental restoration. The Climate Change and Sustainability Coordinator was created in 2015 as a lead in coordinating regional and county efforts in mitigation. Local urban planner Natalie Schneider filled the position and in her first year the county "added 181 hybrid vehicles to its fleet, purchased propane-fueled and hybrid buses, created 'living shorelines' where plants provide protection instead of concrete, and adjusted traffic signal timing for smoother traffic flow and less idling." (Swisher, 2016) This position's creation has its origin in the April 2014 amendment to the County's Comprehensive Plan. The amendment added Sub-Objective 1.1.1 Climate Change, in which the County "shall adopt, implement, and encourage strategies which increase community resiliency and protect property, infrastructure, and cultural and natural resources from the impacts of climate change, including sea level rise, changes in rainfall patterns, and extreme weather events." (Palm Beach County, 2015, p. 10) This amendment has ensured that adaptation and resiliency will be a cornerstone of Palm Beach County's future. Other environmental efforts have included significant efforts in restoring Lake Worth Lagoon, renourishing beaches and dunes, building breakwaters, and replanting mangroves along the County's shorelines.

Delray Beach

The City of Delray Beach has a unique administrative feature that makes it a progressive example of sustainability governance. This unique feature is an Environmental Services Department that oversees the offices of Engineering, GIS, Public Utilities, Public Works, Parking, Transportation and Traffic, and Sustainability. This innovative approach subordinates all infrastructural planning and maintenance under a department focused on environmental considerations such as sea level rise and sustainability. According to the department's web page, Environmental Services Department provides cost effective total life cycle management of the

City's public infrastructure and key essential services to enhance sustainability and the health, safety, and welfare of residents, businesses, and visitors." (City of Delray, 2016) Importantly, this consolidation reinforces an integrated government approach that saves money by reducing redundancy and plans for long-term usage and vulnerability of government services.

Duval & St. John Counties

The Northeast of Florida contains both the State's largest city, Jacksonville in Duval County, and the State's oldest city, St. Augustine in St. Johns County—both in coastal positions at great risk to hurricanes and sea level rise. Leading the region's storm and sea level rise mitigation efforts is the Northeast Florida Regional Council (NFRC), a regional planning organization for seven Northeast Counties that include Duval and Saint Johns and contains 27 municipalities. The NFRC established the Regional Community Institute (RCI) of Northeast Florida in 2005 to create a regional body that could adequately response and prepare for various socio-environmental concerns in the public space. The RCI was recently tasked with creating a regional plan to address sea level rise and resiliency, providing policy recommendations for the counties and municipalities apart of the NFRC. RCI released a Regional Action Plan in 2013 that published their findings and organized their recommendations into five actionable and realistic steps that they can take.

The resulting action plan can be summarized as follows (RCI, 2013): 1) 'Create a Clearinghouse on Understanding Risk', this action can be expressed through the creation and maintenance of a website that provides a one-stop shop of regional sea level rise data and resources for local stakeholders to better inform their decision-making processes. 2) 'Engage the Community', this action calls more directly for the formation of educational outreach groups that engage the community at various levels and through diverse means, to both inform and learn of the needed efforts to mitigate sea level rise. 3) 'Save Money', this actions stems from the growing concern on flood insurance costs in Florida, which is primarily covered through the National Flood Insurance Program (NFIP) that has seen dramatic premium increases in recent years. The recommendations to save money stress two considerations, the participation in FEMA's Community Rating System—a program that encourages communities to participate in their mitigation strategies—to reduce insurance premiums, and the implementation of the NOAA Coastal Services Report, entitled "What will Adaptation Cost?", which outlines a cost-benefit decision-making process for stakeholders to adapt in future investments. 4) 'Collaborate and

Leverage Success', this action stressed the importance and regional nature of mitigation and adaptation for community resiliency. The authors stressed the need for regional collaboration and communication to create informed regional knowledge on one another's experiences, citing Jacksonville's recent compilation of a manual on green infrastructure being an example of regional knowledge sharing. 5) 'Engage the Business Sector in Long Term Resiliency', this action centers on their concept of 'Public/Private Regional Resiliency (P2R2)', which a committee can use to formulate a strategy to incentivize physical and economic development outside of regional sea level rise vulnerable areas for both safety and sustainability.

The efforts by the RCI in creating this action plan earned the NFRC the National Association of Development Organizations 2014 Innovation Award, lauding the plan in a press release. "It contains only doable action recommendations, not the 'wish list' recommendations that ensure that so many plans gather dust on the shelves of bureaucrats. It addresses sea level rise in a region that is only at the beginning stages of discussion on regional resiliency" (NADO, 2014).

Jacksonville

The City of Jacksonville, according to Duval County's Local Mitigation Strategy, faces the greatest threat from tropical cyclones, storm surge, floods, and brush, wildfires and forest fires. The Local Mitigation Strategy prioritizes threats and mitigation programs. The Local Mitigation Strategy of the County and its five municipalities—Duval County and the City of Jacksonville being a consolidated government—is led by a Working Group representing the various government and is guided by the Duval Prepares, a group that represents both the local public and private sectors. The 2015 Strategy focused on prioritizing water infrastructure, citing "retrofitting water, sewer and electrical facilities to protect against failure caused by flooding and storm surge, hardening against wind impacts, [and] fully implementing stormwater management plans" (Duval County, 2015, p. 8), along with several other mitigations for other threats.

Between 2013 and 2015, the City of Jacksonville carried out a series of voluntary assessments with coastal and riverfront communities to discuss the regional action plan and open a dialogue on concerns towards future impacts. On August 14, 2015, the City held a final public meeting to present their findings. Some of the greatest concerns centered upon food and water security, infrastructure resiliency, and the prioritization of responses to impacts. Of notable interest, was the communities' concern over South Florida's lack of response and the resulting

potential influx of South Floridians into the Jacksonville area. The administration's focus on sea level rise seems to have been nullified, however, with the Mayoral change in 2015.

As part of the Rockefeller Foundation's '100 Resilient Cities', Jacksonville was chosen under the former City Mayor Alvin Brown's administration in 2013. Jacksonville received $1 million in cash and services to implement hurricane and sea level rise resiliency programs. However, following the election of the current Mayor, Lenny Curry, the two sides seem to have had a falling out, despite Mayor Curry appointing the City's Director of Community Affairs as their Chief Resiliency Officer. In a now public letter from Michael Berkowitz, President of 100 Resilient Cities, to Mayor Curry, the two parties officially parted ways. Berkowitz wrote, "We understand that the priorities of setting up your administration perhaps have made it a challenge to dedicate resources and time to making this partnership a success. We of course respect this decision and wish you and the City of Jacksonville the very best." (Berkowitz, 2016)

St. Augustine

St. Augustine is the United States' oldest European colonial town, established in 1565, with its Castillo de San Marcos fortress standing as both one of the country's greatest historical monuments and one of its most vulnerable to a storms and sea level rise. As a municipality in St Johns County, St. Augustine is a member of the County's Local Mitigation Strategy. In their 2015 Strategy, the County identifies hurricanes and their accompanying threats of storm surge, rainfall and wind damage as the greatest threat facing the population. The City of St. Augustine is currently enacting a number of infrastructural mitigation projects, including rehabilitating their sewer systems and expanding their water treatment plant, flood mitigation projects on King St. and the South Avenida Menendez Seawall, structural improvements on South Dixie Highway and May Street (from Douglas to San Marco), and significant drainage improvements across the municipality.

A recently completed conservation study for the greater Matanzas Basin, of which St. Augustine is located just to the North and included, examined sea level rise's impact on the ecosystem and population. While much of the focus of the study was for conducting research on the ecosystem, the authors noted the lack of local government policy to mitigate growing vulnerabilities for coastal development. St. Johns has become one of the fastest growing counties in Florida, with the study reporting that 26,686 of the total 59,831 single family homes being built

since 2000, many of which are in low lying and coastal areas (Frank, Volk & Jourdan, 2015). The report dishearteningly notes of St. Augustine that, "Jurisdictions for which all or most of the land is vulnerable, such as St. Augustine, do not have many options for shifting development to more suitable areas, nor may they desire to relocate their substantial historical and cultural assets" (Frank, Volk & Jourdan, 2015, p. 242). The study recommends for communities to invest in traditional adaptation and mitigation efforts, including structural hardening, population relocating and ecological restoration.

Pasco, Hillsborough, Pinellas & Manatee Counties

Recognizing the potential impact of sea level rise earlier than most, the Tampa Bay Regional Planning Council released a sea level rise study in 2006 to examine the potential impacts and the existing planning and policy measures in place. Emblematic of the early perceptions of sea level rise policy, the study cites the then current policy norms as "retreat, accommodation, and protection." (TBRPC, 2006, p. 11) Accordingly, the study reviewed the existing policies of the counties and conducted an in-depth mapping analysis based on an EPA recommended 10 ft. elevation impact from sea level rise. The study found that 390 sq. miles of the four counties was affected by a 10 ft. rise, including 805,000 people, a figure they noted as conservative given the dated data source of the 2000 Census, and the overall population growth in the region (TBRPC, 2006). The study concluded that the resulting maps of projected sea level rise should be used for future reference in planning and development efforts, and that the study was "intended to stimulate local government planners and citizens to think about the issue of sea level rise." (TBRPC, 2006, p. 55)

In a motion similar to the Southeast Florida Climate Compact, who originally made a unified sea level rise projection in 2011 and then updated again in 2015, the above four Tampa Bay counties formed a Tampa Bay Climate Science Advisory Panel in 2014 to create a joint sea level rise projection to streamline mitigation efforts. The Panel published a unified projection in 2015 that projected four levels of sea level rise severity using NOAA data with outcomes ranging roughly from 1-7 feet of sea level rise by 2100 (TBCSAP, 2015). The authors wrote, "The decision to use a common set of sea level rise scenarios throughout the Tampa Bay region will promote the efficient development of vulnerability assessment information, provide a platform for broad

consensus that can facilitate political support at the local government level, [and] enable increased inter-governmental sharing of policies." (TBCSAP, 2015, p. 6) The Panel concludes with three recommendations, 1) that adaptation planning account for a variety of sea level rise projections, 2) that future projections align with the National Climate Assessment estimates, and 3) that future regional projections incorporate St. Petersburg tidal gauge date (TBSCAP, 2015).

