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# A FUTURE SUBMERGED: IMPLICATIONS OF SEA LEVEL RISE FOR SOUTH FLORIDA

*Giselle Peruyera\**

*“Sea level rise is a documented reality. It’s only a question of magnitude.”<sup>1</sup>*

## INTRODUCTION

Environmental security has been a topic of much discussion, and while the issue of climate change can be polarizing, the need to craft measures to mitigate and adapt to the risk of sea level rise is logical given South Florida’s topography and history with water. It was not so long ago that South Florida was battling internally with the complexities of controlling water. The fight to tame Florida’s water problem resulted in a complex system of canals, pumps, and levees created to protect a burgeoning population.<sup>2</sup> The low-lying area south of Lake Okeechobee, once the domain of the expansive Everglades, was engineered to combat the elements of flooding as lives and resources were lost as a result of natural inundation and storm surges.<sup>3</sup>

The ability to command and control water is once again reaching a tipping point as the population, resources, and the environment of South Florida lay vulnerable to rising sea levels. This time, the threat is from the exterior as sea level rise could result in increased flooding and erosion, diminishing and contaminated water supply, and destruction to critical habitat. Countless dollars have been spent to protect the population from flooding and to restore and protect the Everglades.<sup>4</sup> Many battles have been waged politically and legally, and yet all the blood, sweat, and tears may be futile if the problem of sea

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1. NOAA MARINE FISHERIES ADVISORY COMM., PROCEEDINGS, 78 (Oct. 21, 2010), [http://www.nmfs.noaa.gov/ocs/mafac/meetings/2010\\_10/docs/1021doc\\_web.pdf](http://www.nmfs.noaa.gov/ocs/mafac/meetings/2010_10/docs/1021doc_web.pdf). (Transcript of the Oct. 21, 2010 meeting of the Marine Fisheries Advisory Comm. with Keith Rizzardi speaking).

2. Comprehensive Everglades Restoration Plan: *Development of the Central & South Florida (C&SF) Project*. available at [http://www.evergladesplan.org/about/restudy\\_csf\\_devel.aspx](http://www.evergladesplan.org/about/restudy_csf_devel.aspx).

3. *Id.*

4. *Id.*

level rise is ignored. Legislation that incorporates mitigation, adaptation, and conservation measures will aid in defending as well as adjusting to increased sea level rise where necessary. South Florida cannot afford to turn a blind eye as a majority of its population sits on the coast, and its infrastructure, economic viability, and environment sit at the precipice of the ocean's reach.

This Article will examine the role that South Florida's environmental policies play in combating and adapting to sea level rise due to climate change. Part I of this paper will review the general concept of climate change and its effects on sea level rise as expressed by the opinions of the Intergovernmental Panel on Climate Change (IPCC), agencies of the United States federal government, and Florida's governmental agencies. Part II will explore various threats to South Florida's environment as a result of sea level rise. Part III will focus on how sea level rise will cause environmental security implications in South Florida. Part IV will provide recommendations concerning protection, mitigation, and adaptation measures to address the effects of sea level rise on South Florida.

## I. SEA LEVEL RISE AND CLIMATE CHANGE: A BASIC BACKGROUND

Sea level can be defined as "the height of the ocean surface above or below some reference, or zero, point".<sup>5</sup> Since the 19th century, tide gauges have measured sea level, and recently satellite altimeters in space have provided an additional means of measurement.<sup>6</sup> A tide gauge is a device that is located in a coastal or deep-sea location that measures the level of the sea continuously "with respect to the adjacent land."<sup>7</sup> Determining relative sea level involves measuring the height of the ocean relative to the adjacent land on which the tide gauge is situated.<sup>8</sup> By averaging data over a specific period of time (months or years<sup>9</sup>), thus canceling out tide variations, mean sea level is measured

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5. Gary T. Mitchum, *Sea Level Changes in the Southeastern United States: Past, Present, and Future*, FLORIDA CLIMATE INSTITUTE/SOUTHEAST CLIMATE CONSORTIUM, Aug. 2011, at 1, available at [http://www.seclimate.org/pdfpubs/201108mitchum\\_sealevel.pdf](http://www.seclimate.org/pdfpubs/201108mitchum_sealevel.pdf).

6. *Id.* For measurements done by satellite altimeters, the center of the Earth is considered the zero point versus measurements done by a tide gauge where "the zero point is some point on the land near the gauge." Further distinctions between measurements provided by a tide gauge and satellite altimeters is beyond the scope of this paper.

7. Intergovernmental Panel on Climate Change (IPCC), *Glossary of Terms Used in the IPCC Fourth Assessment Report, Annex 1* (2007), at 953, available at <http://www.ipcc.ch/pdf/glossary/ar4-wg1.pdf> (last visited Apr. 16, 2012).

8. Mitchum, *supra* note 5, at 1.

9. The U.S. Army Corps of Engineers' Manual on Sea Level Measurement and Interpretation recommends that a tidal record should encompass a two-tidal epoch duration

and can provide insight into how climate is affecting sea level rise.<sup>10</sup> Averaging mean sea level can be done on a regional basis or globally (also referred to as global mean sea level).<sup>11</sup>

Durational variations in sea level are influenced by a variety of factors such as seasonal weather patterns, man-made influences (such as dredging), and coastal and ocean circulation.<sup>12</sup>

Short-term variations generally occur on a daily basis and include waves, tides, or specific flood events, such as those associated with a winter snow melt, or hurricane or other coastal storm. Long-term variations in sea level occur over various time scales, from monthly to several years, and may be repeatable cycles, gradual trends, or intermittent anomalies.<sup>13</sup>

Sea level rise as a result of climate change is caused by two major factors: thermal expansion of the oceans (expansion occurs as heat is transferred into the ocean) and overall volume increase in the ocean due to land-based ice melt.<sup>14</sup> The United States Environmental Protection Agency (EPA) has noted that the range cited by the Intergovernmental Panel on Climate Change (IPCC) for global sea level rise depicts an uncertainty as to how warmer temperatures will impact the rate at which ice sheets will melt.<sup>15</sup> Nonetheless, even noting this variability, the IPCC has held that sea level rise will be “overwhelmingly negative” in its impact.<sup>16</sup>

### A. *Effects of Sea Level Rise: An International Perspective*

The IPCC is a scientific body created by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) to provide reviews and assessment of current cli-

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(about 40 years) at the least in order to estimate a local mean sea level trend. See U.S. ARMY CORPS OF ENGINEERS, *Sea-Level Change Considerations for Civil Works Programs*, Engineer Circular (EC) 1165-2-212, October 1, 2011, Appendix B, at B-3, available at <http://planning.usace.army.mil/toolbox/library/ECs/EC11652212Nov2011.pdf> (last visited Apr. 17, 2012).

10. *Id.*

11. *Id.*

12. NOAA Tides & Currents, *Sea Level Trends: Frequently Asked Questions, Why Does Sea Level Change Over Time?* available at <http://tidesandcurrents.noaa.gov/sltrends/faq.shtml> (last visited Mar. 22, 2012).

13. *Id.*

14. INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC), *Climate Change 2007: Working Group I: The Physical Science Basis, 5.5 Changes in Sea Level*, available at [http://www.ipcc.ch/publications\\_and\\_data/ar4/wg1/en/ch5s5-5.html](http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch5s5-5.html) (last visited Mar. 22, 2012).

15. ENVIRONMENTAL PROTECTION AGENCY, *Climate Change: Coastal Zones and Sea Level Rise* (2011), available at <http://www.epa.gov/climatechange/effects/coastal/index.html> (last visited Mar. 22, 2012).

16. *Id.*

mate change reports.<sup>17</sup> The IPCC's defined role is "to assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation."<sup>18</sup> The IPCC issues comprehensive assessment reports at regular intervals based on its review process.<sup>19</sup> Four assessment reports have been published with the first report issued in 1990 and the latest completed in 2007.<sup>20</sup>

The IPCC's *Fourth Assessment Report: Climate Change 2007*<sup>21</sup> states that the average sea level globally is estimated to rise between 0.6 and 2 feet (0.18 to 0.59 meters) in the next century, although with regional variability.<sup>22</sup> Since 1961, global average sea level has risen "at an average rate of 1.8 (1.3 to 2.3) mm/yr and since 1993 at 3.1 (2.4 to 3.8) mm/yr, with contributions from thermal expansion, melting glaciers and ice caps, and the polar ice sheets."<sup>23</sup> However, uncertainty remains as to whether the increased rate of sea level rise from 1993 to 2003 is a reflection of "decadal variation or an increase in the longer-term trend."<sup>24</sup> The IPCC reports that sea level will inevitably continue to rise for many centuries due to warming trends, and thus "long time scales of thermal expansion and ice sheet response to warming" will continue despite stabilization of warming contributors such as greenhouse gases (GHG).<sup>25</sup>

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17. INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, *Organization*, available at <http://www.ipcc.ch/organization/organization.shtml> (last visited Mar. 22, 2012).

18. INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, *Principles Governing IPCC Work*, October 1, 1998, at 1, available at <http://www.ipcc.ch/pdf/ipcc-principles/ipcc-principles.pdf> (last visited Mar. 22, 2012).

19. INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, *Publications and Data: Assessment Reports*, available at [http://www.ipcc.ch/publications\\_and\\_data/publications\\_and\\_data.shtml](http://www.ipcc.ch/publications_and_data/publications_and_data.shtml) (last visited Mar. 22, 2012).

20. *Id.* The Fifth Assessment Report (AR5) is due to be completed sometime in September 2013.

21. INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, *Climate Change 2007: Synthesis Report, Observed Changes in Climate & Their Effects* (2007), available at [http://www.ipcc.ch/publications\\_and\\_data/ar4/syr/en/spms1.html](http://www.ipcc.ch/publications_and_data/ar4/syr/en/spms1.html) (last visited Mar. 22, 2012).

22. INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, *Climate Change 2007: Impacts, Adaptation and Vulnerability* (2007), at 1000. CONTRIBUTION OF WORKING GROUP II TO THE FOURTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (Martin L. Parry, Osvaldo F. Canziani, Jean P. Palutikof, Paul J. van der Linden & Clair E. Hanson eds., 2007) (Cambridge University Press, Cambridge, United Kingdom).

23. INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, *Climate Change 2007: Synthesis Report*, [http://www.ipcc.ch/publications\\_and\\_data/ar4/syr/en/spms1.html](http://www.ipcc.ch/publications_and_data/ar4/syr/en/spms1.html).

24. *Id.*

25. INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, *Climate Change 2007: Synthesis Report, The Long-Term Perspective* (2007), available at [http://www.ipcc.ch/publications\\_and\\_data/ar4/syr/en/spms5.html](http://www.ipcc.ch/publications_and_data/ar4/syr/en/spms5.html) (last visited Mar. 22, 2012).

### B. *Effects of Sea Level Rise: A National Perspective*

On a national level, U.S. federal agencies such as the National Oceanic and Atmospheric Administration (NOAA), the U.S. Army Corps of Engineers, the U.S. Geological Survey (USGS), and the Environmental Protection Agency (EPA) have all produced analyses of how sea level rise will impact the United States.<sup>26</sup> According to the EPA, sea level has risen in most of the U.S. Atlantic and Gulf coast regions between 0.08-0.12 inches per year (2.0-3.0 mm per year).<sup>27</sup> The Army Corps of Engineers has reported that coastal and estuarine zones, as a result of changes in sea level, will confront a variety of impacts such as “changes in shoreline erosion, inundation or exposure of low-lying coastal areas, changes in storm and flood damage, shifts in extent and distribution of wetlands and other coastal habitats, changes to groundwater levels, and alterations to salinity intrusion into estuaries and groundwater systems.”<sup>28</sup> The Army Corps of Engineers has stated that U.S. tide stations, operated by NOAA, have shown that a majority of local mean sea levels have risen in the twentieth century.<sup>29</sup> Local mean sea levels have shown a rise between 0 and 0.6 meters per century.<sup>30</sup>

### C. *Effects of Sea Level Rise: A Local Perspective*

On a local level, the Florida Oceans and Coastal Council (FOCC) created by the Florida legislature in 2005 under the Oceans and Coastal Resources Act, has noted Florida’s vulnerability to sea level rise.<sup>31</sup> In FOCC’s 2010 report, *Effects of Climate Change on Florida’s Ocean and Coastal Resources*, a similarity is noted between the rate of global sea level rise and Florida’s sea level rise.<sup>32</sup> Sea level

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26. Niki L. Pace, *Wetlands or Seawalls? Adapting Shoreline Regulation to Address Sea Level Rise and Wetland Preservation in the Gulf of Mexico*, 26 J. LAND USE & ENVTL. LAW 327, 331-332 (2011).

27. ENVIRONMENTAL PROTECTION AGENCY, *Climate Change: Sea Level Changes* (2011), available at <http://www.epa.gov/climatechange/science/recentstlc.html> (last visited Mar. 22, 2012).

28. United States Army Corps of Engineers, *Sea-Level Change Considerations for Civil Works Programs*, Engineer Circular (EC) 1165-2-212, Oct. 1, 2011, Appendix B, at B-1, available at <http://planning.usace.army.mil/toolbox/library/ECs/EC11652212Nov2011.pdf> (last visited Mar. 22, 2012).

29. *Id.* at B-2.

30. *Id.*

31. Florida Oceans and Coastal Council, *The Council*, available at <http://www.floridoceanscouncil.org/> (last visited Mar. 22, 2012).

32. Florida Oceans and Coastal Council, *Climate Change and Sea-Level Rise in Florida: An Update of The Effects of Climate Change on Florida’s Ocean and Coastal*

around Florida has risen slowly in the past few thousand years; however, in recent decades the rate of sea level rise has persistently increased.<sup>33</sup> What remains unclear is how the rate of melting from ice reservoirs in the next century will affect sea level.<sup>34</sup> Therefore, as rising global sea levels have increased during the twentieth century, and warming of the ocean continues, Florida's unique resources, environment, and population are at risk.<sup>35</sup>

[Florida] has more than 1,200 miles of coastline; almost 4,500 square miles of estuaries and bays, and more than 6,700 square miles of other coastal waters. The entire state lies within the Atlantic Coastal Plain, with a maximum elevation less than 400 feet above sea level, and most of Florida's 18 million residents live less than 60 miles from the Atlantic Ocean or the Gulf of Mexico. Three-fourths of Florida's population resides in coastal counties that generate 79% of the state's total annual economy, and represent a built-in environment and infrastructure with a replacement value in 2010 of \$2.0 trillion and by 2030 an estimated value of 3.0 trillion.

In addition, Florida's coastal and marine resources comprise some of the nation's most diverse and productive ecosystems . . . some of which exist nowhere else on Earth.<sup>36</sup>

Based on these features, the FOCC stresses that the question is not whether Florida will be affected by sea level rise but rather "how much—that is, to what degree sea level rise will continue, how rapidly, what other climate changes will accompany sea level rise, and what the long term effects of these changes will be."<sup>37</sup> Accordingly, the FOCC in its 2010 report provides an analysis of the potential risks of sea level rise to Florida's resources through probable and possible impacts, thus accounting for uncertainties.<sup>38</sup>

The Florida Department of Environmental Protection (DEP) has stated that South Florida is an area of low elevation and is therefore threatened by rising seas which could cause "inundation, shoreline erosion and severe damage to both property and coastal ecosystems

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*Resources*, Dec. 2010, at 3, [http://www.floridaoceancouncil.org/reports/Climate\\_Change\\_and\\_Sea\\_Level\\_Rise.pdf](http://www.floridaoceancouncil.org/reports/Climate_Change_and_Sea_Level_Rise.pdf).

33. *Id.*

34. *Id.*

35. *Id.*

36. *Id.* at 1-2.

37. *Id.* at 9.

38. *Id.* at 3-4.

such as mangroves and wetlands that protect the shore from storms.”<sup>39</sup> Responding to Florida’s vulnerability to rising sea levels, four counties, under a regional climate change compact, initiated a unified regional projection of the impact of sea level rise on Southeast Florida.<sup>40</sup> Under the Southeast Florida Regional Climate Change Compact (Compact) Monroe, Miami-Dade, Broward, and Palm Beach Counties have joined together to collaborate on resolving climate change issues, including sea level rise, for Southeast Florida.<sup>41</sup> The Compact has concluded, based on a unified model, that the rate of sea level rise will increase “3 to 7 inches by 2030 and 9 to 24 inches by 2060.”<sup>42</sup> Furthermore, it is projected that sea level will “rise one foot from the 2010 level between 2040 and 2070, but a two foot rise is possible by 2060.”<sup>43</sup> Through the Compact the four counties will coordinate measurements with state and federal agencies to aid in adapting to and mitigating climate change issues.<sup>44</sup>

South Florida Water Management District (SFWMD) in 2009 presented a draft paper, *Draft: Climate Change and Water Management in South Florida*, and noted that “the seas around Florida have been rising about 0.1 inches per year.”<sup>45</sup> Furthermore, it was stipulated that there is a probability that sea level rise in South Florida will range from 5 to 20 inches by 2060.<sup>46</sup> To account for uncertainty, SFWMD also noted that as a result of rising seas it is possible that Florida will face “direct impacts on coastal beaches, infrastructure, and

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39. Florida Department of Environmental Protection, *Climate Change and Coral Reefs* (2011), available at [http://www.dep.state.fl.us/coastal/programs/coral/climate\\_change.htm](http://www.dep.state.fl.us/coastal/programs/coral/climate_change.htm) (last visited Mar. 22, 2012).

40. Southeast Florida Regional Climate Change Compact, available at <http://www.southeastfloridaclimatecompact.org/> (last visited Mar. 22, 2012).

41. *Id.*

42. Technical Ad Hoc Work Group, Southeast Florida Regional Climate Change Compact, *A Unified Sea Level Rise Projection for Southeast Florida*, Apr. 2011, at iii, available at <http://www.broward.org/NaturalResources/ClimateChange/Documents/SE%20FL%20Sea%20Level%20Rise%20White%20Paper%20April%202011%20ADA%20FINAL.pdf> (last visited Apr. 16, 2012).

