Adaptation in a Sea of Uncertainty

Stormwater outfalls, Satellite Beach, FL

July 19, 2016

Photo by Emily Niederman

Sea Level Rise Planning at the Local Level

Jason M. Evans, Ph.D.
Assistant Professor of Environmental Science
Stetson University

November 17, 2016
Sea-level Rise and Flooding:
Planning and Law for Local Governments
Cocoa, FL

Sea Grant

STETSON UNIVERSITY

My Past Few Years

Outreach > Hyde County, NC Adaptation Plan

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Researcher Helps Florida Cities Adapt to Sea-Level Rise

August 11, 2016

Satellite Beach, FL Public Works

(From left to right) Emily Niederman, Jason Evans, Ph.D., and Adam Carr are mapping out the vulnerable areas of Satellite Beach, Fla. Photo by Rhiannon Boyer

community in the form of tailored resilience and adaptation plans.

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RANT

GEORGIA COAST

GALLERY

Go Fish...

son Evans, Charles Hopkinson, Roger eaver and Mayor John Morrissey meet launch the St. Marys Flood Resiliency nning project.

stablished in 1787, t. Marys is a historic ity that is vulnerable o anticipated coastal hanges, such as ncreased coastal ooding, rising seas nd intensified storm urges.

the project.

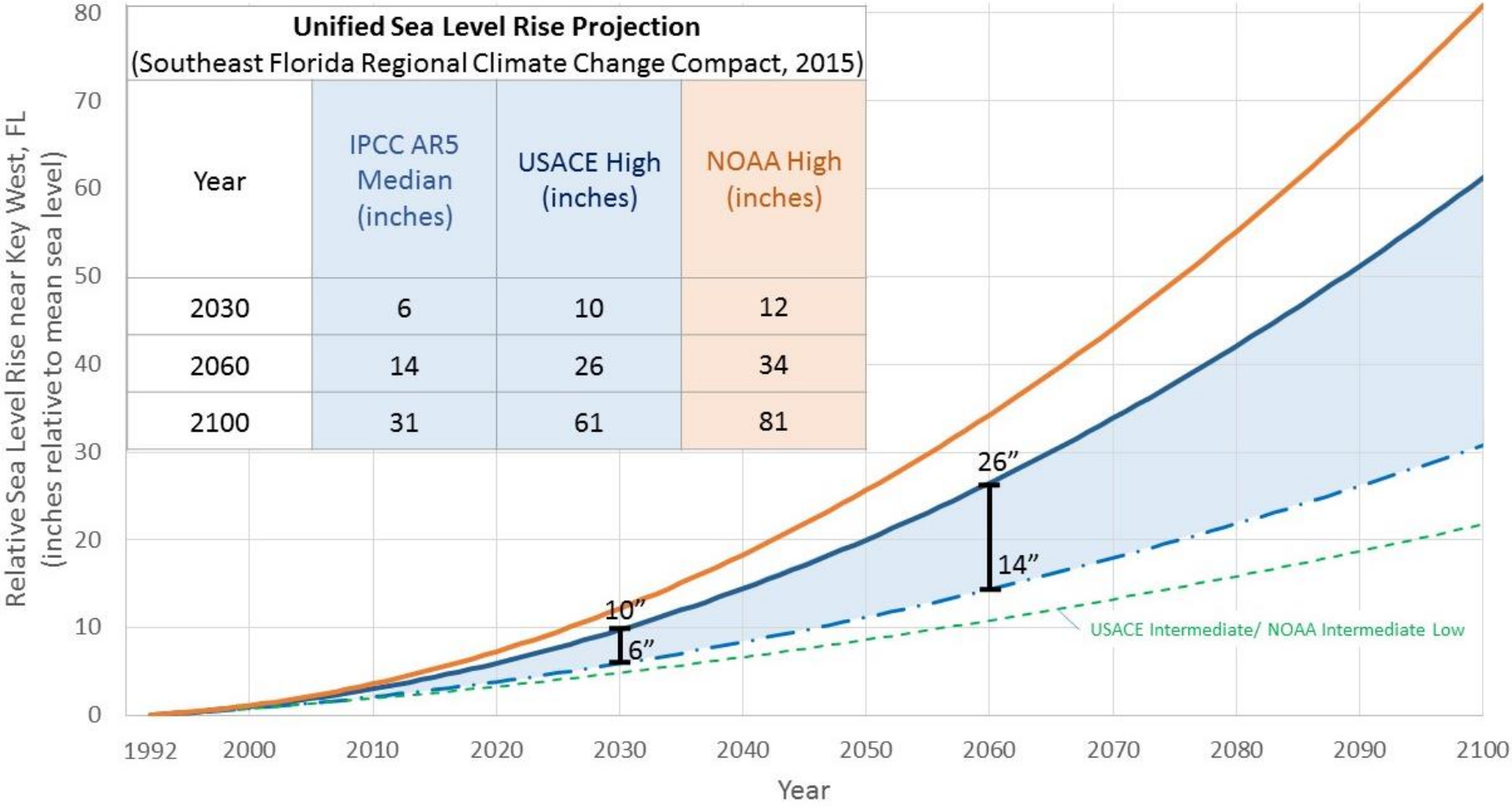
Assertion #1

Climate change adaptation is one of the most complex and daunting challenges ever faced by human civilization.

Sea-level Rise is a big deal for FL…

Unified Sea Level Rise Projection
(Southeast Florida Regional Climate Change Compact, 2015)

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



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NOAA: 'Nuisance flooding' an increasing problem as coastal sea levels rise

Study looks at more than 60 years of coastal water level and local elevation data changes

July 28, 2014

Eight of the top 10 U.S. cities that have seen an increase in so-called "nuisance flooding"--which causes such public inconveniences as frequent road closures, overwhelmed storm drains and compromised infrastructure--are on the East Coast, according to a new NOAA technical report.

Annapolis, Maryland, pictured here in 2012, saw the greatest increase in nuisance flooding in a recent NOAA study. (Credit: With permission from Amy McGovern.)

This nuisance flooding, caused by rising sea levels, has increased on all three U.S. coasts, between 300 and 925 percent since the 1960s.