At a more localized level, city governments have deferred much of the greater preparatory measures to the county level administration. Included in such planning are traditional county wide emergency preparedness and mitigation strategies, guidance on flood plain management, risk and threat identification and analysis, and community awareness campaigns. A unique effort worth note in the Tampa Bay area is the Hillsborough County Post-Disaster Redevelopment Plan, created in 2010 to develop a resiliency strategy to recover from disasters. The Post-Disaster Redevelopment Plan, or PDRP, is an extensive planning document meant to prepare public and private sector stakeholders to coordinate through a Redevelopment Task Force, which is activated immediately following a catastrophic event. The PDRP identifies hurricanes as the greatest threat to the area, yet acknowledges that the County has not been directly hit in over 50 years. The documents organizes redevelopment into eight categories: public/private infrastructure, environmental restoration, financial administration, economic redevelopment, public outreach, health and social services, land use, and housing recovery. The PDRP outlines a similar timeline as Florida's general economic impact of hurricanes, as illustrated in **Figure 1** on page 8 of this report, with redevelopment efforts spanning from immediate coordination efforts, to five-year physical and economic normalization.

While the PDRP does not provide any projected costs of individual policies, or the economic impact of the plan as a whole, the document provides a monumental list of actions to be taken, both pre-and-post disaster. The list, spanning more than 100 pages, provides detailed and specific actions in each of the above-mentioned eight categories and provides an implementation timeline, the assigned responsible parties, and the applicable technical advisory committees. The pre-disaster list has been fully implemented since the passing of the plan, examples include mutual aid agreements to establish business assistance centers, permitting incentives to encourage redevelopment and mitigation, and develop reconstruction cost estimates for the most vulnerable publicly-owned infrastructure (PDRP, 2010). Examples of post-disaster actions include subsidized

temporary business space, analyze the funding capacity of Community Redevelopment Agencies, and activate Priority Redevelopment Areas policies and incentives upon disaster declaration (PDRP, 2010).

Punta Gorda

Possibly one of the most prescient plans was created for Punta Gorda in 2009 that was, and still is, years ahead of most other Florida communities in solving local vulnerabilities from sea level rise and greater storm surge. Resulting from the impact of Hurricane Charley in 2004 that hit the city of Punta Gorda, city leaders welcomed the offer of the Charlotte Harbor National Estuary Program to develop a strategy to address climate change. The final product was a comprehensive adaptation plan for the city that assessed the city's risks and vulnerabilities, and then adaptation responses approved by the community that can directly address them. The plan was developed in 2008 through a partnership between the City of Punta Gorda, the South West Florida Regional Planning Council, and the Charlotte Harbor National Estuary Program. The group held public workshops to receive input on the recommendations, and the final plan was adopted in November 2009 by the city.

The City of Punta Gorda Adaptation Plan identified 54 specific vulnerabilities and 254 possible adaptations the city could implement in response. The vulnerabilities were categorized into eight general categories: "Fish and Wildlife Habitat Degradation, Inadequate Water Supply, Flooding, Unchecked or Unmanaged Growth, Water Quality Degradation, Education and Economy and Lack of Funds, Fire, and Availability of Insurance" (Beever, 2009, p. 322). The Plan further provides the following list as the policies with the greatest approval by the public: "Seagrass protection and restoration. Xeriscaping and native plant landscaping. Explicitly indicating in the comprehensive plan which areas will retain natural shorelines. Constraining locations for certain high risk infrastructure. Restrict fertilizer use. Promote green building alternatives through education, taxing incentives, green lending. Drought preparedness planning." (Beever, 2009, p. 322-323) These measures, combined with the other recommendations, and the greater knowledgebase of local vulnerabilities creates a laudable plan that predates even the Southeast Florida Compact and lays down a groundwork model for other coastal communities to emulate.

Lee County

Lee County on the Southwest of the peninsula has made considerable progress in preparing its community for a future with a changing climate and sea level. The county has maintained a Unified Local Mitigation Strategy since 2000, encompassing all municipalities, and recently updated in 2011. The strategy is a comprehensive program that analyzes vulnerability and risk, compiles mitigation programs and initiatives to assess their effectiveness, monitors development trends in relation to future risk, and provides future goals and direction. Other notable steps taken by Lee County include a series of policies to address their environmental impact and quality of life. The first such effort, their Climate Change Resiliency Strategy, was delivered to the county by the Southwest Florida Regional Planning Council in 2010 and is a guidance document meant to frame future resiliency efforts in regards to the impact of climate change on the county. The same team created the Punta Gorda Adaptation Plan, and thus stress that the Resiliency Strategy will need public involvement in prioritizing adaptation steps and deciding which parts of the county require action before they can move the strategy into a plan authored the document.

Two other programs that were not explicitly designed to respond to sea level rise or tropical cyclones are the Conservation 20/20 program and the CompleteLEE Sustainability Plan. The first program, Conservation 20/20, was a land acquisition program to moderate rapid development in the county. Established in 1996, it is financed through a .5 mil ad valorum tax that has allowed them to purchase almost 25,000 acres from willing owners (Conservancy, 2015). While the land is intended for general ecological conservation, some areas result in restraining of development in coastal and flooding areas that mitigates against future losses. The second program, their Sustainability Plan, is a multifaceted approach that sets a series of goals for the county to meet economically, environmentally, and socially. These goals are categorized under: Built Environment, Climate and Energy, Economy and Jobs, Education, Arts and Community, Health and Safety, Natural Systems, and Innovation and Process. This Plan was ultimately transferred to the Southwest Florida Community Foundation to monitor for Lee County, as well as expand into Hendry, Glades, Charlotte, and Collier Counties.

Satellite Beach

Located in central Florida on an island off the Atlantic Coast, Satellite Beach is aptly named for its proximity to Cape Canaveral. The city recently became one of the few communities in

Florida utilizing Adaptation Action Areas (AAA's) as a means to mitigate sea level rise's impact. Satellite Beach adopted AAA's in 2013 and in 2014 was awarded a Florida Department of Protection Grant as a part of the Coastal Partnership Initiative. The city distinguishes between two AAA's in their 2016 Comprehensive Plan, and Inland Flooding AAA and an Erosion AAA, allowing for a catered policy approach to the city's two distinct terrains that face different threats rather than a one-size fits all. The Inland Flooding AAA is on the west side of the island along the Banana River, while the Erosion AAA is along the east coast and is comprised of the city's beach. Beyond designation, the city further compiled an inventory of all critical infrastructure during a vulnerability assessment, categorized the assets, and determined the elevation of sea level at which the assets would become inundated with water.

V. NATIONAL MITIGATION AND ADAPTATION EFFORTS

Connecticut

The State of Connecticut has taken a series of steps in preparing its coastal communities for the impacts of sea level rise. The first major step the state took was the 2010 risk assessment entitled The Impacts of Climate Change on Connecticut Agriculture, Infrastructure, Natural Resources and Public Health, which provided a broad illustration of the future impacts of climate change on the state. The final product was a large list of risks the state was facing, and to mitigate against those risks, the state published the Connecticut Climate Change Preparedness Plan in 2011 that enumerated dozens of recommended actions steps to create adaptation strategies unique to each impacted sector. The report found five themes for their recommendations: "1) intensify efforts to ensure preparedness planning; 2) integrate climate change adaptation planning into existing plans; 3) update standards to accommodate anticipated change expected during design life (i.e., build for conditions of the future); 4) plan for flexibility and monitor change; and 5) protect natural areas and landscape features that buffer changing climatic condition." (GSC, 2011, p. 5) Other steps taken by the state include the 2012 updating of the Coastal Management Act that included the incorporation of sea level rise projections and officially favoring living shorelines and environmental soft structures over armoring and intrusive hard structures (Sorrell, 2015). In 2013, the state further created the Connecticut Institute for Resilience and Climate Adaptation at the University of Connecticut, which provides multidisciplinary research while building intergovernmental relationships across local, regional, and national agencies.

Massachusetts

The Commonwealth of Massachusetts and its cities are on the forefront of climate change adaptation, and well aware of coastal impacts from tropical storms, the governments have put coastal defense and resiliency as a priority. While producing a number of reports analyzing climate change and the Commonwealth's vulnerabilities, the Massachusetts Climate Change Adaptation Report, published in 2011, was the first document to provide comprehensive strategies for local governments in all effected sectors. The second section of this report provides adaptation strategies for natural resources, infrastructure, residential healthcare and welfare, the economy and government, and coastal zones. Following this report, Massachusetts created a number of

governmental structures to foster coastal resilience, leading this effort is the Massachusetts' Coastal Erosion Commission. Established in 2013, the Commission was formed to "investigate and document the levels and impacts of coastal erosion in the Commonwealth and to develop strategies and recommendations to reduce, minimize, or eliminate the magnitude and frequency of coastal erosion and its adverse impacts on property, infrastructure, public safety, and beaches and dunes." (MCEC, 2015, p. i) The Commission published a thorough, two volume report in 2015 that included complete inventories of relevant programs and policies at different levels of government, complete inventories of the Commonwealth's shoreline and structures, and a series of strategies with complementary action items.

While created separately from the Commission, Massachusetts made an important funding mechanism for the 78 municipalities and nonprofits located along the Commonwealth's coast, the Coastal Resilience Grant Program. Through this grant initiative, the Commonwealth has funded over $7 million in three years. Eligible projects include: 1) vulnerability and risk assessments; 2) public education and communication; 3) local bylaws, adaptation plans, and other management measures; 4) redesigns and retrofits; and 5) natural storm-damage protection techniques and green infrastructure.