43. *Id.*

44. *Id.*

45. South Florida Water Management District, *Draft: Climate Change and Water Management in South Florida*, Nov. 12, 2009, at 6, available at [http://home.fau.edu/jlambert/web/Reports/Climate%20Change%20and%20Water%20Management%20in%20South%20Florida\\_12Nov2009\\_final.pdf](http://home.fau.edu/jlambert/web/Reports/Climate%20Change%20and%20Water%20Management%20in%20South%20Florida_12Nov2009_final.pdf) (last visited Mar. 22, 2012). See Miami-Dade County, *Green Print: Our Design for a Sustainable Future*, December 2010, at 72. (Providing an example of how mean sea level trends have increased through the Key West tide gauge. The Key West tide gauge has shown that from the year 1913 to 2006, mean sea level has increased approximately 2.24 millimeters per year, “which is roughly equivalent to a change of 0.73 feet in 100 years”).

46. *Id.*



wetlands due to high tides and storm surges. Urbanized areas along the coasts may be more prone to flooding. Coastal water supplies could be impacted by accelerated saltwater intrusion.<sup>47</sup> Ultimately, SFWMD postulated that South Florida may see a 5 to 20 inch rise in sea level within the next fifty years.<sup>48</sup>

## II. SOUTH FLORIDA'S ENVIRONMENT AND RISING SEA LEVELS

“Southeast Florida with its populous coastal counties, subtropical environment, porous geology and low topography is particularly vulnerable to the effects of climate change, especially sea level rise.”<sup>49</sup> As a result of sea level rise, South Florida's infrastructure will be at risk, including flood control mechanisms and wellfields that provide drinking water.<sup>50</sup> Eventually, flooding will become more severe as flood control structures battle to prevent saltwater intrusion while attempting to discharge rainwater.<sup>51</sup> Potable water supply will also be affected by rising sea levels as wellfields that supply Southeast Florida with drinking water will be at an increased risk for saltwater intrusion.<sup>52</sup> The quality and quantity of potable water will be affected by the intrusion of saltwater that will contaminate and shutdown wellfields thus causing water supply issues.<sup>53</sup> Modification or destruction of environmentally sensitive areas, such as critical habitats for endangered species, will be likely with rising sea levels, and further severe implications for South Florida's environment are possible if the rate of sea level rise increases.<sup>54</sup>

### A. Flooding

According to the FOCC, sea level rise will cause tidal flooding in coastal areas, higher hurricane storm surge and wave heights, and compromised stormwater drainage in low-lying areas during heavy rains.<sup>55</sup> During seaward storms, strong onshore winds, and spring and fall high tides, low-lying coastal areas as a consequence of sea level rise

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47. *Id.* at 6.

48. *Id.* at 7.

49. Southeast Florida Regional Climate Change Compact Technical Ad hoc Work Group, *supra* note 42.

50. South Florida Water Management District, *supra* note 45, at 8-9.

51. *Id.*

52. *Id.*

53. *Id.* at 9.

54. *Id.* at 11.

55. Florida Oceans and Coastal Council, *supra* note 32, at 19.

will be more prone to coastal flooding.<sup>56</sup> Furthermore, coastal water depths will increase as sea level rises, and during a hurricane, storm surge and wave heights will increase causing amplified damage.<sup>57</sup> Additionally, the effectiveness of stormwater drainage systems will be reduced for those systems relying mainly on gravity.<sup>58</sup> Lastly, low-lying interior flood plains such as those in southeastern Florida will experience a higher risk of inland flooding during heavy rainfall as a result of sea level rise.<sup>59</sup>

In light of a probable 3 to 6 inch increase in sea level rise, coastal flood control structures' overall effectiveness may begin to be compromised and their capacity reduced "by as much as 20 to 40 percent by 2030" and by as much as 65 to 70 percent by around 2040 if sea level rises 6 to 9 inches.<sup>60</sup> "Most of these early impacts will be felt in low-lying coastal areas, such as southern Miami-Dade. . . ."<sup>61</sup> In the realm of possibilities, sea level rise will cause a 100-year flood event to likely become a 50 to 20 year flood event.<sup>62</sup> Lastly, pumps will need to replace gravity gates for primary drainage canals to function and offset the effects of sea level rise.<sup>63</sup>

SFWMD anticipates that sea level rise "may cause significant saltwater flooding of coastal property and infrastructure, greater vulnerability to storm surges and erosion, and the destruction of vital coastal habitats."<sup>64</sup> Sea level rise will impact vulnerable coastal water management infrastructure and regional water control structures, and as a result hamper or disable the ability to control flooding.<sup>65</sup> Currently, stormwater that is not absorbed by the surficial aquifer or detention areas becomes coastal runoff that enters into canals and gravity driven weirs to be drained ultimately into the ocean.<sup>66</sup> "When these structures discharge to the ocean, the water level difference between upstream (land side or headwater) and downstream (ocean side

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56. *Id.*

57. *Id.*

58. *Id.*

59. *Id.*

60. *Id.*

61. *Id.*

62. *Id.*

63. *Id.*

64. *Id.* at 8.

65. *Id.*

66. South Florida Water Management District, *Past and Projected Trends in Climate and Sea Level for South Florida, Hydrologic and Environmental Systems Modeling*, Technical Report, July 5, 2011, at 117, available at [http://my.sfwmd.gov/portal/page/portal/xrepository/sfwmd\\_repository\\_pdf/ccireport\\_publicationversion\\_14jul11.pdf](http://my.sfwmd.gov/portal/page/portal/xrepository/sfwmd_repository_pdf/ccireport_publicationversion_14jul11.pdf) (last visited Apr. 17, 2012).

or tailwater) may be as little as 6 inches or less for some structures under design conditions.”<sup>67</sup>

Due to South Florida’s low elevation, the ability for flow capacity to be reduced as a result of sea level rise is likely, and has already begun to occur.<sup>68</sup> Several coastal drainage structures have been identified as being in danger of losing flow capacity if sea level rises 6 inches or more.<sup>69</sup> “Since the structures were designed and installed, sea level has risen approximately 5 inches, such that some coastal structures have already lost some flow capacity as a result of sea level rise.”<sup>70</sup> In light of projected sea level rise, rain-driven flooding will exacerbate the inability of coastal flood control structures to discharge excess water, thus “affecting flood protection in urban areas.”<sup>71</sup>

South Florida coastal areas will face potentially devastating impacts due to higher sea levels as present erosion problems will increase and inundation of coastal infrastructure (including bridges and roads) will be likely.<sup>72</sup> If a rise in sea level reaches 2.25 feet then “9 percent of Florida’s current land area—an area with a population of 1.5 million—[will be] underwater during high tide.”<sup>73</sup> At significant risk under this projection is Monroe County facing a 99 percent risk of submergence, and Miami-Dade County, facing a nearly 70 percent risk of submergence.<sup>74</sup> Furthermore, property in Palm Beach County under a 2 foot sea level rise will face possible inundation, thus making property valued at \$1.3 to \$1.9 billion vulnerable.<sup>75</sup> Lastly, flooding and erosion will be intensified through the combination of hurricanes and higher sea levels that will result in higher storm surges.<sup>76</sup>

Infrastructure “such as wastewater treatment and reclamation facilities, water supply treatment facilities, and sewer lift stations” will be threatened by sea level rise as flooding from high tides can cause short-term access problems and damage if such infrastructure is not

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67. Florida Oceans and Coastal Council, *supra* note 32, at 9.

68. South Florida Water Management District, *supra* note 66, at 117-118.

69. *Id.* at 118.

70. *Id.*

71. Florida Oceans and Coastal Council, *supra* note 32, at 8-9.

72. Ben Chou, Natural Resources Defense Council, *Ready or Not: An Evaluation of State Climate and Water Preparedness Planning*, April 2012, at 61, available at <http://www.nrdc.org/water/readiness/files/Water-Readiness-full-report.pdf> (last visited Apr. 17, 2012).

73. *Id.* at 62.