The report, Sea Level Rise and Nuisance Flood Frequency Changes around the United States, also finds Annapolis and Baltimore, Maryland, lead the list with an increase in number of flood days of more than 920 percent since 1960. Port Isabel, Texas, along the Gulf coast, showed an increase of 547 percent, and nuisance flood days in San Francisco, California increased 364 percent.

"Achieving resilience requires understanding environmental threats and vulnerabilities to combat issues like sea level rise," says Holly Bamford, Ph.D., NOAA assistant administrator of the National Ocean Service. "The nuisance flood study provides the kind of actionable environmental intelligence that can guide coastal resilience efforts."

"As relative sea level increases, it no longer takes a strong storm or a hurricane to cause flooding," said William Sweet, Ph.D., oceanographer at NOAA's Center for Operational Oceanographic Products and Services (CO-OPS) and the report's lead author. "Flooding now occurs with high tides in many locations due to climate-related sea level rise, land subsidence and the loss of natural barriers. The effects of rising sea levels along most of the continental U.S. coastline are only going to become more noticeable and much more severe in the coming decades, probably more so than any other climate-change related factor."

The study was conducted by scientists at CO-OPS, who looked at data from 45 NOAA water level gauges with long data records around the country and compared that to reports of number of days of nuisance floods.

News release on July 28, 2014

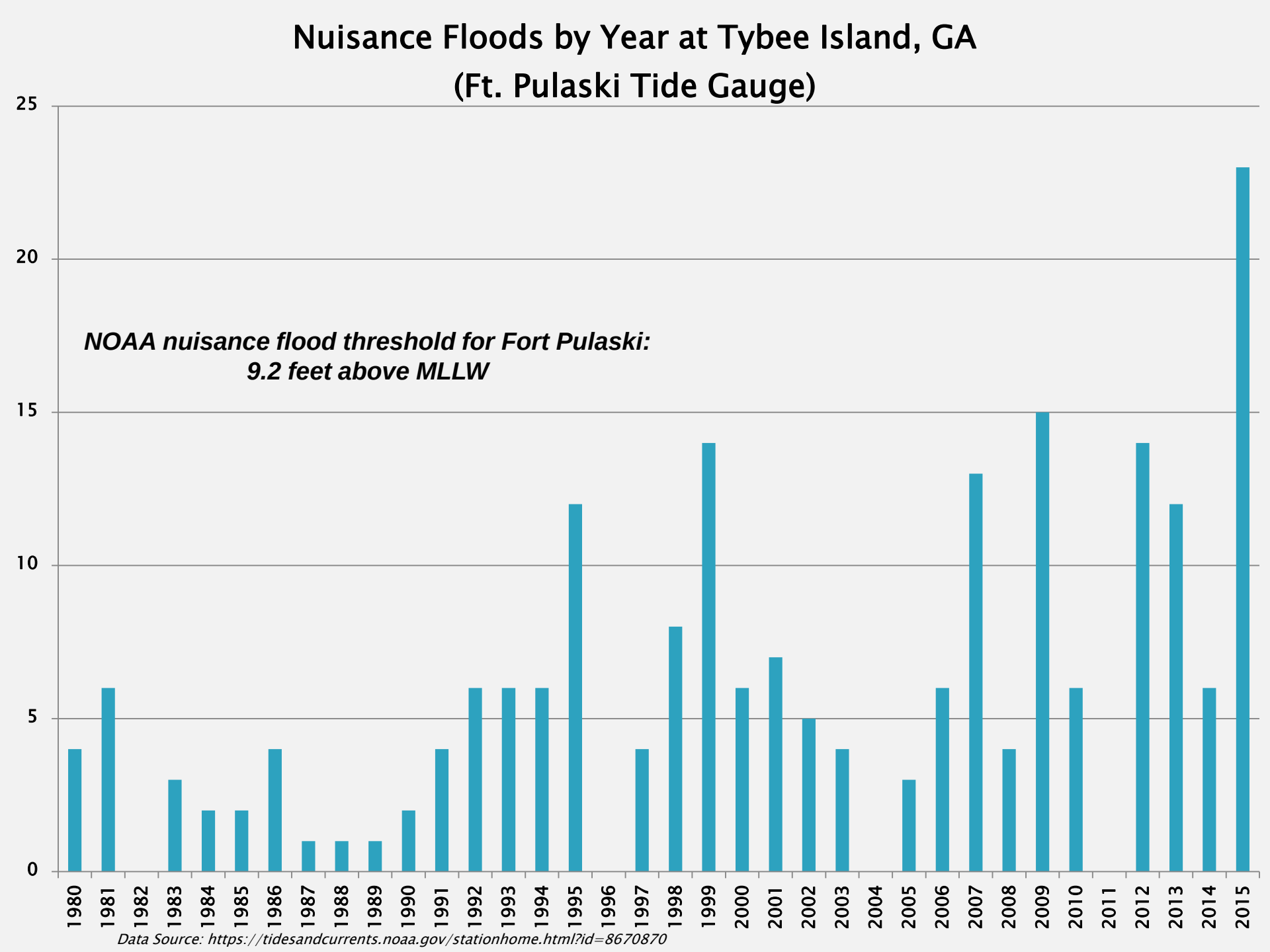
Miami Beach

http://s13.therealdeal.com/trd/m/up/2013/07/Miami-flooding-4-13-13.jpg.jpg

Tidal flooding on Tybee Island, GA
US Highway 80
October 27, 2015

Third highest tide on record (since 1935) for this gauge

Only exceeded by tropical storm surges


Nuisance Floods by Year at Tybee Island, GA
(Ft. Pulaski Tide Gauge)
25
20
15
10
5
0
NOAA nuisance flood threshold for Fort Pulaski:
9.2 feet above MLLW
1980
1981
1982
1983
1984
1985
1986
1987
1988
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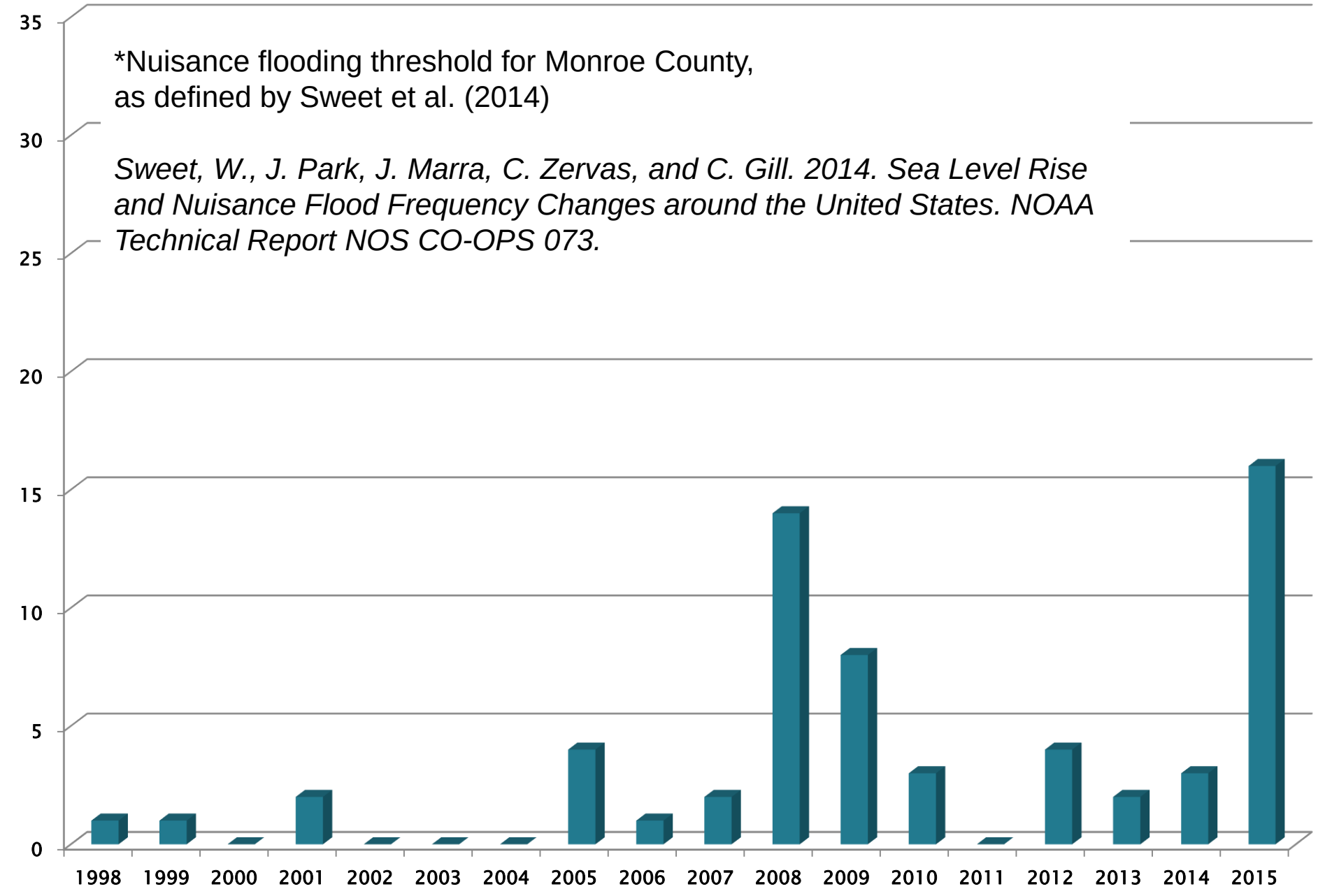
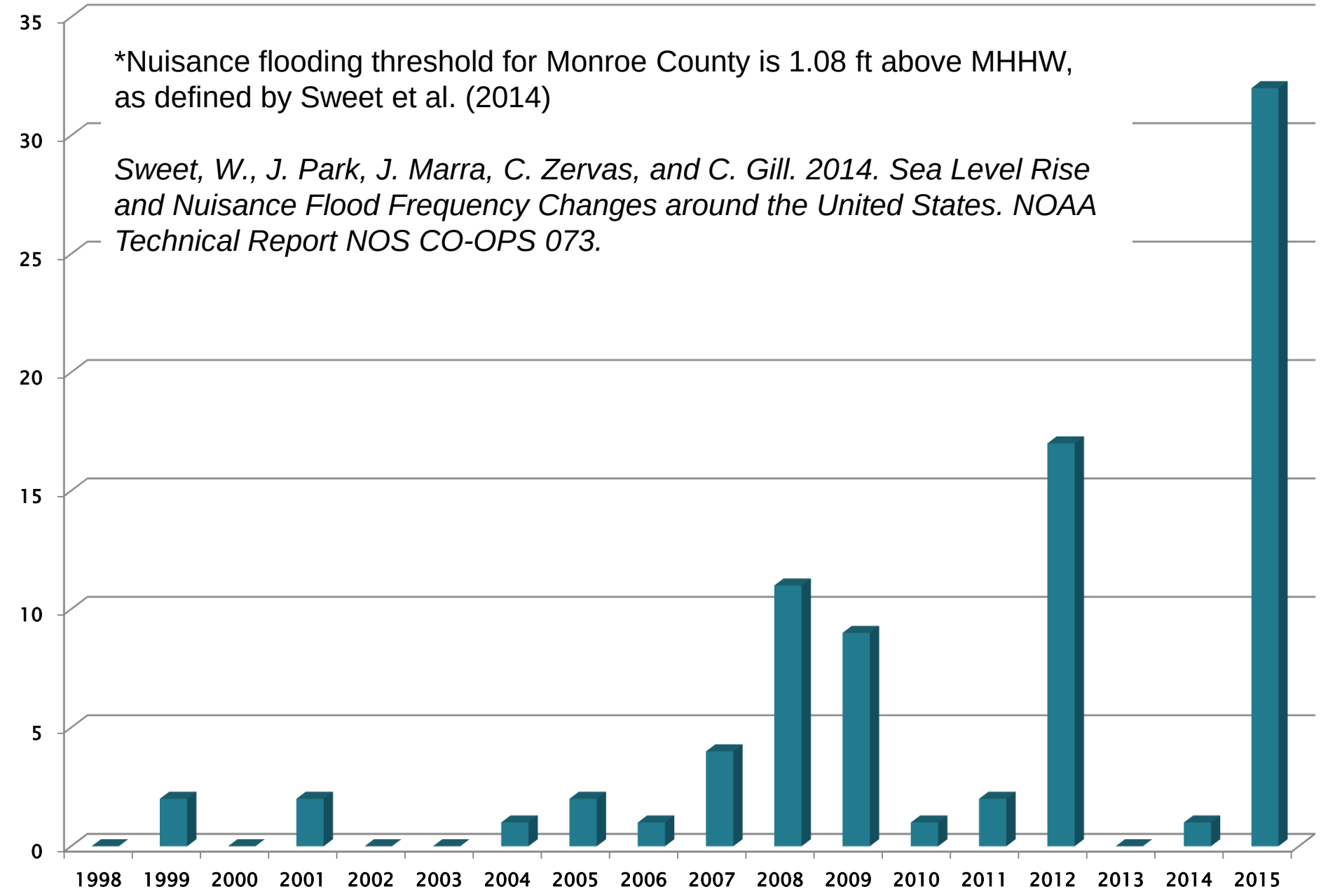
2013
2014
2015
Data Source: https://tidesandcurrents.noaa.gov/stationhome.html?id=8670870