Metropolitan Boston

The City of Boston made a historic pledge with 13 of its neighboring municipalities on May 13, 2015 when they signed the 'Metropolitan Boston Climate Preparedness Commitment'. The 17 signatories represented the 14 municipal members of the Metro Mayors Coalition and heads of regional critical infrastructure. The Commitment formally created the Metro Boston Climate Preparedness Taskforce meant to coordinate "regional and cross-governmental effort to protect critical infrastructure and other important resources and systems, such as transportation, energy, food, telecommunications, clean water, health and safety protections." (MBCPC, 2015) While Boston alone has completed Climate Action Plans and a Climate Change Vulnerability Study before the commitment, this joint approach perceptively recognizes the regional approach needed for a problem that will not simply effect communities on a singular level, but rather, on an interdependent level exemplified by Metro Boston's infrastructure.

New York

New York State may have one of the most advanced programs in addressing climate change's impact on infrastructure, starting with the New York State Smart Growth Public Infrastructure Policy Act of 2010. This Act outlines eleven smart growth criteria that must be used to evaluate all future infrastructural projects to optimize long-term planning of development and prevent unfettered sprawl. A major aspect of this smart growth policy is sustainability of investment, inadvertently laying the foundation for a need to account for sea level rise to prevent the construction of infrastructure that will be highly vulnerable or even damaged. The significance of sea level rise and climate change became more explicit in the New York Metropolitan Transportation Council's 2013 adoption of Plan 2040 Regional Transportation Plan: A Shared Vision for a Sustainable Region. The Plan's first and last shared goals of the 10-counties within the metropolitan planning organization's membership is to "enhance the regional environment" and "improve the resiliency of the reginal transportation system". (NYMTC, 2013, p. 1-6) To enhance the environment, the Council lists the following as desired environmental outcomes through improved infrastructure planning: "reduced traffic congestion and improved air quality; reduced greenhouse gas emissions; improved water quality; and preservation of open space, especially wetlands." (NYMTC, 2013, p. 1-7) To build resiliency into their transportation system, the Council list the following desired outcomes: "member-defined adaptation measures for critical components of the transportation system to accommodate variable and unexpected conditions without catastrophic failure; greater resiliency of the regional supply chain by identifying options for goods movement during and after events; cooperative partnerships with federal, state, local agencies, and other stakeholders to adapt the transportation system and improve recovery from disruptions." (NYMTC, 2013, p. 1-11) Demonstrated by the havoc struck by Hurricane Sandy across the Northeastern United States, and especially New York, the State and its regional planning agencies have been preparing for weather's future impact on infrastructure.

These smart growth initiatives laid the foundation for the State Legislature's passing of the New York Community Risk and Resiliency Act in 2014, which requires all "state monies and permits include consideration of the effects of climate risk and extreme weather events." (2014) The Act defines the risks and events to be evaluated in use with any state funds as sea level rise, flooding, and storm surge, in effect codifying future resiliency. The Act was a direct result of the

recommendations on infrastructure resiliency from the State's NYS 2100 Commission in 2012. The Commission's lengthy report provides a wealth of information and recommendations both broad and sector-specific. Other significant legislation from the State includes the Water Infrastructure Improvement Act of 2015, which allocated $200 million to fund grants to municipalities for infrastructural improvements to enhance water quality and mitigate against sea level rise, flooding, and extreme weather events.

Charleston

Recognizing the lack of action in South Carolina over the looming threat of sea level rise, the City of Charleston has taken serious steps by forming a regional Charleston Resilience Network and adopted a Sea Level Rise Strategy in April 2016. The Resilience Network is a volunteer collective of subject matter experts from local and national government agencies that provide support in sea level rise and climate change knowledge and planning. Participants in the Network include, "the City of Charleston, S.C. Department of Health and Environmental Control, Ocean and Coastal Resource Management Office, S.C. Sea Grant Consortium, Charleston County, SCANA Corporation, Charleston Water System, Berkeley-Charleston-Dorchester Council of Governments and the U.S. Department of Homeland Security's Office of Infrastructure Protection." (Riley, 2015) The City's Sea Level Rise Strategy begins by illustrating the threat Charleston faces with the projected growth of days of tidal flooding, rising from 11 in 2014 to 189 in 2040, along with a projected rise of sea level 2 to 7 feet over the next 100 years (City of Charleston, 2015). The documents sets three pillars for the city's strategy: Reinvest, Respond, and Ready. The Strategy highlights the ongoing and future stormwater improvements being made by the City that total over $230 million dollars, with significant focus on the historical downtown's new drainage system including a tunnel expansion from 10 to 12 feet wide and a new pump station. The Strategy further notes that Charleston loses $12.4 million for each major flooding event, and that over a 50 year period, the losses reach $1.53 billion, underscoring the economic impetus to plan for sea level rise and elevated storm surge. The goals for the City are listed as, "Put in place systems that prevent or reduce the impacts of SLR and significant rainfall; Ensure public safety given flooding potential; [and] Ensure community and economic viability and recovery given flooding potential" (City of Charleston, 2015, p. 11).

Hampton Roads

The area of Hampton Roads, comprising of much of coastal southern Virginia including Virginia Beach and Norfolk, is unique to the sea level rise threat due to its density of military facilities and colonial history. This area was deemed at such risk, that the Commonwealth of Virginia passed legislation in 2015 that requires all municipalities in Hampton Roads to incorporate sea level rise and heightened flooding projections into all future comprehensive plans. To offset any incurred costs or lack of expertise, the Commonwealth will provide "technical assistance to any such locality upon request" from "The Department of Conservation and Recreation, the Department of Emergency Management, the Marine Resources Commission, Old Dominion University, and the Virginia Institute of Marine Science" (Virginia SN-1443). This legislation is likely the result of the Hampton Roads Planning District Commission's 2013 recommendation as such in their report Coastal Resiliency: Adapting to Climate Change in the Hamptons. Moreover, these recent developments are compounded by the 2016 report by the ACU on the threat to military facilities, mentioned above, and the Commonwealth's successful Hampton Roads application in the National Disaster Resilience Competition, discussed below.

Armoring Greater New Orleans

Following the devastating 2005 hurricane season that included the devastating Hurricane Katrina, the need to build hard structures and barriers to protect the greater New Orleans area was not just apparent, but the City's very future was dependent upon it. The USACE was charged with designing and constructing the colossal Hurricane & Storm Damage Risk Reduction System (HSDRRS), which provides a 133 mile controlled barrier around the greater New Orleans area and

Image 4. Map relating HSDRRS perimeter with major features highlighted. Source: USACE (2016)

includes some of the largest and technologically advanced systems in the world. Planning by the USACE was completed in 2007 and construction and contracts began being awarded by 2008. The $14.6 billion mega-project, billed to be able to withstand a 100-year storm surge, has 350 miles of levees and floodwalls, and 78 pump stations. Two of the most impressive features include the system's 1.8 mile Lake Borgne Surge Barrier and the West Closure Complex drainage pump station, both the largest of their kind in the world. While the design-stage of the project accounted for sea level rise and subsidence through vigorous hydrological and storm modeling, that the hard features' projected 100-year storm surge efficacy is only valid until 2057 raises serious questions on the long-term viability of hard structure mitigation for the protection of New Orleans (Zolkos, 2012).

VI. INNOVATION BY COMPETITION

Rebuild by Design

In June 2013, less than a year after the monumental physical and financial damage wreaked by Hurricane Sandy, US Department of Housing and Urban Development (HUD) Secretary Shaun Donovan unveiled an innovative approach to disaster resiliency, the Rebuild by Design competition. The contest, formed between HUD and numerous regional organizations in the New Jersey-New York region, was developed with the aim of creating a competitive environment to generate innovative solutions to address failures illuminated by Sandy. Six winners were selected in June 2014, from ten finalists, and split a total of $930 million. All successful applicants were teams made up of numerous local organizations, architectural firms, environmentalists, and various other regional stakeholders. At the core of all six winning proposals was the creation of spaces that operated as green and community space, ecological flood mitigation, and barriers to storm surge. A green or communal space provides an incentive for a multidimensional area where communities will have access and connectivity rather simply a large, mono-functional structure that provides resiliency. The ecological spaces double as visually appealing to the community and businesses while also serving as an environmental solution to flooding and sea level rise. Finally, to directly address storm surge, all projects had various hard structures worked into their designs that created elevated barriers in the form of berms, hills, walls, levees, and breakwaters. The hard structures were all designed for connectivity and to compliment either ecological space, community space, or both.

Table 12. Rebuild by Design Winners

Project Name	*Area*	*Awarded Amount*
Big U	Manhattan, NY	$335 Million
Resist, Delay, Store, Discharge	Hoboken, NJ	$230 Million
New Meadowlands	Meadowlands, NJ	$150 Million
Living with the Bay	Long Island, NY	$125 Million
Living Breakwaters	Staten Island, NY	$60 Million
Hunts Point Lifelines	Bronx, NY	$20 Million
Total		**$930 Million**

Source: Rebuild by Design (2016)

Big U

The biggest winner of the contest, a concept that has continued to develop over time and is mentioned again in the subsequent section, is Manhattan's Big U project. This project, only partially funded from the Rebuild by Design grant, sets the lofty goal of building a protective community space that spans the waterfront of Lower Manhattan. This portion funds the

construction of a berm, a raised section of grassy land along a waterfront, along the East River Park that will enhance recreation space and provide salt tolerant foliage to provide a green buffer.

Resist, Delay, Store, Discharge

The second largest grant provided, of $230 million for the Resist, Delay, Store, Discharge: A Comprehensive Strategy for Hoboken, creates a complete urban water system to manage the city's waterfront. The plan relies on a combination of hard and soft structures that compliment each other to form hard barriers and soft-ecological methods of water storage and movement. The team breaks down the resulting strategy into four categories: Resist, with coastal shoreline hard structures like terraced edged seawalls, bulkheads, and deployable floodwalls. Delay, by absorbing as much water as possible with green space and parkland, green roofs, and strategically placed bioswales. Store, by installing a modern cistern, creating a bioretention basin, and constructing wetlands. Finally, Discharge, through the upgrading of the storm drain system and building new stormwater pump stations.