74. *Id.*

75. *Id.*

76. *Id.*

adequately elevated or flood proofed.<sup>77</sup> “Altered hydraulic head differentials may negatively affect wastewater discharge ocean outfalls, gravity-flow storm sewers, ditches, and canals, and the effectiveness of tide gates in storm water drainage canals and mosquito control ditches.”<sup>78</sup> Furthermore, coastal infrastructure will be vulnerable to disrepair and damage based on the design and build of the structures.<sup>79</sup> Most coastal infrastructures have referred to the National Geodetic Vertical Datum of 1929 for historical data of local mean sea level and flooding, which incorporates neither current nor future sea level projections.<sup>80</sup> Therefore, infrastructure such as “port facilities, marinas, piers, and others that must be located at or near the waterline are very likely to be at gradually increasing risk of damage from flooding, hydrodynamic pressure from storm surge, and wave impact because of sea level rise.”<sup>81</sup>

Additional consequences as a result of flooding due to sea level rise will be that infrastructure will face added stress and fatigue physically, thus affecting structural integrity.<sup>82</sup> The functional life of roads, ports, airports and rail systems will require accelerated maintenance in light of increased flooding from sea level rise.<sup>83</sup> Roads, many “built lower than the surrounding land,” will be inundated as road drainage systems will become less effective and more susceptible to flooding during rainstorms as a result of sea level rise.<sup>84</sup> During hurricanes and coastal flooding, higher hydrostatic pressure will increase the risk of structural damage to “ground floor slabs and foundations of buildings and infrastructure.”<sup>85</sup>

Areas considered outside the Federal Emergency Management Agency (FEMA) 100-year floodplain will experience increased flooding as a result of frequent coastal floods and hurricane storm surges that will move higher and farther inland beyond vulnerability zones.<sup>86</sup> Levees and dikes will have limited effectiveness because the geology of

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77. Robert E. Deyle, Katherine C. Bailey & Anthony Matheny, *Adaptive Response Planning to Sea Level Rise in Florida and Implications for Comprehensive and Public-Facilities Planning*, Presented at the 48th Annual Conference of the Association of Collegiate Schools of Planning, Oct. 18, 2007, at 5, available at [http://www.coss.fsu.edu/durp/sites/coss.fsu.edu.durp/files/WPS\\_08\\_02\\_Deyle.pdf](http://www.coss.fsu.edu/durp/sites/coss.fsu.edu.durp/files/WPS_08_02_Deyle.pdf) (last visited Apr. 17, 2012).

78. *Id.* at 6.

79. Florida Oceans and Coastal Council, *supra* note 32, at 11.

80. *Id.*

81. *Id.* at 11-12.

82. *Id.* at 12.

83. *Id.*

84. *Id.*

85. *Id.*

86. Deyle, Bailey & Matheny, *supra* note 77, at 6.

South Florida, highly porous limestone and sand substrate, will make it difficult to “wall off the encroaching sea.”<sup>87</sup> FEMA reports that existing development in the U.S. coastal zone will experience a 36-58 percent increase in annual damage in light of a 1-foot sea level rise, and a 3-foot rise would increase damage by 102-200 percent.<sup>88</sup>

As flood zones shift higher and further landward, facilities previously sited in what were considered to be safe areas, e.g. outside the FEMA 100-year floodplain, may experience floods formerly classified as 100-year events, and structures designed to withstand the force of storm waves and moving floodwaters of a given intensity will be more likely to be subjected to stronger forces.<sup>89</sup>

### B. Saltwater Intrusion

As a result of sea level rise, flooding will not be the only issue facing South Florida. Saltwater intrusion will be another battle to fight. Saltwater intrusion is not a problem for the future but is already occurring as current sea level and coastal development have increased the threat of saltwater seeping into the water supply.<sup>90</sup> “In South Florida it is known that sea level and coastal aquifer groundwater levels are coherently linked, and that sea level rise promotes saltwater intrusion into the surficial aquifer.”<sup>91</sup> Most of the coastal communities in the southern portion of Florida depend on an underground freshwater aquifer to provide water supply through wellfields.<sup>92</sup> Acceleration of saltwater intrusion into the underground aquifer will worsen as sea level rises and withdrawals from the aquifer increase due to a growing South Florida population.<sup>93</sup>

The primary source of drinking water for South Florida is the Biscayne Aquifer because of its accessibility and the quality of its water, whereas the Floridian Aquifer, which also underlies South Florida, consists of brackish, salty water, which requires treatment for the

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87. Elizabeth A. Stanton and Frank Ackerman, *Florida and Climate Change: The Costs of Inaction*, Tufts University, Global Development and Environment Institute and Stockholm Environment Institute—US Center, Nov. 2007, at vi, available at [http://www.ase.tufts.edu/gdae/Pubs/rp/Florida\\_lr.pdf](http://www.ase.tufts.edu/gdae/Pubs/rp/Florida_lr.pdf) (last visited Apr. 17, 2012).

88. Environmental Protection Agency, *supra* note 15.

89. Deyle, Bailey & Matheny, *supra* note 77, at 6.

90. South Florida Water Management District, *supra* note 45, at 10.

91. South Florida Water Management District, *supra* note 66, at 105.

92. South Florida Water Management District, *supra* note 45, at 10.

93. Florida Oceans and Coastal Council, *supra* note 32, at 13.

water to be potable.<sup>94</sup> Rainfall and freshwater from the Everglades recharges the Biscayne Aquifer which is “the principal water supply to southeastern Florida and the Florida Keys.”<sup>95</sup> As sea level rises, hydraulic backpressure on coastal aquifers will increase, and groundwater flow towards the ocean will be reduced causing “the saltwater front to move inland, thus threatening to contaminate water supply wells in coastal areas with seawater.”<sup>96</sup> Areas of the low-lying southernmost Everglades will face an increase of brackish water that will move farther northward with sea level rise.<sup>97</sup>

During periods of drought and dry winter and spring seasons, saltwater intrusion will increase as sea level rises.<sup>98</sup> Furthermore, saltwater intrusion could contaminate sewer collection systems by increasing the salt content and is likely to complicate wastewater treatment operations.<sup>99</sup> “The flooding of flat, coastal regions and the resulting wave run-up during extreme storms may cover large depressions in the interior and result in rapid vertical infiltration of saltwater down into the freshwater aquifers.”<sup>100</sup> To assure an adequate water supply in light of a 6 inch or greater sea level rise or more, water management strategies will need to be implemented that include desalination, “water conservation, wastewater reuse, recovery and recharge, stormwater storage, and other advance water management strategies.”<sup>101</sup>

Another issue that saltwater intrusion will affect is the issue of drainage.<sup>102</sup> As the network of canals in South Florida fight against saltwater intrusion, a predetermined water level is necessary to abate contamination of the water supply.<sup>103</sup> “The canal networks in Palm Beach, Broward, and Miami-Dade counties and in the lower West Coast are typically maintained at predetermined water levels to reduce saltwater intrusion into the wellfields that provide drinking water to the region and to provide flood protection.”<sup>104</sup> The canal system in

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94. South Florida Water Management District, *Groundwater Modeling*, <http://www.sfwmd.gov/portal/page/portal/xweb%20-%20release%203%20water%20supply/ground%20water%20modeling> (last visited Apr. 17, 2012).

95. Florida Oceans and Coastal Council, *supra* note 32, at 13.

96. *Id.*

97. *Id.*

98. *Id.*

99. *Id.*

100. South Florida Water Management District, *supra* note 66, at 121.

101. Florida Oceans and Coastal Council, *supra* note 32, at 13.

102. South Florida Water Management District, *supra* note 45, at 8-9.

103. *Id.*

104. *Id.*

South Florida is a dichotomy as in essence the canal's function must maintain a level of water that is both high and low because there is a need to maintain a water level low enough to prevent flooding but high enough to raise aquifer levels to limit saltwater intrusion.<sup>105</sup> Sea level rise will complicate this delicate balance, and increase the risk of saltwater intrusion and/or detrimentally impact flood control capabilities.<sup>106</sup>

### C. Ecological Destruction

Due to South Florida's low-lying topography, ecologically sensitive areas such as the Dry Tortugas and Biscayne National Parks, and two-thirds of Everglades National Park, at an elevation lower than 3 feet, will be particularly susceptible to sea level rise.<sup>107</sup> Other ecological effects as a result of sea level rise will be the inundation of coastal habitats, including mangrove trees that stabilize sediments, if the rate of sea level rise is rapid.<sup>108</sup> "A June 2006 report by the National Wildlife Federation and the Florida Wildlife Federation highlighted these potential impacts and suggested that sea level rise would harm the world-class recreational fishery in Florida Bay for bonefish, yellowtail snapper, permit, redfish, snook, spotted sea trout, and tarpon."<sup>109</sup> In the past, sea levels in Florida have risen slowly allowing for tidal wetlands, including mangrove forests and salt marshes, to accumulate sediment "and grow into expansive habitats for estuarine and marine life."<sup>110</sup> Nonetheless, tidal wetlands will disappear if sea level rise exceeds the capacity of these wetlands to accumulate sediment.<sup>111</sup> Furthermore, as a result of sea level rise "sandbars and shoals, estuarine beaches, salt flats, and coastal forests will be altered."<sup>112</sup>

Tidal river ecosystems in light of sea level rise will see changes to coastal geological processes that will affect distribution, abundance, and productivity.<sup>113</sup> Examples of these changes are already occurring

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105. South Florida Water Management District, *supra* note 66, at 131.

106. *Id.*

107. National Park Service, *Climate Change and South Florida's National Parks: Portrait of a Changing Landscape*, Fact Sheet, South Florida Natural Resources Center, 2005, at 2, available at <http://www.nps.gov/ever/naturescience/upload/ClimateChangeFSHiResSecure.pdf> (last visited Apr. 17, 2012).