Nuisance Floods Per Year at Key West



Nuisance Floods Per Year at Vaca Key (Marathon, FL)



Assertion #2

Very few development decisions being made today in vulnerable coastal communities are considering the consequences in a worst-case scenario at 2100.

nature climate change

LETTERS

PUBLISHED ONLINE: 14 MARCH 2016 | DOI: 10.1038/NCLIMATE2961

Millions projected to be at risk from sea-level rise in the continental United States

Mathew E. Hauer[1]*, Jason M. Evans[2] and Deepak R. Mishra[3]

Sea-level rise (SLR) is one of the most apparent climate change stressors facing human society[1]. Although it is known that many people at present inhabit areas vulnerable to SLR[2,3], few studies have accounted for ongoing population growth when assessing the potential magnitude of future impacts[4]. Here we address this issue by coupling a small-area population projection with a SLR vulnerability assessment across all United States coastal counties. We find that a 2100 SLR of 0.9 m places a land area projected to house 4.2 million people at risk of inundation, whereas 1.8 m affects 13.1 million people—approximately three times larger than indicated by current populations. These results suggest that the absence of protective measures could lead to US population movements of a magnitude similar to the twentieth century Great Migration of southern African-Americans[5]. Furthermore, our population projection approach can be readily adapted to assess other hazards or to model future per capita economic impacts.

Sea-level rise is widely recognized as one of the most likely and socially disruptive consequences of future climate change[2]. Scenarios of future SLR at the year 2100 range from a low of 0.3 m to a high scenario of 2.0 m associated with collapse of polar ice sheets[3]. Understanding the specific locations at risk of SLR impacts is a high priority in climate change research[6] and adaptation planning[7,8].

Although there is growing worry and debate that climate change could cause widespread human migration over the next century[2,9,10], relatively few studies have attempted to merge climate change scenarios with population growth trends and projections in high-risk areas (however, see ref. 11). Notably, several previous studies

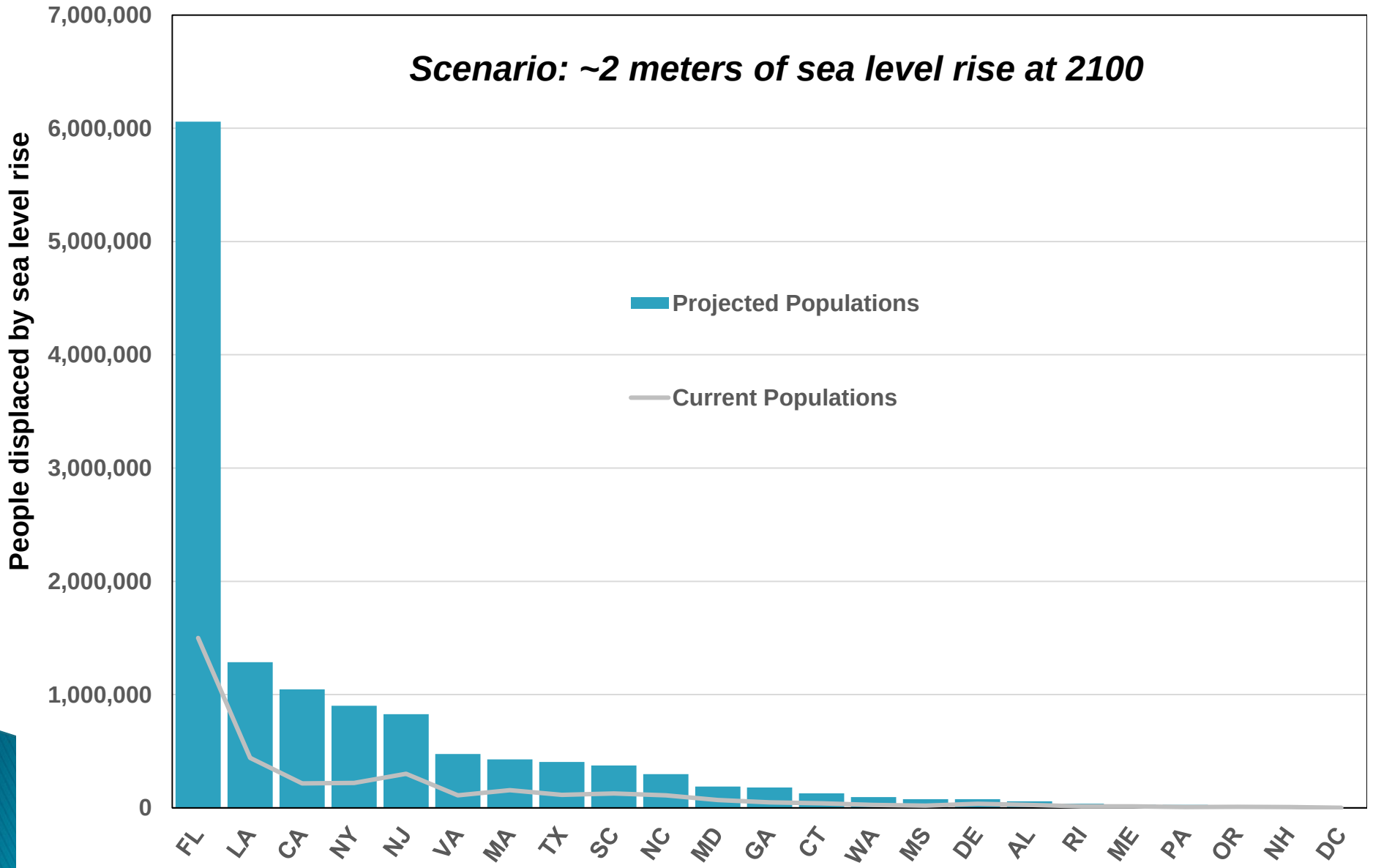
data (that is, elevation and associated flood risk) with small-area population projections developed with a modified version of the Hammer method[17,18] in a dynamic flood hazard model. By spatially and temporally aligning small-area population projections from coastal states in the continental United States (US) to 2100, we are able to assess who could be at risk from future SLR.