New Meadowlands

Moving outside of the urban cores of the region, the New Meadowlands: Productive City + Regional Park project identified one of the most at risk areas from sea level rise and flooding to create a massive environmental space to minimize future flooding from storms and develop a new area for green urbanization. The plan ultimately envisions a restored wetlands and marsh preserve that is surrounded by berms and recreational areas that will stimulate mixed-used investment. The area as a whole is defined by the Meadowpark, the restored ecological area, then surrounded by a berm and the Meadowband, a connective community space that includes transit lines, parks, and access points to Meadowpark.

Living with the Bay

The Living with the Bay: A Comprehensive, Regional Resiliency Plan for Nassau County's South Shore creates a comprehensive green development plan for Long Island that weds the natural environment with the suburban. The core of this plan is the integration of the environment into the suburban landscape to mitigate against future storm surge or heavy flooding. The team proposed three pillars to this integrated approach: an elevated and improved coastal barrier, expanded

saltwater marshes, and a carved out network of new streams and tributaries to trickle through the city.

Living Breakwaters

The Living Breakwaters plan, simpler and cheaper than the multidimensional plans above, creates straightforward mitigation by constructing breakwater ecological structures off the southern shore of Staten Island to prevent storm surge or any significant wave growth. The plan outlines the construction of a number of large structures positioned a quarter mile from shore, are made of hardened natural sediments, have a 16 foot width above the sea level, and ultimately create vast new space for marine life. The breakwaters cut down dramatically on wave action, limits long-term coastal erosion, mitigates storm damage, and creates new habitat for a variety of sea life.

Hunts Points Lifelines

Finally, the smallest grant project, the Hunts Point Lifelines located in the Bronx, funds the planning of a resilient Hunts Point neighborhood of the South Bronx. The area is a major industrial point for New York City, providing a significant hub for the City's food supply, warehousing, and sewage treatment. The planning teams will use the funding to develop and design an ecologically integrated levee system with improved wetlands and river flow that will also improve the community's quality of life with greenspace, improved coastal infrastructure, and sustainable business.

National Disaster Resilience Competition

Financially sourced from the 2013 Disaster Relief Appropriations Act, HUD created one of the largest and most ambitious post-disaster planning projects from the Federal government, the National Disaster Resilience Competition (NDRC). The NDRC was developed under the Obama Administration as a competitive catalyst to formulate real-world innovations to post-disaster resiliency. The parameters of the competition allowed for all States, Counties, Cities, Territories, and Tribal governments issued a Presidentially Declared Major

Table 13. NDRC Winners

Winners	*Awarded Amount*
New York City, NY	$176,000,000
New Orleans, LA	$141,260,569
Virginia	$120,549,000
Iowa	$96,887,177
Louisiana	$92,629,249
Minot, ND	$74,340,770
California	$70,359,459
Shelby County, TN	$60,445,163
Connecticut	$54,277,359
Tennessee	$44,502,374
New York	$35,800,000
Springfield, MA	$17,056,880
New Jersey	$15,000,000
Total	**$1 Billion**

Source: HUD (2016)

Disaster between 2011 and 2013. Implicit in this project was the modeling of HUD's prior venture of New York's Rebuild by Design competition that laid a groundwork for HUD's allocation and selection framework, and its strategic relationship with the Rockefeller Foundation who provided technical knowledge and support for applicants.

The competition was conducted over the course of two selection phases, with 40 states and communities selected following the first phase of applicants, and 13 final winners after the second phase. In announcing the competition's winners, HUD Secretary Julián Castro said, "Climate change is real and we must think more seriously about how to plan for it. The grants we award today, and the other sources of capital these grants will leverage, will make communities stronger, more resilient and better prepared for future natural disasters such as floods and wildfires. The National Disaster Resilience Competition exemplifies how government can work hand-in-hand with the philanthropic and private sectors to create lasting partnerships that will allow us to together face the challenges of tomorrow."(HUD, 2016) The winners and their awarded amounts can be seen above in **Table 9**. Awardees and the proposed projects most relevant to this study include New Orleans and Louisiana, New York City and New York, and Virginia, and are highlighted below.

New Orleans and Louisiana

The state of Louisiana and the City of New Orleans have become possibly the most significant areas, along with South Florida, for facing the twin threats of sea level rise and hurricanes. Both applicants were successful in the NDRC, combined winning almost a quarter of the total awarded funding. The state of Louisiana was awarded over $92 million to capitalize a gap-financing program called the LA SAFE Fund and to relocate the population of the now famous Isle de Jean Charles; and New Orleans was awarded $141 million to carry out a series of programs and efforts to create a Resilience District in the city's Gentilly neighborhood. The first of Louisiana's two projects, the LA SAFE fund, is a state-run fund meant to provide gap financing for public and non-profit entities to design, plan, build, or rebuild resilient housing, transportation, energy, mitigation or economic development projects. The second state project, the relocation of the Isle de Jean Charles population, is viewed as the resettling of America's first 'Climate Refugees', with the goal of moving 60 people north to a new community in Houma, Louisiana (Davenport & Robertson, 2016). The Isle de Jean Charles community is a historically Native

American population that has lost 98 percent of its dryland mass since 1955 and has failed in multiple efforts to relocate due to political and logistical complications (HUD, 2016). New Orleans' project, the Gentilly Resilience District, sets the goal of being "a national model for retrofitting post-war suburban neighborhoods into resilient, safe, and equitable communities of opportunity." (HUD, 2016) The various projects and programs will include flood mitigation construction, small-scale investments in adaptation for low to middle-income households, resilient energy and water infrastructure, eco-restoration, and a citywide resiliency-tracking database. The viability and success for any of these three Louisiana-based projects hold great replicable potential for South Florida.

New York City and New York

Similar to Louisiana's significant portion of the total awards, New York City and the state of New York took almost a combined quarter billion dollars. Each applicant proposed a single project, with New York City focusing on structural barriers that double as public space along the coastal extent of Lower Manhattan, and New York State proposed a pilot program to apply resiliency reconstruction to public housing impacted by Hurricanes Sandy and Irene, and Tropical Storm Lee. Of the entire competition, New York City's Lower Manhattan Protect and Connect Project may be the most innovative and ambitious. The Protect and Connect Project capitalizes on a number of previously planned and funded projects that has the ultimate goal of hardening Manhattan's lower waterline through various community structures including green space, parks and buildings to break storm surge, and deployable walls under highways and bridges. Artistic renderings illustrate new and innovative public spaces where communities can meet and connect, while at the same time creating ecological solutions to flood mitigation and soft and hard structures that will break future storm surges that were so destructive during Superstorm Sandy. HUD describes the massive project as "a coastal protection system that will enhance the connection between neighborhoods, add green spaces and seating areas, and retail areas, and protect public housing projects that are vulnerable to storm surge and flooding." (HUD, 2016) New York State's project, in contrast, is directly funding resilience reconstruction for the State's Public Housing Authorities, where they have otherwise been constrained from helping the most vulnerable populations to storm and flood damage due to limited financing and assets. The projects funded will incorporate the resiliency adaptations developed by the affordable housing organization

Enterprise Community Partner and their 'Ready to Respond Toolkit'. Examples of specific actions include raising structures above flood waters, relocating integral utilities to higher parts of the structure, installing backflow preventers on buildings' sewer lines, installing flood gates or flood doors on the first floor, or even providing 'Tiger Dam Systems' which are large water-filled barriers that can surround an entire structure prior to a flooding event. HUD explains the importance of this specific project because "This will enable the State to repair damage from recent disasters like Superstorm Sandy and Hurricane Irene and pilot new and innovative approaches to build resilience in low-income multifamily properties." (HUD, 2016) Relevantly to South Florida, New York City's Protect and Connect project can illustrate new ways in which urban areas can integrate public spaces for public defense, while New York State's investment in affordable housing resiliency can test the effectiveness of new adaptation construction for multi-residence structures.

Virginia

The Commonwealth of Virginia was awarded the third largest grant after New York City and New Orleans for a multidimensional project to address sea level rise and resiliency in the historically termed Hampton Roads area of Southeastern coastal Virginia. The $120.5 million project will be spent on two overarching plans, one to adapt and mitigate flooding in the Ohio Creek Watershed and the other to construct a Coastal Resilience Laboratory and Accelerator Center (CRLAC) in Norfolk. Speaking after the announcement of the State's selection, Governor Terry McAuliffe said, "These funds will significantly aid our work to protect the economic vitality and quality of life in areas like Hampton Roads by preparing now for the real impacts of climate change and sea level rise." (Pearson, 2016) The Ohio Creek Watershed project will build a variety of green infrastructure that mitigate flooding, including rain barrels, bioswales, rain gardens, water retention areas, and even a water street park where water will flow along small structural features. These green interventions will be combined with restrictive zoning in flood zones, adaptive planning incorporating more natural water features and a 'living shoreline', and a number of pumping stations to reintroduce floodwaters to natural waterways. Adding to the long-term impact for the greater Hampton Roads community's resiliency to sea level rise and flooding, the second project of a CRLAC will "create an economic development center that supports technical and organizational innovation to help businesses respond to climate change while ensuring access to

and better management of water resources." (HUD, 2016) While the specifics on how the CRLAC will enhance resiliency techniques and improve economic development, the center will be an independent 501(c)(3) entity that will support a small research team and administration focusing on combining technology, water management, construction, and water-sector business resiliency.