108. *Id.*

109. *Id.*

110. Florida Oceans and Coastal Council, *supra* note 32, at 8.

111. *Id.*

112. *Id.*

113. *Id.*

in vital wetlands of the Big Bend and the Everglades, as estuarine and coastal forests and swamps “are retreating or perishing and being replaced by salt-marsh vegetation or open water.”<sup>114</sup> Eventually, some tidal wetlands will “pinch out” at constant rates of sea level rise as infrastructure such as seawalls, roads, and developments will prevent upslope migration.<sup>115</sup> Additionally, most tidal wetlands in areas that have a low supply of freshwater and sediment will drown out as the tidal wetlands will be unable to accrete vertically.<sup>116</sup> As a result of the loss of tidal wetlands, a key buffer against storm impacts will be lost.<sup>117</sup>

The probability that low-lying barrier islands of the Florida Keys and Ten Thousand Islands will be inundated will increase as sea level rises, and this will cause the reduction and elimination of habitat for rare and endemic plant and animal species.<sup>118</sup> Low-lying, flood-prone ecosystems or open water will replace plant communities in tidal rivers and bayheads.<sup>119</sup> Seagrass and tidal freshwater plants will be affected by sea level rise as existing habitat will be redistributed, and productivity will be reduced as an increase in water depth will prevent light from reaching underwater seagrass.<sup>120</sup> “Increased saline flooding will strip upland soils of their organic content.”<sup>121</sup> The ability of coastal plant communities to grow and form peat will possibly be reduced in light of extended hydroperiods as it relates to increased sea level rise.<sup>122</sup> “Everglades National Park and the Institute for Regional Conservation (IRC) have identified 27 rare plant species that they believe will be affected by sea level rise on the basis of their primarily or entirely coastal distribution. Of these . . . 4 are endemic.”<sup>123</sup>

Tropical and temperate fish species will also be affected by an increase in sea level since most of those fish species living in Florida Bay live in “shallow water, tidal flats, seagrass banks, and mud-

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114. *Id.*

115. *Id.*

116. *Id.* at 9.

117. *Id.*

118. *Id.*

119. *Id.*

120. *Id.*

121. *Id.*

122. *Id.* at 10.

123. National Park Service, *Potential Ecological Consequences of Climate Change in South Florida and the Everglades: 2008 Literature Synthesis*, Resource Evaluation Report, SFNRC Technical Series 2009:1, at 14-15, available at <http://www.nps.gov/ever/nature/science/upload/TRClimateChangeLoResSecure.pdf> (last visited Apr. 17, 2012).



flats."<sup>124</sup> Increased turbidity due to resuspension of sediment materials on top of tidal flats and mud banks will result if sea level rise continues at its projected rate, causing a loss of nursery function ("fish shelter and sustenance") of tidal flats.<sup>125</sup> Displacement or population shift will occur as a result, and important recreational and ecological marine fish species will be affected including tarpon, snook, and mullet.<sup>126</sup> Sea turtle populations will also be affected by sea level rise as beach erosion (as a result of both sea level rise and secondary effects of hard structures such as seawalls) and inundation of rising seas will cause a loss of sea turtle nesting habitat.<sup>127</sup> "In the Ten Thousand Islands area in southwestern Florida, success of loggerhead sea turtle hatchlings decreased as inundations, sand water content, and sand water salinity increased on low-relief mangrove islands."<sup>128</sup>

The loss of coastal marshes as sea level rise increases will affect resident and migratory wading birds and shorebirds.<sup>129</sup> As a result of loss of habitat, wading birds will find it increasingly difficult to find suitable nesting habitat and prey.<sup>130</sup> Furthermore, birds in the Everglades, such as the endangered Cape Sable Seaside Sparrow, time their breeding cycle with hydrologic events, and nests will likely be flooded with rising sea level if water depths are too great.<sup>131</sup> Potentials for nest abandonment due to reversals of water level may occur with wading birds such as the White Ibis and Wood Stork that "initiate nesting as water recedes in the dry season."<sup>132</sup>

Mammals will also be affected by rising sea levels and resulting storm surges as portions of habitat will be inundated permanently or episodically.<sup>133</sup> Endangered species endemic to the Florida Keys "such as the Key deer, Key Largo woodrat, Key Largo cotton mouse, silver rice rat, and Lower Keys marsh rabbit" will all face permanent or episodic habitat loss as a result of sea level rise.<sup>134</sup> Changes in habitat and prey availability due to sea level rise will affect species such as the endangered Florida panther, and "if freshwater flows are not restored . . . animals [will] not have time to adjust to the saltwater flooding and

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124. *Id.* at 15.

125. *Id.*

126. *Id.*

127. *Id.* at 18.

128. *Id.*

129. *Id.*

130. *Id.* at 15.

131. *Id.* at 19.

132. *Id.*

133. *Id.* at 20.

134. *Id.*

there may be catastrophic food web changes across thousands of acres in the Everglades, river mouths, coastal lagoons, and bays.”<sup>135</sup> Nevertheless, it is suggested that direct phenological or distributional responses in mammals is less likely as a result of climate change overall; however, a change in habitat and prey availability will have an impact.<sup>136</sup>

### III. SECURITY IMPLICATIONS FROM SEA LEVEL RISE FOR SOUTH FLORIDA

How can rising sea levels cause South Florida to be at a security risk? What is the nexus between sea level rise and insecurity? The concept of environmental security evolved from the expansion of traditional concepts of security after the Cold War where the notion of the use of force amongst state actors dominated security discourse and policy.<sup>137</sup> The concept of security can be defined as reducing fears of the future through “control, certainty, and predictability.”<sup>138</sup> Environmental security recognizes that environmental stress can lead to conflict and that such a threat can be on a regional, national, or even global scale.<sup>139</sup> Individuals and state actors are susceptible to environmental degradation in which economic livelihoods, health, quality of life, and increased conflict-induced inequalities or scarcity will lead to an unstable and insecure environment.<sup>140</sup>

Security is about the future or fears about the future. It is about contemporary dangers but also thwarting potential future dangers. It is about control, certainty, and predictability in an uncertain world . . . . It is about maintaining certain collective identities, certain senses of who we are, of who we intend to remain, more than who we intend to become. Security provides narratives of danger as the stimulus to collective action . . . Security discourses specify the endangered identity. . . To be effective they need to interpellate existing social identities and articulate them to other discourses in circulation and to commonsense geopolitical reasoning.<sup>141</sup>

National security in the United States has begun to take into account issues of environmental security in a field largely dominated

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135. South Florida Water Management District, *supra* note 45, at 11.

136. National Park Service, *supra* note 123, at 20.

137. JON BARNETT, *THE MEANING OF ENVIRONMENTAL SECURITY: ECOLOGICAL POLITICS AND POLICY IN THE NEW SECURITY ERA* 27 (New York: Zed Books 2001).

138. SIMON DALBY, *ENVIRONMENTAL SECURITY* 164 (University of Minnesota Press 2002).

139. *Id.* at 43.

140. *Id.*

141. DALBY, *supra* note 138, at 163-164.

in the past by military concerns grounded in the idea that security threats come from other nations (states).<sup>142</sup> The national security agenda in the United States has thus expanded to include concepts such as climate change, resource scarcity and environmental degradation as areas of concern that can lead to instability as a result of weakened infrastructure, intra and inter-state conflict, and economic deterioration springing from the decline of agriculture and other industries.<sup>143</sup> In 2010, the National Security Strategy, issued by the White House, incorporated climate change as a problem facing United States national security.<sup>144</sup> “The danger from climate change is real, urgent, and severe.”<sup>145</sup> In fact, The National Security Strategy notes that conflicts over resources will occur due to climate change, and that the issue is not just a domestic matter, but also a global concern.<sup>146</sup> In response to these nontraditional threats, the National Security Strategy calls for an increase in technological innovation and scientific discovery to combat climate change and resource scarcity.<sup>147</sup>

It is the combination of environmental stress with intervening variables that can lead to conflict, and therefore warrants attention in the national security agenda.<sup>148</sup> On a global scale, international forums like the United Nations have recognized the importance of environmental security.<sup>149</sup> The Brundtland Report, created during the United Nations World Commission on Environment and Development, noted that “environmental stress is both a cause and effect of political tension and military conflict . . . such conflicts are likely to increase as these resources [become] scarcer and competition for them will increase.”<sup>150</sup> While environmental conflict is one aspect of environmental security, a second feature is the ability of environmental degradation to impact a nation’s political economy and the quality of life of its citizens.<sup>151</sup>

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142. BARNETT, *supra* note 137, at 38.

143. NAROTTAM GAAN, ENVIRONMENTAL SECURITY: CONCEPT AND DIMENSIONS 98 (Gyan Books 2004).

144. National Security Strategy, United States Government (May 2010), *available at* [http://www.whitehouse.gov/sites/default/files/rss\\_viewer/national\\_security\\_strategy.pdf](http://www.whitehouse.gov/sites/default/files/rss_viewer/national_security_strategy.pdf) (last visited Apr. 17, 2012).

145. *Id.* at 43.

146. *Id.*

147. *Id.* at 30.

148. GAAN, *supra* note 143, at 45.

149. *Id.* at 43.

150. *Id.*

151. *Id.* at 30.