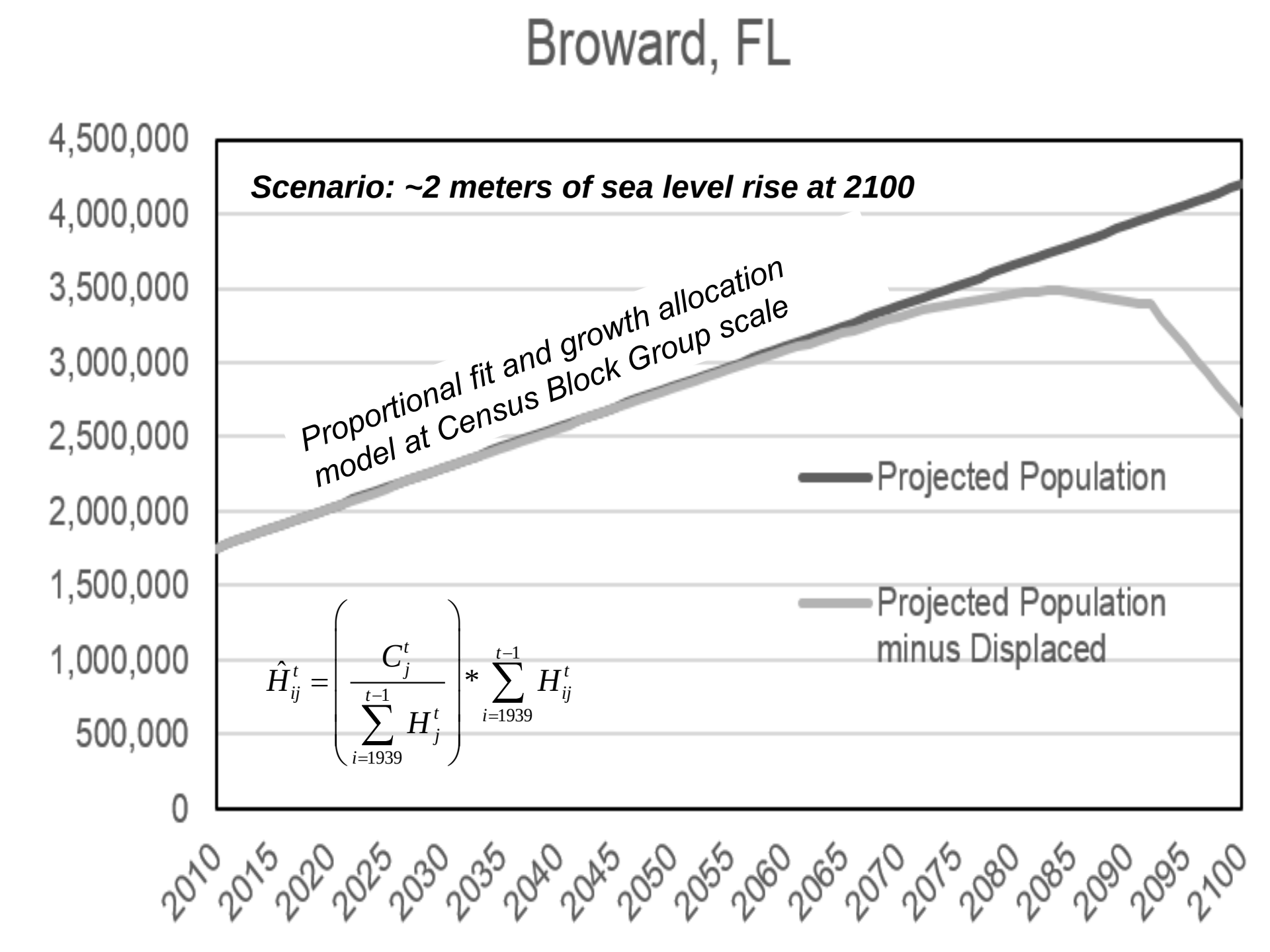
This approach addresses two fundamental questions concerning the vulnerability of future coastal populations in the United States: How many people are potentially at risk of impact from SLR? and What areas in the US are likely to experience the greatest population exposure to SLR? Accordingly, our results can be used to inform local adaptation infrastructure and growth management strategies, alerting officials to the areas where interventions and policies are most needed.

We assess the populations at risk of SLR by using the National Oceanic and Atmospheric Administration's (NOAA) 0 m through 1.8 m (6 feet) SLR data sets for twenty-two coastal states and the District of Columbia[19]. These data sets simulate expected changes in the mean higher high water (MHHW) mark on areas that are hydrologically connected to coastal areas, without taking into account additional land loss caused by other natural factors such as erosion. Notably, the state of Louisiana was not included in the data set at the time of analysis owing to local hydrologic complexities associated with coastal levees and accelerated land subsidence; however, we have recreated NOAA's hydrologic connectedness approach for Louisiana using USGS's National Elevation Dataset (NED) (Methods).