NOAA's Resiliency Grants

Like the above mentioned HUD grant contests, the National Oceanic and Atmospheric Administration (NOAA) has recently created two grant competitions to foster seaside resiliency against climate change and extreme weather's impact on the country's coastal communities and ecosystems. NOAA's Regional Coastal Resilience Grants (RCRG's) are an attempt to foster innovation for adaptation and resilience through federally funded competition. Administered by the Office of Coastal Management, an Office within NOAA's National Ocean Service, the RCRG's were awarded to 12 applicants out of over 130 proposals with federal monies totaling almost $9 million and matching funding totaling almost $5 million (RCRGA, 2016). While awarded within a month of each other, the $9 million was split evenly between fiscal years 2015 and 2016, making the annual amount of this grant program $4.5 million (RCRGA, 2016). Recognizing the importance and value of such programs, however, the proposed budget by President Obama's administration seeks to raise the amount to $20 million in 2017 (Holland, 2016). Most successful applicants will be developing, improving and implementing a variety of vulnerability assessments, resiliency strategies, adaptation plans, regional agency coordination, and social, economic, and environmental research. The second new NOAA grant program, yet to have any awards issued, is the Coastal Ecosystem Resiliency Grants Program (CERG's). The CERG will focus on environmental conservation rather than in support for governmental planning and policy. With total funding for 2016 of $8.5 million, qualifying projects will concentrate on habitat restoration

Table 14. 2015 & 2016 RCRG Winners

Winners	*Awarded Amount*
University of San Diego	$689,850
Washington Sea Grant	$879,255
Assn. of State Floodplain Managers & APA	$703,028
Cap Code Commission	$522,348
NERACOOS & NROC	$891,243
New Jersey Dept. of EP	$898,656
Virginia Beach	$844,487
MARCO	$514,507
Coastal States Stewardship Foundation	$803,713
SC Sea Grant Consortium	$510,319
Gulf of Mexico Alliance	$867,700
University of Hawaii Sea Grant	$845,160
Total	$8,970,266

Source: RCRGA (2016)

that will provide ecological sustainability, provide social and environmental benefits, and mitigate against climate change and extreme weather events.

Table 15. Public Sector Response Typology

	Governance	Zoning &	Transportatio	Hardening	Environmenta
Short-term	Budgetary Prioritization Public Awareness Campaign (threats, zoning, mitigation) Open Data/Documents	Improve Construction Codes Elevate Structures & Utilities	Raise Roads Pervious Concrete Damage Repair Planning & Asset Management	Flood-proofing buildings (flood doors/gates, relocate utilities, temporary barriers)	Beach Renourishment Dunes & Berms Green Public Space in Flood Zones
Mid-term	Master Plans & Vulnerability Studies Retrofitting & Resiliency Grants Insurance (de)Regulation	Development Regulations in Coastal Areas or Flooding Zones Flood & Storm Mapping	Account for SLR & Hurricane Projections in Future Infrastructure Optimize Public Transportation	Bioswales & Water Retention Sea Walls & Revetments Dredging & Leveeing	Barrier Islands, Breakwaters, & Coral Reefs Wetlands & Mangroves
Long-term	Comprehensive & Actionable Long-term Strategy Regional Commitments & Organizing (public & private)	Adaptation Action Areas Commercial or Residential Relocation	Construct Resilient Public Space Connectivity Reduce Infrastructure Usage & Reliance	Surge Barriers Large Hydrological Systems (networks of pumps, cisterns, & rerouting water flows)	Low-Impact Development Ecological Restoration Ecological Reclamation

Table 15 above, and their elaboration below, is meant to be a starting point for organizing public sector responses to the challenges posed by tropical cyclones and the growing impact of sea level rise. While this list is not comprehensive, nor are individual policies mutually exclusive from others on the list, the policies and concepts introduced provide a broad introduction into the public policy realm and spans from traditional to innovative. Each policy below will have an example hyperlinked to the bolded-text of the term itself for further conceptual development and real-world implementation. The timeframes provided, short-term, mid-term and long-term, are not static or absolute, instead they are guideposts for potential impact-time of the policy once implemented. The greater implication provided by this list should be of an interdependent and multifaceted government approach crafted by well-informed public sector officials vertically integrated from the municipal to the state level.

Governance

Short-Term

I. **Budgetary Prioritization:** This policy is by no coincidence the first on this list. Most public policies will require funding, and this begins with budgetary prioritization for both areas that are most immediately impacted, as well as for programs and policies that will have the greatest effect.

II. **Public Awareness Campaigns:** Awareness campaigns can take a variety of forms, from messaging and informative releases, to publicly funded mapping systems to let residents visualize impacts.

III. **Open Data & Documents:** To foster greater informed public with the capacity to facilitate their own planning, analysis, and innovation, governments at all level should provide easily accessible data and documents related to storms and sea level rise. Examples can include mapping, vulnerability studies, budgets, program and policy analyses, etc.

Mid-Term

IV. **Master Plans & Vulnerability Studies:** While these policies are different, at their core is impactful planning. Updating Master Plans to account for sea level rise will improve the turnaround time on addressing issues that are handled on a daily basis with departments like public works; vulnerability studies, moreover, prepare public officials to know what infrastructure and areas to prioritize.

V. **Retrofitting & Resiliency Grants:** Providing grants, loans, and tax credits are an effective way to entice residential and commercial property owners to prepare for potential storms through mitigations efforts like roof retrofitting, hurricane shutters, flood proofing, etc.

VI. **Insurance (de)Regulation:** The regulation or deregulation of insurance can be a powerful policy to guide public behavior. The state of Florida has seen turbulent implications through its

various actions in the insurance market, and its most recent efforts have centered upon depopulating the portfolio of the state insurer, Citizens, and opening flood insurance to the private market.

Long-Term

VII. **Comprehensive & Actionable Long-Term Strategy:** The role of government ultimately must be to take the long view and provide a comprehensive strategy that incorporates a multitude of policies. A long-term strategy will only be effective if it has concrete and actionable steps to implement over the coming years, as well as lays a foundation for future improvement and development.

VIII. **Regional Commitments & Organizing (public & private):** At the local and regional level, the involvement of the private sector has largely been reserved to political imperatives and occasional public, private partnerships (PPP). In reality, there must be greater partnership with, and commitment from, the private sector. Recent notable initiatives have originated at the federal level.

Zoning & Code

Short-Term

I. **Improve Construction Codes:** Florida, as noted early in this report, has a nationally recognized construction code with robust standards in mitigating against the impact of cyclones. It will be important to continue incorporating the growing knowledge of sea level rise and storm impacts, as well as staying abreast with available construction research.

II. **Elevate Structures & Utilities:** This is a step that can be taken at both the individual or governmental level. Raising structures where possible limits impacts from raising waters and surges, while elevating utilities makes those buildings in the path of flood waters more resilient and less impacted.

Mid-Term

III. **Development Regulation:** Effective coastal development regulation will need to be implemented given risk and vulnerability studies; an extensive literature already abounds. The policy of limiting development in coastal and high hazard areas will always be controversial due to its inherent prevention of private and commercial access, yet preventing the loss and damage of property and life must balance this notion.

IV. **Flood & Storm Mapping:** Publicly accessible, and more importantly easily understood, mapping will be more significant for residential and commercial decision-making as technology becomes more effective in sharing information.

Long-Term

V. **Adaptation Action Areas:** A policy that has taken hold in Florida, Adaptation Action Areas allow for governments to target specific places in their jurisdiction that are most likely to be impacted by sea level rise and flooding. By prioritizing certain areas and not others, governments optimize their response effectiveness and allow for broad initiatives.

VI. **Commercial or Residential Relocation**: In some cases, the complete relocation of residential and commercial structures may be necessary. Low-lying areas coastal areas will be the greatest affected by sea level rise and many are already beginning to prepare for the inevitable move.

Transportation

Short-Term

I. **Raise Roads:** Many roads on Florida's barrier islands and coasts will need to be raised as tides and storm surge become more impactful from sea level rise.

II. **Pervious Concrete:** One innovation that is beginning to be common for parking lots in residential and small commercial developments is pervious, or porous, concrete. Pervious concrete allows for rapid draining of water into bioswales, retention areas, cisterns, or redirection to storm water drains. Recently, pervious concrete has begun to be used for low-traffic roads as well.

III. **Damage Repair:** As water damage becomes more regular from flooding in low-lying areas, it will be important to maintain the integrity of former construction. Damage can range from major losses from storm surge, to an increase in the mundane potholes. An effective way for dealing with flooding and damage related to sea level rise is to implement a mobile app for residents to report localized flooding and potholes from their cellphones.

IV. **Planning & Asset Management:** An important ongoing step is to have a comprehensive knowledge of existing assets, their individual vulnerabilities, how that affects the greater transportation network, what future assets will be needed, and how can existing infrastructure be optimized and enhanced given all the above.

Mid-Term

V. **Account for SLR & Hurricane Projections in Future Infrastructure**: The Southeast Florida Regional Climate Change Compact broke new ground in this policy, tying a regional agreement between county governments to a unified sea level rise projection to be incorporated into future infrastructural projects. Other factors to consider are the logistical nature in emergency preparedness for shelter locations, evacuation routes, and the assistance of vulnerable populations.

VI. **Optimize Public Transportation**: The importance of public transit to reduce traffic may not be felt more critically than during an evacuation. Public transportation allows for improved

evacuation times, a reduction in infrastructure congestion, and improved emergency preparedness coordination.

Long-Term

VII. **Construct Resilient Public Space Connectivity:** This concept is less about a single policy, and instead about the convergence of many policies. Stemming from the language used in New York City's massive Lower Manhattan resiliency project, the larger concept is to build a grid of public space, hard and soft barriers, and public transit that fosters a protected and connected city that creates resiliency and enhances the quality of life of the community.

VIII. **Reduce Infrastructure Usage & Reliance:** To reduce vulnerability for city's major corridors impacted by sea level rise and hurricanes, strategies can create a diverse, multimodal landscape that will increase capacity and reduce reliance and infrastructural deterioration. Long-term planning accounts for land use and development, locational vulnerability of demographics and the environment, multimodal transit sources and their connectivity, and capacity that extends beyond the average and accounts for emergency preparedness.

Hardening

Short-Term

I. **Flood-proofing Buildings:** One of the most cost effective policies with the greatest impact is the individual retrofitting of flood-proofing measures. Individual measures may include floodgates on low position doorways, pumps, flood shields, backflow valves, impervious walls, and emergency outer barriers.

Mid-Term

II. **Bioswales & Water Retention:** These policies, utilized individually or together in more complex designs, provide excellent and cost effective measures to reduce localized flooding and ponding following heavy rains and flooding.