The environmental threats facing the planet are not simply the result of scientific miscalculations. Nor are they merely the consequence of ill-conceived management decisions. Ironically, it is the notion of security upon which our entire modern worldview is based that has led us to the verge of ecocide . . . . In less than a century the practice of geopolitics has pushed the world to the brink of both nuclear Armageddon and environmental catastrophe, forcing us to reconsider the basic assumptions of security that animate the modern worldview.<sup>152</sup>

Former U.S. Secretary of Defense, Leon Panetta, commented on the issue of climate change and national security by stating, “[T]his isn’t about the battle of climate change and the issues related to that. This is about what we are seeing happen and the intelligence that flows from that. And that is important for us to consider as we look at issues that can threaten America’s national security.”<sup>153</sup> According to NOAA’s Sectoral Engagement Fact Sheet on National Security, sea level rise and storm surges threaten to significantly impact low-lying, coastal defense installations that are both critically and strategically important.<sup>154</sup> Furthermore, effects of climate change, such as sea level rise, will increase U.S. security vulnerability by stretching the availability of resources in light of large-scale migrations, food and water scarcity, and political instability in developing regions.<sup>155</sup> Other security implications will be the ability of infrastructure to withstand the effects of sea level rise and increasing storm surges.<sup>156</sup>

### A. *Local and Regional Security*

In light of sea level rise, several areas of concern can cause local and regional instability for South Florida including destruction and disrepair of infrastructure, spread of pollution and hazardous waste contaminants that can affect human health, economic and political instability, and scarcity of resources compounded by an influx of

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152. NAROTTAM GAAN, *RELEVANCE OF ENVIRONMENT: A CRITIQUE ON INTERNATIONAL RELATION THEORIES* 42 (Gyan Books 2005) (quoting Jeremy Rifkin).

153. Francesco Fernia & Caitlin Werrell, *U.S. Secretary of Defense Leon Panetta on Climate Change and National Security*, The Center for Climate and Security, Mar. 5, 2012, at 1, available at <http://climateandsecurity.org/2012/03/05/u-s-secretary-of-defense-leon-panetta-on-climate-change-and-national-security/> (last visited Apr. 17, 2012).

154. National Oceanic and Atmospheric Administration, *NOAA’s National Climatic Data Center Sectoral Engagement Fact Sheet: National Security*, June 2010, at 1, available at <http://www.ncdc.noaa.gov/oa/userengagement/security.pdf> (last visited Apr. 17, 2012).

155. *Id.*

156. Alyson Kenward, *Sea Level Rise Brings Added Risks to Coastal Nuclear Plants*, Climate Central, Mar. 23, 2011, at 1, available at <http://www.climatecentral.org/news/sea-level-rise-brings-added-risks-to-coastal-nuclear-plants> (last visited Apr. 17, 2012).

temporary and permanent environmental refugees that will compete for limited resources. Critical facilities in Florida are at an increased risk from sea level rise including “2 nuclear power plants, 3 state prisons, 68 hospitals, 74 airports, 115 solid waste disposal sites, 140 water treatment facilities, 334 public schools, [and] 341 hazardous-material cleanup sites including 5 Superfund sites.”<sup>157</sup> The nuclear reactor at Turkey Point in Miami-Dade County will have to account for the rate of sea level rise and how that will impact safety assessment baselines including guarding against the maximum storm surge in a worst-case scenario.<sup>158</sup> Acceleration in sea level rise may cause worst-case scenario storm assessments to fall short, thus causing security concerns for both human health and safety.<sup>159</sup>

Beyond the threat of destruction and damage to infrastructure, South Florida also faces economic instability as a result of sea level rise. South Florida’s economy will be at risk as tourism, agriculture, commercial and recreational fishing, and industrial sectors will have to deal with environmental degradation and destruction from sea level rise. Beach erosion as a result of sea level rise will have a substantive impact on Florida’s tourist-based economy.<sup>160</sup> Economic impacts on South Florida will have a ripple effect across the nation as Southeast Florida “account(s) for a combined Gross Domestic Product of more than 2.5 billion [dollars] annually and more than 37 [percent] of state-wide economic output.”<sup>161</sup> Sea level rise impacts on infrastructure and the economy will enhance tensions within South Florida, and conflict is possible when multiplied by additional sources of stress on the system such as resource scarcity and competition for limited resources by the arrival of environmental refugees.

From a regional outlook, sea level rise amongst South Florida’s Caribbean neighbors, such as the Bahamas, Haiti and Cuba, can cause environmental security implications, such as increased immigration to South Florida. These impacts can lead to further strains on resources already targeted by rising sea levels, such as drinking water. An environmental refugee can be defined as “people who can no longer gain a secure livelihood in their homelands because of drought, soil erosion, desertification, deforestation and other environmental problems, to-

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157. Florida Oceans and Coastal Council, *supra* note 32, at 24.

158. Kenward, *supra* note 156.

159. *Id.*

160. Florida Oceans and Coastal Council, *supra* note 32, at 26.

161. Southeast Florida Regional Climate Change Compact, 2010, at 2, available at <http://www.southeastfloridaclimatecompact.org/documents/compact.pdf> (last visited Apr. 17, 2012).

gether with associated problems of population pressures and profound poverty.”<sup>162</sup> Complications arise as the host countries’ capacity is limited in its ability and willingness to take in environmental refugees.<sup>163</sup> As a result, immigration policies will have to be amended on both a national and local level in order to confront the challenge of preventing outbreaks of social tension, civil disorder, and the possibility of political upheaval.<sup>164</sup>

On a local level, sea level rise may bring domestic refugees migrating from counties such as Monroe, Miami-Dade and Broward inland to higher grounds or northward. Migration of domestic environmental refugees in the United States is not a novel phenomenon, but was documented after Hurricane Katrina.<sup>165</sup> “One estimate put the number of refugees in Katrina’s immediate aftermath, over an area of Louisiana, Mississippi and Alabama much larger than just New Orleans, at close to one million.”<sup>166</sup> As a result of sea level rise, inland migration from domestic refugees in South Florida may raise environmental justice issues, conflict with Everglades preservation, and tensions may be exacerbated as both domestic and international environmental refugees compete for shelter and food security.

#### IV. RECOMMENDATIONS

Sea level rise has already begun to impact South Florida and will continue to have deleterious effects on South Florida’s environment, economy, and population. In order to confront the challenge of sea level rise it will be necessary to adopt and implement resolutions that will mitigate and adapt to the various issues that South Florida will face. In 2007, the Florida Action Team on Energy and Climate Change commented on the need for adaptation by stating that “Florida’s ecosystems should be managed for resiliency by enhancing their

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162. Norman Myers, *Environmental Refugees: An Emergent Security Issue*, 13th Economic Forum, Prague, 2005, at 1, available at [http://www.osce.org/documents/eea/2005/05/14488\\_en.pdf](http://www.osce.org/documents/eea/2005/05/14488_en.pdf) (last visited Apr. 17, 2012).

163. *Id.* at 3.

164. *Id.*

165. Ethan Goffman, *Environmental Refugees: How Many, How Bad?*, Christian Science Monitor, June 2006, at 13, available at <http://www.csmonitor.com/2005/0912/p01s01-ussc.htm> (last visited April 17, 2012); see also Peter Grier, *The Great Katrina Migration*, Christian Science Monitor, Sept. 12, 2005, at 1, available at <http://www.csmonitor.com/2005/0912/p01s01-ussc.htm> (last visited Apr. 17, 2012).

166. *Id.*

ability to naturally adapt to the stresses of climate change.”<sup>167</sup> The Florida Constitution mandates under Article II, Section 7(a) that “[i]t shall be the policy of the state to conserve and protect its natural resources and scenic beauty, [and a]dequate provision shall be made by law for the . . . conservation and protection of natural resources.”<sup>168</sup> Under the foregoing directive, the State of Florida and local governments have a duty to pursue policies that will protect the natural resources and scenic beauty of Florida, and sea level rise and its various impacts is a threat that must be confronted.

The regulatory framework addressing sea level rise will need to encompass a new approach that moves beyond action plans and that implements mitigation and adaptation measurements into federal, state and local laws. A reevaluation of the laws must take place and an assessment must be made as to whether the framework for preparation for sea level rise has been adequately established. Comprehensive land use planning and growth management along with conservation measurements, such as land acquisitions, can be an overarching tool for implementing strategies to deal with sea level rise.<sup>169</sup> Specifically, there is a link between land use planning and sea level rise in Florida as “current growth plans and development projections have the majority of residents clustered near the coast or in flood plains, reinforcing current growth patterns.”<sup>170</sup>

### A. National Regulations

On a national level, comprehensive management guidance can be found in the Coastal Zone Management Act (CZMA) of 1972, which “provides recommendations for a voluntary adoption of a coastal management plan in exchange for funding as a means to coordinate the development and preservation of coastal waters and shoreline.”<sup>171</sup> Voluntary development and execution under the CZMA occurs under local Coastal Zone Management Programs (CZMPs), and the Office of Ocean

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167. Florida Action Team on Energy and Climate Change, *Florida Action Team Final Report*, Chapter 8: Adaptation Strategies, 2007, at 8-4, available at <http://www.flclimatechange.us/ewebeditpro/items/O12F20146.PDF> (last visited Apr. 18, 2012).