We used a linear/exponential extrapolation approach for

Population growth = Underestimation of problem




Broward, FL
Scenario: ~2 meters of sea level rise at 2100
Proportional fit and growth allocation model at Census Block Group scale
Projected Population
Projected Population minus Displaced
$\hat{H}_{ij}^{t} = \left(\frac{C_j^t}{\sum_{i=1939}^{t-1} H_j^t} \right) * \sum_{i=1939}^{t-1} H_{ij}^t$
4,500,000
4,000,000
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
2010
2015
2020
2025
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2035
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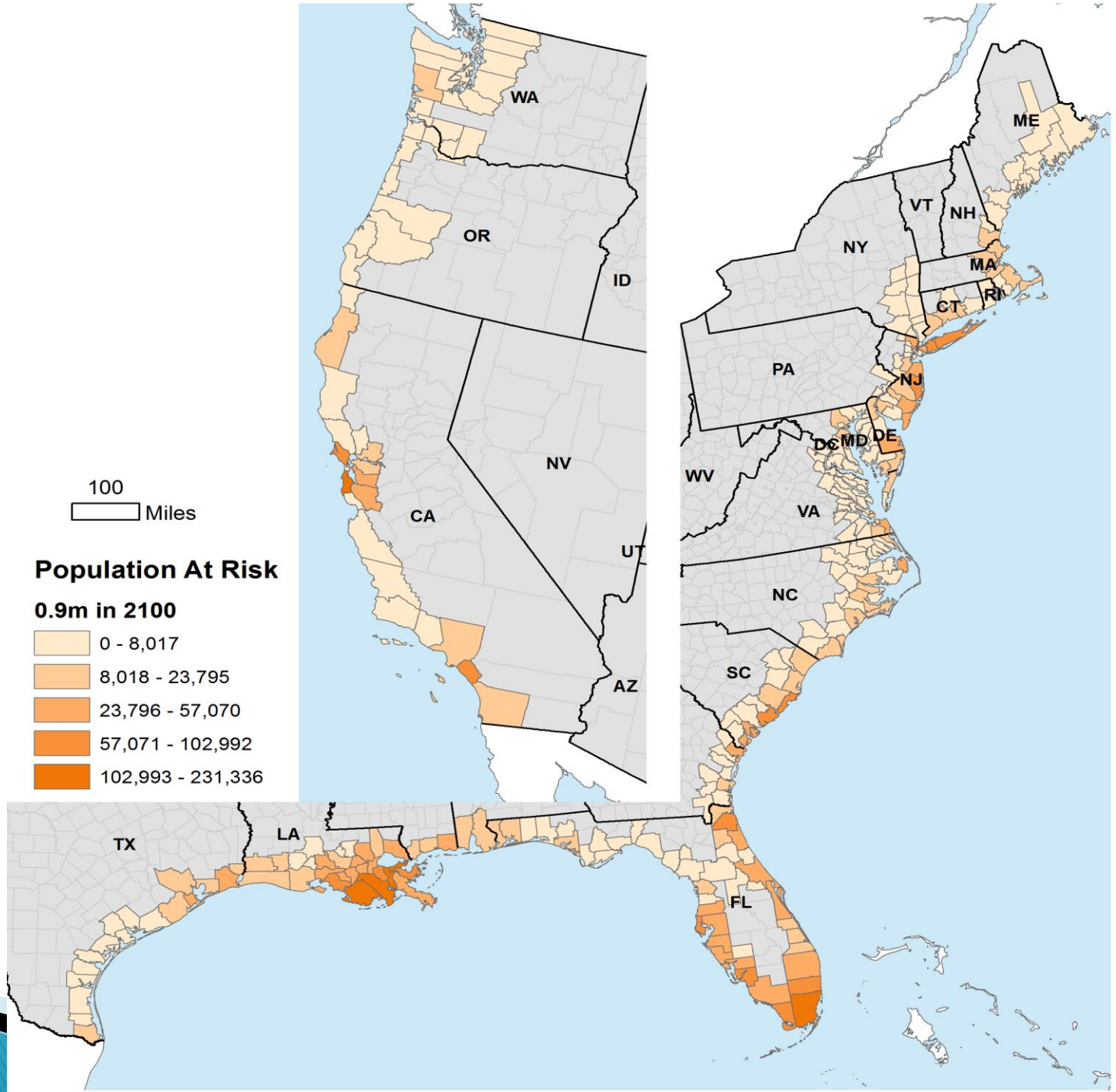
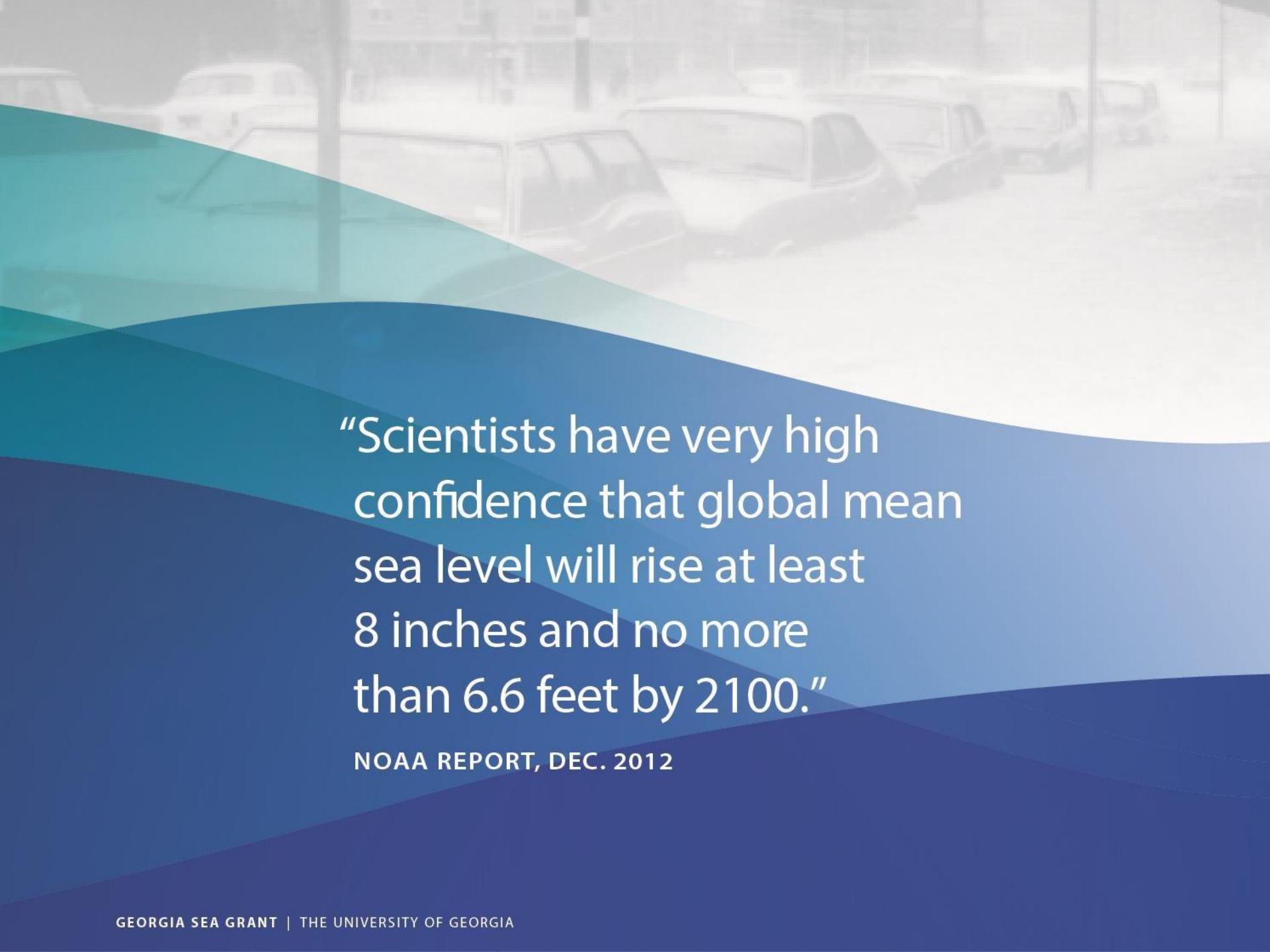
Credit: M.J. Hauer, J.M. Evans and D. Mishra