III. **Sea Walls & Revetments:** A cornerstone in coastal armoring, hard-structures like sea walls and revetments create man-made structures that can be engineered to the specification needed per coastal scenario.

IV. **Dredging & Leveeing:** These large structures, most famously in the Netherlands and New Orleans, are barriers that control and keep water out of areas are at, or below, sea level. Most levees in the US were historically constructed to make land accessible for agricultural purposes and are not maintained by the USACE. As metropolitan areas move closer to, or even below, sea level, it will be important to incorporate new levee systems into water management portfolios.

Long-Term

V. **Surge Barriers:** Surge barriers, or sometimes called flood barriers, are large and diversely designed walls that are capable of opening and closing across great lengths of waters around cities. Surge barriers are generally just one segment in a larger network of the following policy.

VI. **Large Hydrological Systems:** In some instances, such as the dire cases of New Orleans or South Florida, require major and elaborate systems that incorporate many of the above policies must be designed. The important part will be to not only incorporate the large hard structures, but to incorporate a variety of environmental and sustainable measures, as well as account for rising seas to ensure greater lifespans of effectiveness.

Environmental

Short-Term

I. **Beach Renourishment:** A policy actively used in Florida at all levels of government, beach renourishment is the rebuilding of eroded beaches by pumping sand. Sand is sourced by dredging from a distant location, pumping directly offshore, or trucking in from a distant location or plant.

II. **Dunes & Berms:** These soft structures are barriers that would occur naturally just beyond beaches. The creation of dunes and berms are integral for both mitigation of erosion and surge events, as well as are a significant part of the ecosystem for native flora and fauna.

III. **Green Public Space in Flood Zones:** Dense development and its expanse of concrete roads and buildings obstruct rainfall from absorption into the ground or direction to natural drainage. Cities' traditional response have been storm water systems that can in turn be overwhelmed during heavy storms, or cause flash flooding and erosion in runoff streams. Innovative solutions to these problems have been to create public parks in flood zones or create floodable public space.

Mid-Term

IV. **Barrier Islands, Breakwaters, & Coral Reefs:** These natural and manmade structures provide some of the most effective protection from wave surge. These, as well as the rest of the policies in this section, can be used together to create greater coastal resiliency. For a wide variety of resources for both these and the policies below, visit this collection of the Nature Conservancy.

V. **Wetlands & Mangroves:** Both wetlands and mangroves provide a variety of natural coastal barriers to attenuate wave surge, while also providing much needed ecosystem support and erosion mitigation. For a wide variety of resources for both these and the policies above, visit this collection of the Nature Conservancy.

Long-Term

VI. **Low-Impact Development (LID):** A fast growing school in planning and development, LID is the design of urban and suburban projects that incorporate a variety of environmentally sustainable components. Examples include many previously mentioned, bioswiles, water retention, and porous concrete, but also include features like vegetated/green roofs, rain barrels, bioretention, and infiltration trenches. The aim of such planning focuses on creating greener city space, water harvesting, and flood control. These concepts have recently been taken to the much larger level in China, where they plan to create 'Sponge cities'.

VII. **Ecological Restoration:** Restoration provides one of the greatest long-term programs for coastal communities and must be planned at a larger scale to have greater impact. Restoration incorporates all of the above policies for creating, protecting, and expanding native coastal ecosystems to improve resiliency and mitigation against sea level rise and storm surge.

VIII. **Ecological Reclamation:** A more dramatic policy is outright reclamation by the greater ecosystem; this is more commonly called 'managed' or 'planned retreat'. This policy entails a concerted effort to eliminate and remove most development in an area that will become so vulnerable to sea level rise or storms as to make it economically, or even physically, untenable. While this is similar to the policy previously mentioned of commercial and residential relocation, the difference here would be to recognize areas that would still be at or above sea level and could be used as space for any of the aforementioned environmental barriers to mitigate from storms.

VIII. PUBLIC SECTOR SURVEY RESULTS

To better understand the various public sector methods to mitigate against hurricanes and sea level rise across the state of Florida, Metropolitan Center staff conducted 30 interviews with public officials over the phone and online during June and July 2016. These 30 participants represented primarily county (7) and municipal (9) governments, but also included regional planning councils (3), and state and federal agencies (2). Some participants worked for different departments within the same government, and in all, there were 21 different Florida governments and agencies that participated in the interview process. While the majority of respondents where from South Florida, there was significant participation from entities in the Tampa Bay area, as well as general representation of most major population centers in the state. Of all significant coastal population centers in the state, Jacksonville was the only notable absence in respondent participation, despite Metropolitan Staff reaching out to multiple individuals and departments in the City government.

Most participants filled out a survey online and were asked to cater their responses to their professional expertise and the government they represent, those that participated over the phone had the questions tailored more specifically to their experiences. The online survey had a total of 11 questions, 8 specifically addressing their government's policies and plans in regards to hurricane and sea level rise mitigation. The main purpose of the survey was to discern the level of regard local government showed towards sea level rise, its relation to storm risk, and means of government intervention. Specifics requested included whether governments have an officially recognized sea level rise projection, if and how they are being incorporated in policy, if there were any vulnerability studies conducted, what adaptation and mitigation actions were being taken, and how government funded such policies or plans. The online survey can be found in its entirety in the **Appendix**.

The results of the interviews fell in line with much of the previously discussed local information on Florida community adaptation and mitigation. Much of the progress and action taken on sea level rise and hurricane mitigation and planning is occurring at the county-level of local government, with moderate state and regional efforts facilitating further county-level efforts. Only cities that fell within the South Florida Climate Change Compact and Tampa Bay Science Advisory Panel geographies, each of which have produced recommended sea level rise

projections, had official sea level rise projections for their areas. This reliance on regional bodies, which are normally staffed by county employees or academics, for local projections is due to the lack of resources at much of Florida's municipal level. Regional bodies utilize local experts and provide a technical knowledge base not always readily available in smaller municipalities.

Notably, most governments that did not have official sea level rise projections were still able to provide national sources of sea level rise projections, citing either ACE or NOAA reports. While it is a considerable risk for these municipalities to not have official recognition of sea level rise to prepare their community for any impacts, it is meaningful that at least many recognize the threat and reported having unofficial internal or departmental committees related to infrastructure. An example of this came from two separate respondents, one in the Northeast and the other in the Southwest of the state. Both reported having informal groups within their respective governments on sea level rise, yet not official committee or policy. However, both later in the survey stated they had upcoming sea level rise initiatives, one opening the bidding process to create a sea level rise vulnerability assessments and adaptation planning to be integrated into the city's comprehensive plan, and the other entering into a multi-County study to examine sea level rise's local impact on storm surge.

Another finding was the clear divergence between government responses, without geographic regard, that divided on the fault line of strategies versus planning. Those governments that were still in the early phases of a strategy process had made little progress in any meaningful way of mitigating, adapting, or preparing for sea level rise's existing impacts on community infrastructure or coastal development. In contrast, Governments that instead focused on planning were already far along on integrating vulnerability studies into existing capital improvements, locating areas in need of adaptation plans, and integrating sea level rise and storm surge projections into not just a comprehensive plan, but into departmental planning and all future projects. While in some cases this can be seen a natural governmental progression of moving from strategies to planning, in other cases any development in addressing these issues seemed to be mired in 'discussions' rather than action.

Finally, across many responses, governments perceived sea level rise in relation to climate change and environmental conservation rather than in physical threat from flooding, storm surge, or storms. Overall, half of respondents affirmed having county or municipal committees that

address sea level rise, yet few were solely dedicated to the specific phenomenon. Instead, most committees in name and concern were of ‘sustainability’, ‘green’, ‘climate change’, and ‘resiliency’. Although these issues are important, the results from such multi-issue committees are plans and programs that reduce greenhouse gas emissions from government cars and buildings, reduce water usage, plant more trees and increase city canopies, and promote land conservation without consideration for its location vulnerability or potential for mitigation. These policy proposals stand in deep contrast to those from sea level rise committees concerned with physical and economic impact, which result in policies and programs that identify vulnerable areas or infrastructure and formulate responses in line with the typology in the previous section.

IX. FLORIDA RESIDENT SURVEY RESULTS

The Metropolitan Center has been collecting Floridians' opinions for eleven years, with the Center's residential survey providing the greatest detail and chronological trends between 2006 and 2016. At the core of this survey is understanding residents' perceptions of risks, preparations for potential impacts, and preferences for government policy. **Table 16** illustrates some of the basic questions asked through all years: how vulnerable do residents feel to hurricane damage, how certain are they in their access to hurricane-related information, do they have a plan prepared in advance of a forecasted storm, and if they would evacuate when ordered to. While 2008 still remains the highest affirmative response rate across all four questions, 2016 marked the smallest percentage of respondents with a hurricane plan, at 61%.