168. FLA. CONST. art. II, § 7, para. a.

169. Barbara Lausche, *Synopsis of an Assessment: Policy Tools for Local Adaptation to Sea Level Rise*, Technical Report #1419 (Oct. 2009) 8, [http://www.mote.org/clientuploads/MPI/Synopsis-Policy Tools for Local Adaptation to Sea Level Rise\(fin\).pdf](http://www.mote.org/clientuploads/MPI/Synopsis-Policy Tools for Local Adaptation to Sea Level Rise(fin).pdf) (last visited Apr. 18, 2012).

170. *Id.*

171. Lauren Coleman, *Making Soft Infrastructures a Reality in New York City: Incorporating Unconventional Storm Defense Systems as Sea Levels Rise*, 36 WM. & MARY ENVTL. L. & POLY REV. 529, 543 (2012).

and Coastal Resources Management provides states with funding in exchange for the development of CZMPs.<sup>172</sup> The CZMA addresses sea level rise in 16 U.S.C. § 1451(I) and states that “because global warming may result in a substantial sea level rise with serious adverse effects in the coastal zone, coastal states must anticipate and plan for such an occurrence.”<sup>173</sup> Furthermore, 16 U.S.C. § 1452(2)(B) states that the congressional declaration of policy includes sea level rise considerations in “the management of coastal development to minimize the loss of life and property.”<sup>174</sup> Under the CZMA, “Coastal Zone Enhancement Grants” are provided for nine specific purposes.<sup>175</sup> “The most relevant purposes are (1) protecting and enhancing wetlands, (2) addressing natural hazards, (3) fostering special area management planning, (4) planning for ocean resources, and most importantly, (5) anticipating and managing the effects of potential sea level rise.”<sup>176</sup>

In the end, the CZMA is a useful tool for states and local government agencies to use in implementing coastal policy that deals with sea level rise.<sup>177</sup> Nevertheless, it remains a voluntary program with “a great deal of latitude for states and local government agencies to implement and emphasize the programs of their choosing.”<sup>178</sup> Thus, the CZMA’s overall power to help mitigate potential consequences of sea level rise in Florida may be minimal at best because it depends on the voluntary desires of the state or local government agencies. Nevertheless, the funding component in exchange for development of CZMA programs is a helpful motivator for states, such as Florida, to include sea level rise considerations in coastal management plans.

Another helpful piece of federal legislation that promotes the incorporation of mitigation against sea level rise in coastal management policies is the Coastal Barrier Resources Act (CBRA) of 1982.<sup>179</sup> CBRA limits federal spending and programs “that encourage further

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172. *Id.*

173. 16 U.S.C. § 1451(I) (2012).

174. 16 U.S.C. § 1452(2)(B) (2012); *see also* 16 U.S.C. § 1452(2)(K) (CZMA programs should at least provide “the study and development, in any case in which the Secretary considers it to be appropriate, of plans for addressing the adverse effects upon the coastal zone of . . . sea level rise.” Furthermore, under 16 U.S.C. § 1452(3): CZMA policy is “to encourage the preparation of special area management plans which provide for increased specificity in protecting significant natural resources. . . improved protection of life and property in hazardous areas, including those areas likely to be affected by. . . sea level rise. . . and improved predictability in governmental decision making.”

175. Coleman, *supra* note 171, at 545.

176. *Id.*

177. *Id.*

178. *Id.*

179. *Id.*



construction and expansion on coastal barriers,” and “sets aside ‘undeveloped coastal barriers and adjacent areas’ from increased development.”<sup>180</sup> CBRA seeks to protect coastal barriers, including those along the Atlantic and Gulf coasts, because “coastal barriers serve as natural storm protective buffers and are generally unsuitable for development because they are vulnerable to hurricane and other storm damage . . . .”<sup>181</sup> By designating certain undeveloped coastal barriers as areas ineligible for “most new federal expenditures and financial assistance,” including federal flood insurance, CBRA “encourages the conservation of hurricane prone, biologically rich coastal barriers.”<sup>182</sup>

Nevertheless, while federal funding of development and assistance is curtailed and provides protection for certain coastal barriers, state laws have not provided the same extent of protection, and certain development has been allowed to continue.<sup>183</sup> For example, in Walton County, Florida, “communities may permit development in [Coastal Barrier Resources protected areas] even though no federal assistance, such as flood insurance, is available, provided that the development meets NFIP (National Flood Insurance Program) requirements.”<sup>184</sup> Therefore, to strengthen the conservation of coastal barriers, a similar state law should be incorporated that mirrors the federal legislation. This double layer of federal and state regulation would increase Florida’s resiliency to sea level rise through the protection of coastal barriers.

Another federal legislative tool that can incorporate sea level rise into policy considerations is through the National Flood Insurance Program (NFIP), administered by the Federal Emergency Management Act (FEMA).<sup>185</sup> The NFIP is

a voluntary program based upon a mutual agreement or partnership between the federal government and local communities. This partnership provides that the federal government will make federally backed flood insurance available to home and business owners

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180. *Id.* at 545-46.

181. 16 U.S.C. § 3501(a)(3) (2012).

182. U.S. Fish and Wildlife Service, *Coastal Barrier Resources Act*, at 1, 2012, available at <http://www.fws.gov/CBRA/Act/index.html> (last visited Apr. 18, 2012).

183. Walton County, Florida, *COBRA Zones*, 1 available at <http://www.co.walton.fl.us/index.aspx?NID=721> (last visited Apr. 18, 2012).

184. *Id.*

185. Tampa Bay Regional Planning Council, *Sea Level Rise in the Tampa Bay Region*, August 14, 2006, 15, available at [http://www.tbrpc.org/mapping/pdfs/sea\\_level\\_rise/Tampa%20Bay%20-%20Sea%20Level%20Rise%20Project%20Draft%20Report%20without%20maps.pdf](http://www.tbrpc.org/mapping/pdfs/sea_level_rise/Tampa%20Bay%20-%20Sea%20Level%20Rise%20Project%20Draft%20Report%20without%20maps.pdf) (last visited Apr. 18, 2012).

in communities that agree to adopt and enforce comprehensive floodplain management standards designed to reduce flood damage.<sup>186</sup>

While the federal flood insurance program does not directly address sea level rise, the program does provide “important components of local responses to its effects.”<sup>187</sup>

### B. State Regulations

Florida law mandates that every county and incorporated city or town have a local comprehensive land use plan to balance several elements including, but not limited to, environmental and economic development.<sup>188</sup> However, sea level rise is not explicitly required under state law to be included in local comprehensive land use plans.<sup>189</sup>

Florida’s comprehensive planning laws and procedures will need careful reexamination in light of climate change predictions. In particular, coastal communities and regions that are likely to experience long-term sea level rise and the combination of sea level rise, hurricanes, and storm surge will want to ensure that development over the next several decades does not put people and communities in harm’s way [and] [f]uture land use maps will have to be revisited, and climate change impacts should be assessed in Comprehensive Plans, including especially Coastal Management and Capital Improvement elements.<sup>190</sup>

In 2011, several changes were incorporated into Florida’s comprehensive planning laws that were both positive and negative as it relates to sea level rise.<sup>191</sup> On a positive note, the Southeast Florida Regional Climate Change Compact (Compact) was able to lobby the Florida Legislature to designate “Adaptation Action Areas” as part of Florida’s growth management laws “as a means to prioritize investments for building resilience and guide future development in a more

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186. *Id.*

187. Land Use Law Center, Pace University School of Law, *Local Land Use Response to Sea Level Rise*, 9, available at [http://www.csc.noaa.gov/digitalcoast/\\_pdf/Pace\\_Final\\_Report.pdf](http://www.csc.noaa.gov/digitalcoast/_pdf/Pace_Final_Report.pdf) (last visited Apr. 18, 2012).

188. Lausche, *supra* note 169, at 8.

189. *Id.*

190. Florida Atlantic University (FAU), *Florida’s Resilient Coasts: A State Policy Framework for Adaptation to Climate Change*, Center for Urban and Environmental Solutions, 2008, 28, available at [www.ces.fau.edu/files/projects/climate\\_change/F1\\_ResilientCoast.pdf](http://www.ces.fau.edu/files/projects/climate_change/F1_ResilientCoast.pdf).