Assertion #3

Very few development decisions being made today in vulnerable coastal communities are considering the consequences in a worst-case scenario at 2100.

This is understandable – even appropriate – given uncertainty about the future over such a long time-horizon.



"Scientists have very high confidence that global mean sea level will rise at least 8 inches and no more than 6.6 feet by 2100."

NOAA REPORT, DEC. 2012

BIG difference between low and high scenario

Unified Sea Level Rise Projection
(Southeast Florida Regional Climate Change Compact, 2015)

Year	IPCC AR5 Median (inches)	USACE High (inches)	NOAA High (inches)
2030	6	10	12
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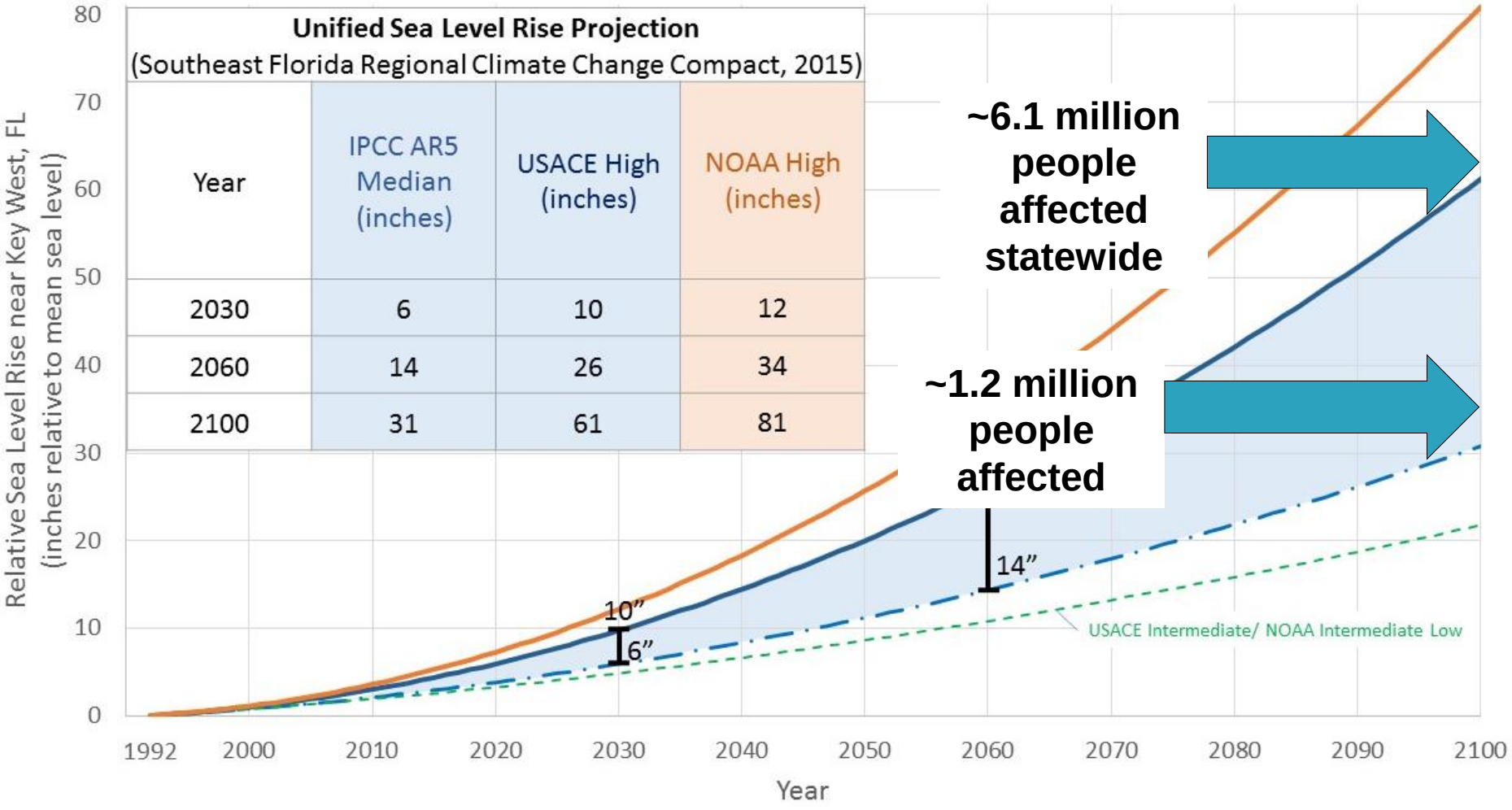