Table 16. Florida Residential Survey Trends

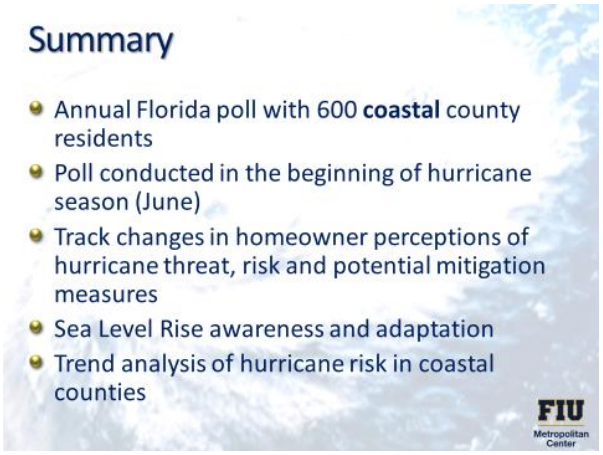
	2006	2007	2008	2009	2010	2011	2013	2015	2016
Perception of vulnerability	46%	54%	58%	48%	43%	50%	57%	46%	46%
Information access	87%	90%	95%	93%	92%	90%	93%	92%	92%
Plan of action	85%	85%	89%	87%	78%	70%	75%	77%	61%
Evacuate if ordered	28%	37%	43%	40%	37%	40%	38%	36%	38%

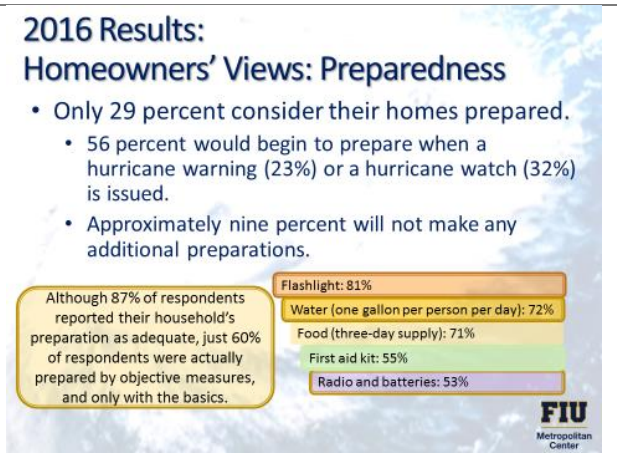
Other notable results include:

- Only a third (31%) of respondents reported having personally experienced hurricane damage to their home, likely influential in the low perception of vulnerability (46%);
- While access to information has remained high (92%), the sources have changed with internet rising from 5% in 2006 to 10% in 2016, and TV falling from 87% in 2006 to 74% in 2016;
- Residents have also significantly changed where they would go in the event of evacuation, with those reporting a local shelter rising from 11% in 2006 to 26% in 2016, going to a nearby friend or family member's house rising from 13% to 27%, and leaving the state falling from 29% to 17% over the same time period;

- The household uninsured rate has risen dramatically since 2006, rising from 3% to 25% in 2016; Notably, this phenomenon is not limited to uninsured renters (48% of renters, or 74 total), but extends to uninsured owners as well (16% or homeowners, or 73 total);
- There was only a slight increase in those that believe in sea level rise, from 47% in 2015 to 48% in 2016, and a general rise of those that believe they will be affected by it, from 20% to 22%;
- Respondents favored greater government action over 2015, with the establishment of a legislative authority to regulate development reaching 44% support, with stricter elevation plans in vulnerable areas (40%) and the creation of a national fund to assist homeowners and local governments to act on sea level rise (37%) just behind.

Survey Results Presentation





2016 Results: Awareness

- One in eight (12%) do not know if their home is in a flood or evacuation zone. Additionally, of those who said they are not (59%), one third actually are.
  - Population in floodplain: Miami-Dade 48%, Broward 79%, Palm Beach 18%
- One in seven homeowners (16.4%) are without home insurance and of those who have it, 16% would cancel their insurance once their mortgage is paid off.
- 50% do not receive any discounts from their insurance company for mitigation, and 13% are not aware of any discounts being offered.

up from 9% in 2015

up from 13% in 2015

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2016 Results: Sea Level Rise

- Half either do not believe sea level rise is happening or they do not know.
- Only 22 percent think they will be affected.

Up from 52% in 2015

Up from 41%

Up from 35%

How much do you think each of these actors should do to reduce the effects of rising sea level in the future?	A great deal (leading role)	Some (supporting role)	A little (minor role)	Nothing
Federal Government	52%	27%	6%	16%
State government and agencies	53%	26%	7%	14%
Local governments near the coast	61%	20%	5%	14%
Businesses near the coast	42%	30%	10%	17%
Homeowners near the coast	48%	26%	10%	16%
Real estate developers	48%	25%	7%	20%
General public	42%	30%	11%	17%
Scientists	66%	15%	6%	13%

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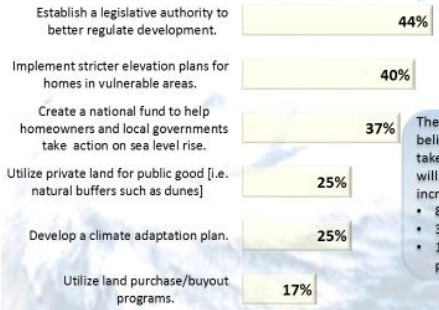
2016 Results: What should governments do reduce the effects of rising sea level in the future ?



The majority of those who believe government should take the leading role are willing to have taxes increased.

- 8% income
- 31% property
- 19% both income and property

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Conclusions

- Coastal development continues despite the risk.
- There has been a decline in risk awareness and preparedness.
- The majority of Florida homeowners are not aware of the effect of sea level rise or they do not believe they will be affected.

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Appendix A: Public Agency Interview Schedule

FIU Metropolitan Center Study - Hurricane Mitigation & SLR Policy

1) How long have you been working in this field and what is your educational background and training? (i.e. current position, prior work experience, specializations)

2) Does this county and/or agency have a climate change or sea-level rise committee? If so, how involved are you with this committee or proposal planning? Which issues have been discussed/focused on? (i.e. name of the committee, names of projects, plans or reports produced)

3) Does this local jurisdiction have its own definition of sea-level rise rates, or does it adopt the federal or regional projections? Which projection model is this county and/or agency using? (e.g. projected rise of sea level by SFRCCC is 6-12 inches by 2030, 14-34 inches by 2060 and 31-81 inches by 2100)

4) How are the sea-level rise projections being incorporated into your Master Plans or long-term designs? What departments and which programs are being altered, and how?

5) How are those sea-level rise projections influencing any hurricane mitigation measures due to potentially more damaging hurricanes? Are departmental or governmental budgets and finances accounting for greater potential losses or impacts from sea-level rise and hurricanes?

6) Have any county and/or agency officials conducted a formal evaluation to identify the infrastructure elements that are vulnerable to the impacts of sea-level rise and hurricanes? If so, when were the evaluations completed and who conducted them? Are these evaluations periodically updated and by whom?

7) Regarding sea-level rise, what specific adaptation and mitigation measures have been implemented in your area within the last 5 years and what is the priority level for each? What has been planned or proposed for the next 5 years? Please provide as much detail as possible. (i.e. programs, projects, policies, short-term, mid-term, long-term solutions)

8) What is the budget for these specific adaptation and mitigation measures?

9) Does this county and/or agency receive funding for hurricane or sea-level-rise-related projects? If so, what is the source and amount? And, is the agency actively seeking future or outside funding? (i.e. grants, investments, etc.)

10) Are there any experts in the public sector who are currently dealing with hurricane mitigation and/or the effects of sea-level rise who you can refer to better inform our study? (e.g. utilities, public works, transportation, land management, planning)

11) May we contact you for any follow-up questions if we need further details? If so, please provide contact information and hours of preference.

Appendix B: Florida Homeowner Survey

Hello, I am _____, calling from Florida International University. We're conducting a survey on residents' perceptions of hurricane threats and damage reduction. The identity of people answering our questions will be kept completely confidential, but your answers will help Florida be better prepared the next time a big hurricane approaches. I need to talk to one of the adults responsible for your household, 18 or older. Would that be you?

Q1 Is your home a

- ❍ Single Family Home, Detached (2)
- ❍ Townhome (1)
- ❍ Apartment/Condominium (3)
- ❍ Manufactured or Mobile Home (4)
- ❍ Other (5) _____

Q2 Do you own or rent your home?

- ❍ Own (1)
- ❍ Rent (2)

Q3 Please tell me, in what year was your home built?_____ [yyyy]

Q4 How many years have you been a permanent resident of Florida?

- ❍ Less than 1 (1)
- ❍ 1-3 (2)
- ❍ 3-5 (3)
- ❍ 5-10 (4)
- ❍ Over 10 (5)

Q5 Have you or any adults in your household experienced any of the following? [ASK ABOUT THE NAME OF THE EVENT AND/OR YEAR]

- ❑ Tropical Storm (1) _____
- ❑ Category 1 Hurricane (2) _____
- ❑ Category 2 Hurricane (3) _____
- ❑ Category 3 or Higher (4) _____
- ❑ NONE OF THE ABOVE (5)

If NONE OF THE ABOVE Is Selected, Then Skip To Q9 How vulnerable do you feel to …

Q6 Have you or any adults in your household lived in a home physically damaged by a hurricane?

- ❍ Yes (1)
- ❍ No (2)

If No Is Selected, Then Skip To Q9 How vulnerable do you feel to …

Q7 How badly was it damaged? Would you say the damage was slight, moderate, or major?

- ❍ Slight (1)
- ❍ Moderate (2)
- ❍ Major (3)

Q8 Can you tell me what were the primary causes of damage to your home? Was it the debris in the wind breaking your windows, wind damaging your windows, wind damaging your roof, ocean surge, flooding, or something else? [MARK ALL THE RESPONSES MENTIONED]

- ❑ Wind Debris Breaking Windows (1)
- ❑ Wind Damaging the Roof (2)
- ❑ Ocean Surge (3)
- ❑ Flooding Related to a Hurricane (4)
- ❑ Trees Falling on House (5)
- ❑ Something Else (SPECIFY) (6) _____

Q9 How vulnerable do you feel to damage from a hurricane, related tornado or flooding hazards? Do you feel…

- ❍ Extremely Vulnerable (1)
- ❍ Somewhat Vulnerable (2)
- ❍ Not Too Vulnerable (3)

Q10 Considering yourself and others in your household, how certain are you that your household would have all the information needed to protect yourselves and your home from hurricane damage? Are you …

- ❍ Very Certain (1)
- ❍ Somewhat Certain (2)
- ❍ Not Certain At All (3)

Q11 Where do you receive the majority of your hurricane information from when a hurricane is approaching?

- ❑ Internet (1)
- ❑ Radio (2)
- ❑ TV (3)
- ❑ Newspapers/Print media (4)
- ❑ Friends and family (5)
- ❑ Other (6) _____

Q12 Do you have a plan for what you would do if a serious hurricane threatens your home?