191. T. Ruppert, *2011 Changes to Florida’s Planning Laws: Impacts on Coastal Planning*, Florida Sea Grant (Aug. 5, 2011) 1, available at <http://www.flseagrant.org/coastalplanning/test-post/> (last visited Apr. 18, 2012).

thoughtful way to reduce risks in vulnerable areas.”<sup>192</sup> Under Section 163.3177(6)(g)(10) of the Florida Statutes, an Adaptation Action Area is an *optional* designation that local governments can develop in low-lying coastal areas prone to flooding from extreme high tides and storm surges “and vulnerable to the impacts of rising sea level.”<sup>193</sup> Overall, the Adaptation Action Area is a helpful planning tool for local governments in mitigating potential damage to infrastructure and communities from the threat of sea level rise.<sup>194</sup>

To strengthen further the planning capacity of Adaptation Action Areas, room for improvement in the definition is needed for maximum protection from sea level rise. The definition of Adaptation Action Area does not incorporate all areas at risk from sea level rise including “low-lying areas that flood during heavy rains because of their low elevation and poor drainage, which may be exacerbated by tides or storms, and [t]he existing definitions in the law should allow for inclusion of such areas as ‘Adaptation Action Areas.’”<sup>195</sup> Additionally, the optional nature of both the designation and boundaries of an Adaptation Action Area by local governments<sup>196</sup> can lead to a lack of uniformity within the State of Florida concerning coastal management of sea level rise. One coastal local government may seek to mitigate and adapt to sea level rise, while another coastal local government may ignore the implications of sea level rise and move towards development in vulnerable areas to generate revenue. The end result is a variance of local vulnerability that can threaten the security of coastal communities throughout the state.

Consequently, as growth management laws have been further amended throughout the years, an opening has been created allowing more building near the coast in areas considered “coastal high-hazard areas.”<sup>197</sup> Under Section 163.3178(2)(h) of the Florida Statutes, a

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192. Steve Adams & Rachel M. Gregg, Southeast Florida Regional Climate Change Compact, *Climate Adaptation Knowledge Exchange* (June 28, 2010), <http://www.cakex.org/case-studies/1469>.

193. FLA. STAT. § 163.3177(6)(g)(10) (2011); *see also* FLA. STAT. § 163.3177(6)(g)(6) (2011) (incorporating the requirement that local coastal management plan elements “limit public expenditures that subsidize development in coastal high-hazard areas”).

194. Adams & Gregg, *supra* note 192.

195. Ruppert, *supra* note 191.

196. Florida Dept. of Economic Opportunity, *Adaptation Planning*, available at <http://www.floridajobs.org/community-planning-and-development/programs/technical-assistance/community-resiliency/adaptation-planning> (last visited Apr. 18, 2012).

197. Andy Reid, *Palm Beach County Shrinks Coastal ‘Hazard Areas,’ Opens Door to Development*, SUN SENTINEL, Oct. 11, 2011, available at [http://articles.sun-sentinel.com/2011-10-11/news/fl-coastal-hazard-palm-20111011\\_1\\_hazard-sea-level-rise-areas](http://articles.sun-sentinel.com/2011-10-11/news/fl-coastal-hazard-palm-20111011_1_hazard-sea-level-rise-areas) (last visited Apr. 18, 2012).

coastal high hazard area (CHHA) is defined as “the area below the elevation of the category 1 storm surge line as established by a Sea, Lake, and Overland Surges from Hurricanes (SLOSH) computerized storm surge model[, and a]pplication of mitigation and the application of development and redevelopment policies . . . and any rules adopted thereunder, shall be at the *discretion* of local government.”<sup>198</sup> Under future land use planning requirements, a Coastal Management Element must be included by coastal local governments which “[m]aintain[s], restore[s], and enhance[s] the overall quality of the coastal zone environment . . . . [u]se[s] ecological planning principles and assumptions in the determination of the suitability of permitted development . . . . [l]imit[s] public expenditures that subsidize development in *coastal high-hazard areas* . . . . [and] [p]rotect[s] human life against the effects of natural disasters.”<sup>199</sup> However, designation of a CHHA incorporates considerations of sea level rise because the primary focus is on “managing coastal development density in order to maintain evacuation capacity.”<sup>200</sup>

With recent changes by the legislature, proper land use planning tools such as CHHA may be ill-equipped to protect coastal communities against sea level rise due to its narrow focus. An example of how coastal management tools are failing to recognize the threat of sea level rise can be found in an article in the Sun Sentinel, noting that Palm Beach County has

shrunk its coastal high-hazard area by nearly 90 percent, blaming state mandates for the rule change that allows more building near the coast.

. . . .

Palm Beach County’s hazard area once covered more than 18,000 acres stretching from Jupiter to Boca Raton, but now includes about 2,000 acres due to revamped state requirements.<sup>201</sup>

Another avenue that policymakers can pursue in mitigating and adapting to sea level rise is through conservation measures, such as land acquisitions, that can help increase the resiliency of ecosystems in the face of rising sea levels. The Florida Forever Act “is Florida’s

198. FLA. STAT. § 163.3178(2)(h) (2011) (emphasis added).

199. FLA. STAT. § 163.3177(6)(g)1, 5-7 (emphasis added).

200. JAMES F. MURLEY, ANA PUSZKIN-CHEVLIN, ANN-MARGARET ESNARD & RACHEL KALIN, ASSESSMENT OF REDEFINING FLORIDA’S COASTAL HIGH HAZARD AREA VI (2008), available at <http://docs.edsi.fau.edu/cues/CHHAFINALREPORT-MAY212008.pdf> (last visited Apr. 18, 2012).

201. Reid, *supra* note 197.

premier conservation and recreation lands acquisition program, a blueprint for conserving natural resources and renewing Florida's commitment to conserve the state's natural and cultural heritage."<sup>202</sup> Under the Florida Forever Act, state agencies and programs are provided funding as appropriated by the legislature and distributed by the Florida Department of Environmental Protection to purchase land to be "held in trust for the citizens of Florida."<sup>203</sup> Under Section 259.105(17)(d) of the Florida Statutes, the legislature allows for property subject to sea level rise to be eligible for state land acquisition funding.<sup>204</sup> Florida Statute 259.105(17)(d) stresses the importance of land acquisitions as a means to address sea level rise, and states that

[o]n an annual basis, the Division of State Lands shall prepare an annual work plan that prioritizes projects on the Florida Forever list and sets forth the funding available in the fiscal year for land acquisition. The work plan shall consider the following categories of expenditure for land conservation projects already selected for the Florida Forever list . . . [a] climate-change category list of lands where acquisition or other conservation measures will address the challenges of global climate change, such as through protection, restoration, mitigation, and strengthening of Florida's land, water and coastal resources.<sup>205</sup>

Conservation of vital Florida ecosystems endangered by sea level rise can allow for management strategies that focus on protecting human habitat while ensuring species survival in light of long term effects of sea level rise.<sup>206</sup> "Florida Forever acquisitions have preserved more than 70,000 acres within coastal watersheds and 6,600 acres of fragile coastal resources that provide habitat for native species and build additional resilience through coastal buffering."<sup>207</sup> Further coastal acquisitions under Florida Forever will continue to help coastal communities prepare for sea level rise by providing natural disaster mitigation.<sup>208</sup>

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202. Florida Department of Environmental Protection, *Florida Forever* (2012) available at [http://www.dep.state.fl.us/lands/fl\\_forever.htm](http://www.dep.state.fl.us/lands/fl_forever.htm) (last visited Apr. 18, 2012).

203. *Id.*

204. FLA. STAT. § 259.105(17) & (17)(d)(d) (2012).

205. *Id.*

206. THE NATURE CONSERVANCY, ECONOMIC BENEFITS OF LAND CONSERVATION: A CASE FOR FLORIDA FOREVER 10 (2009) available at [http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/florida/howwework/economic\\_benefits\\_of\\_land\\_conservation-2.pdf](http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/florida/howwework/economic_benefits_of_land_conservation-2.pdf) (last visited Apr. 18, 2012).

207. *Id.*

208. *Id.*

## CONCLUSION

Rising sea level is a reality that is already being felt. Flooding, saltwater intrusion, and ecological modification is happening now. Notions of direct shoreline impacts being the first stage of sea level rise are untrue. The stealthy impacts (such as saltwater intrusion) are already beginning to affect South Florida. As sea levels continue to increase and further affect South Florida's ecosystems, marine and animal life, coastal communities and populations, and housing and infrastructure will have to deal with the implications of sea level rise and the accompanying environmental changes. Security concerns as a result of increasing sea levels will arise further into the future, and policies dealing with resource and land conservation and protection, immigration, and infrastructure stability and maintenance will have to be implemented to assuage potential conflict-inducing situations. The key is for state and local government agencies to prepare for sea level rise now to mitigate and adapt to the challenges that will arise as sea levels increase.

Several federal and state regulations are already in place that can be further amended to provide increasing protection in light of sea level rise. Furthermore, other forms of adaptive responses concerning sea level rise can be implemented in regulations, including more comprehensive planning, siting, and design of public infrastructure, which encompass long range assessments of sea level rise mitigation and adaptation.<sup>209</sup> New pumping mechanisms for flood control structures, elevated design blueprints, desalinization plants, various shoreline protection schemes (including living shorelines), and even reduction in greenhouse gas emissions will aid coastal communities in South Florida as issues from sea level rise become more acute. What is needed now and moving forward is for the State of Florida to establish an overarching program that deals with sea level rise, allowing federal, state, and local regulations to unite in the effort to mitigate and adapt to sea level rise now and into the future.

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209. Deyle, Bailey, & Matheny, *supra* note 77, at 6.

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