- ❍ Yes (If yes, what is your plan?) (1) _____
- ❍ No (2)

Q13 When would you begin to prepare your home for a hurricane? [READ LIST]

- ❍ When a hurricane watch is issued (hurricane conditions are *possible* within ***48 hours*****)** (1)
- ❍ When a hurricane warning is issued (hurricane conditions are *expected* within ***36 hours*****)** (2)
- ❍ Your home is already prepared and could be secured within a few hours (3)
- ❍ You won't make any special preparations to your home (4)
- ❍ Other (5) _____
- ❍ Not sure (DO NOT READ) (6)

Q14 Overall, would you describe your household preparation for a hurricane as…

- ❍ Adequate (1)
- ❍ Inadequate (2)

Q15 Do you have a Basic Emergency Supply Kit with the following: [Mark as many as indicated]

- ❍ Water, one gallon of water per person per day for at least three days
- ❍ Food, at least a three-day supply of non-perishable food
- ❍ Battery-powered radio and extra batteries for it
- ❍ Flashlight and extra batteries
- ❍ First aid kit
- ❍ Whistle to signal for help
- ❍ Dust mask, to help filter contaminated air and plastic sheeting and duct tape to shelter-in-place
- ❍ Personal sanitation items, e.g. moist towelettes, garbage bags
- ❍ Wrench or pliers to turn off utilities
- ❍ Can opener for food [if kit contains canned food]
- ❍ Local maps
- ❍ Other [SPECIFY]: _____
- ❍ I do not have an Emergency Supply Kit

Q16 Is your home located in a flood or evacuation zone? [ASK WHAT IS THE LETTER DESIGNATION FOR THE FLOOD OR EVACUATION ZONE, READ OPTIONS IF NECESSARY]

- ❍ Yes, flood zone (1) _____ [MARK LETTER: A (HIGH FLOOD RISK), B (MODERATE) OR C (LOW RISK)]
- ❍ Yes, evacuation zone (2) _____ [MARK LETTER: A (EVACUATE FOR ALL HURRICANES), B (EVACUATE FOR CATEGORY 3 AND ABOVE HURRICANES), C THROUGH E (EVACUATE IF ADVISED BY AUTHORITIES)]
- ❍ Yes, both flood and evacuation zone (3) _____ [MARK LETTERS]
- ❍ Neither flood, not evacuation zone (4) _____
- ❍ Don't know (DO NOT READ) (5) _____

Q17 When would you evacuate? (READ LIST and SELECT ONE)

- ❍ If a hurricane watch is issued (hurricane conditions are *possible* within ***48 hours*****)** (1)
- ❍ If a hurricane warning is issued (hurricane conditions are *expected* within ***36 hours*****)** (2)
- ❍ If a category 3 hurricane or stronger was going to hit your home within 24 hours (3)
- ❍ If emergency management officials ordered you to evacuate (4)
- ❍ Probably never (5)
- ❍ Other (6) _____

Q18 If you needed to evacuate, where would you go?

- ❍ To a local shelter (1)
- ❍ To the house of a nearby friend/family (2)
- ❍ Another location within the State (3)
- ❍ As far as possible – to another State (4)
- ❍ You would not leave under any circumstances (5)
- ❍ Other (6) _____

Q19 Do you currently have homeowners' or renters' insurance?

- ❍ YES Homeowner's insurance (1)
- ❍ YES, Renters' insurance (2)
- ❍ No (3)
- ❍ Don't know (DO NOT READ) (4)

If YES, Renters' insurance Is Selected, Then Skip To Q26 Do you believe sea level rise is happening in Florida...

If No Is Selected, Then Skip To Q26 Do you believe sea level rise is happening in Florida

Q20 How has your home insurance rate changed in the last:

	Decreased Significantly (Over 10%) (1)	Decreased Somewhat (1-10%) (2)	Remained the Same (3)	Increased Somewhat (1-10%) (4)	Increased Significantly (Over 10%) (5)	Don't Know
One Year (1)	❍	❍	❍	❍	❍	❍
1-3 Years (2)	❍	❍	❍	❍	❍	❍
3-5 Years (3)	❍	❍	❍	❍	❍	❍
5-10 Years (4)	❍	❍	❍	❍	❍	❍

If Remained the Same Is Selected, Then Skip To Q22 Do you currently have Citizens...

Q21 With regards to the changes in your insurance rate...

	Yes (1)	No (2)	Uncertain [DO NOT READ] (3)
Do you understand the reasons for the change? (1)	❍	❍	❍
Do you believe the change was justified? (2)	❍	❍	❍
Do you anticipate that your rate will change again in the next 1-3 years? (3)	❍	❍	❍

Q22 Do you currently have Citizens Insurance?

- ❍ Yes (1)
- ❍ No (2)
- ❍ Don't know [DO NOT READ] (3)

Q23 In recent years there has been a trend among homeowners who have paid off their mortgage to cancel their homeowner insurance policies. Would you consider it if your mortgage was paid off?

- ❍ Yes (1)
- ❍ No (2)
- ❍ I have already dropped my insurance (3)
- ❍ Not Applicable (Don't have insurance) (4)

Q24 Are you currently receiving any discounts on your homeowner insurance policy for hurricane loss mitigation improvements you may have on your home (for example shutters, reinforced roofs, doors etc.)?

- ❍ Yes (1)
- ❍ No (2)
- ❍ Don't Know

Q25 Do you believe sea level rise is happening in Florida, and do you think your property or finances will be affected?

- ❍ Yes, I believe it is happening and I will be affected (1)
- ❍ Yes, I believe it is happening but I do not know if I will be affected (2)
- ❍ Yes, I believe it is happening but I will not be affected (3)
- ❍ No, I do not believe it is happening (4)
- ❍ I don't know if it is happening (5)

If YES Is NOT Selected, Then Skip To Q30 Most of Florida's coastal areas...

Q26 How much do you think each of these actors should do to reduce the effects of rising sea level in the future – a great deal, quite a bit, some, a little, or nothing?

	A great deal (should play a leading role) (1)	Some (Should play a supporting role) (2)	A little (very minor role) (3)	Nothing (4)
A. Federal Government (1)	❍	❍	❍	❍
B. State government and agencies (2)	❍	❍	❍	❍
C. Local governments that are located near the coast of the U.S. (3)	❍	❍	❍	❍
D. Businesses located near the coast (4)	❍	❍	❍	❍
E. Homeowners located near the coast (5)	❍	❍	❍	❍
F. Real estate developers (6)	❍	❍	❍	❍
G. General public (7)	❍	❍	❍	❍
H. Scientists (8)	❍	❍	❍	❍

If A little (very minor role) (3) OR Nothing (4) Is Selected for A. B. and C. Then Skip To Q30 Most of Florida's coastal areas...

Q27 What should the government be doing to combat sea level rise? [Multiple Choice]

- ❍ Establish a legislative authority to better regulate development. (1)
- ❍ Create a national fund to help homeowners and local governments take action on sea level rise. (2)
- ❍ Implement stricter elevation plans for homes in vulnerable areas. (3)
- ❍ Utilize land purchase/buyout programs. (4)
- ❍ Develop a climate adaptation plan. (5)
- ❍ Utilize private land for public goods (i.e. natural buffers such as dunes). (6)
- ❍ The government is not responsible. (7)
- ❍ There is no sea level rise. (8)
- ❍ Other (9) _____
- ❍ Don't Know/No Response

Q28 If you believe the government should take any action, to pay for any initiative, the government could increase everyone's income taxes, or the government could charge higher property taxes to companies and people who own buildings near the coast. In which way would you prefer that the government pay for those initiatives?

- ❍ Increase income taxes (1)
- ❍ Increase property taxes (2)
- ❍ Increase both income and property taxes (3)
- ❍ Other (4) _____
- ❍ Neither (DO NOT READ)

Q29 Most of Florida's coastal areas have a very low elevation (under 10 meters (33 feet) above sea level) and are especially vulnerable to flooding associated with storm surges. How concerned are you about flooding in your area?

- ❍ Extremely concerned (1)
- ❍ Moderately concerned (2)
- ❍ Somewhat concerned (3)
- ❍ Slightly concerned (4)
- ❍ Not at all concerned (5)

Finally, I just have a few general background questions and we will be finished.

Q30 Could you please tell me your age? [READ AGE RANGES AND LET RESPONDENT PICK]

- ❍ 18-34 (1)
- ❍ 35-54 (2)
- ❍ 55-64 (3)
- ❍ 65 OR OLDER (4)
- ❍ NO RESPONSE (5)

Q31 Including yourself, how many people ...

live in your household (1) _____
are under 12 years old (2)_____
are 65 or older (3)_____

Q32 What is your marital status?

- ❍ Single/Never Married (1)
- ❍ Married or Living with partner (2)
- ❍ Widowed (3)
- ❍ Divorced (4)
- ❍ Separated (5)
- ❍ Other (6) _____

Q33 What is the highest grade of school completed by an adult member of your household?

- ❍ Less than high school (1)
- ❍ High school (2)
- ❍ Some college (3)
- ❍ College graduate (4)
- ❍ Graduate Degree (5)
- ❍ Other (6) _____

Q34 What racial groups do you identify yourself with?

- ❍ White/Caucasian (1)
- ❍ Black/African American (2)
- ❍ Asian (3)
- ❍ Native American (4)
- ❍ Other (5)_____

Q35 Are you of Hispanic/Latino descent?

- ❍ Yes (1)
- ❍ No (2)

Q36 What language is most often spoken in your home? [DO NOT READ, MARK RESPONSE]

- ❍ English (1)
- ❍ Spanish (2)
- ❍ Other (3) _____

Q37 Please tell me which is the income range for your household.

- ❍ Under $20,000 (1)
- ❍ $20,000-30,000 (2)
- ❍ $30,000-$50,000 (3)
- ❍ $50,000-$75,000 (4)
- ❍ $75,000-$100,000 (5)
- ❍ Over $100,000 (6)
- ❍ Don't know/No response (7)

These were all the questions I had. Thank you very much for your responses. Have a nice evening.

Q38 Please record information from call list.

Address (1)_____
City (2)_____
ZIP Code (3)_____
Phone Number (4)_____