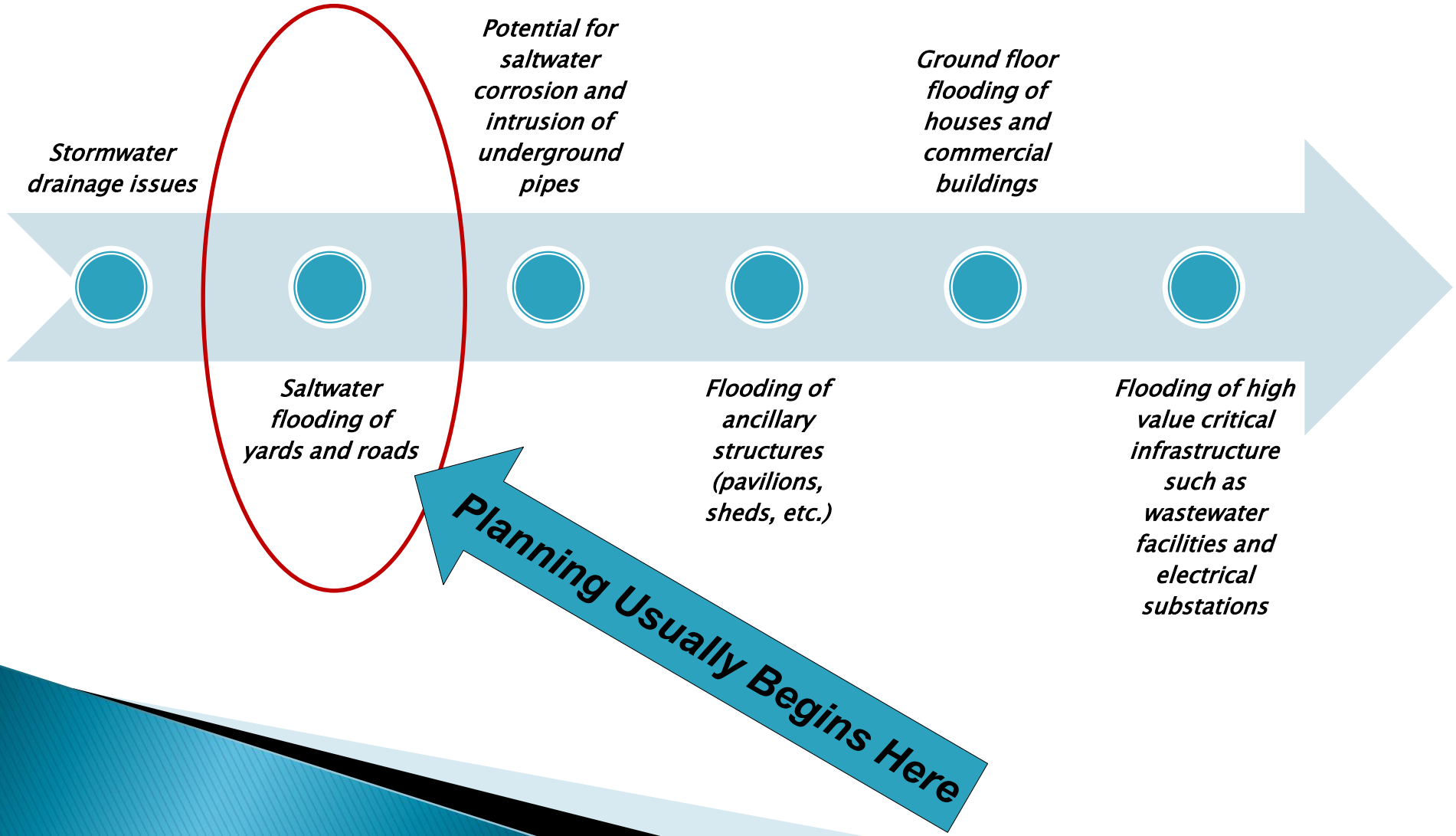
~6.1 million people affected statewide

~1.2 million people affected

Assertion #4

People start to really take notice when roads start flooding on a sunny day.

General Timeline of Sea Level Rise Impacts on the Built Environment



Tidal flooding on Tybee Island, GA
US Highway 80
October 27, 2015

Third highest tide on record (since 1935) for this gauge

Only exceeded by tropical storm surges

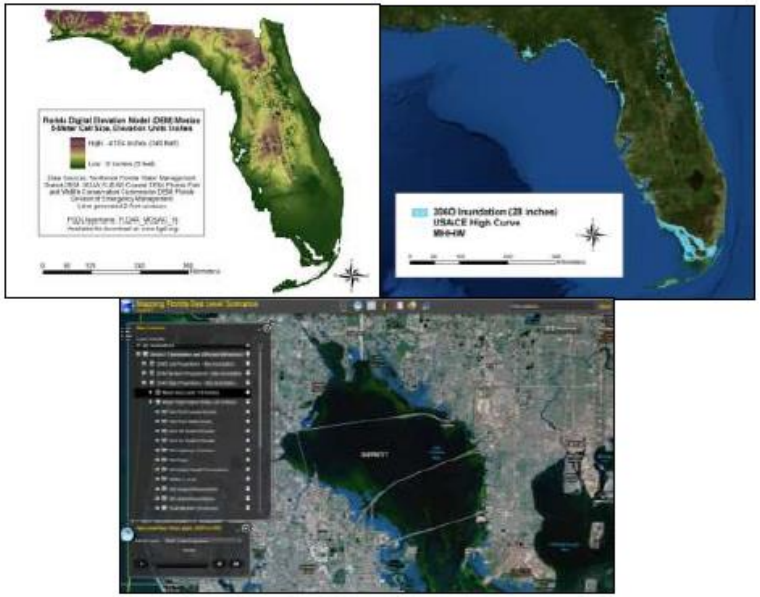
September 29, 2015

Photo credit: Greg Corning, provided by Monroe County staff

Based on FDOT Sea Level Rise Sketch Tool *

Developed by University of Florida

DEVELOPMENT OF A GEOGRAPHIC INFORMATION SYSTEM (GIS) TOOL FOR THE PRELIMINARY ASSESSMENT OF THE EFFECTS OF PREDICTED SEA LEVEL AND TIDAL CHANGE ON TRANSPORTATION INFRASTRUCTURE



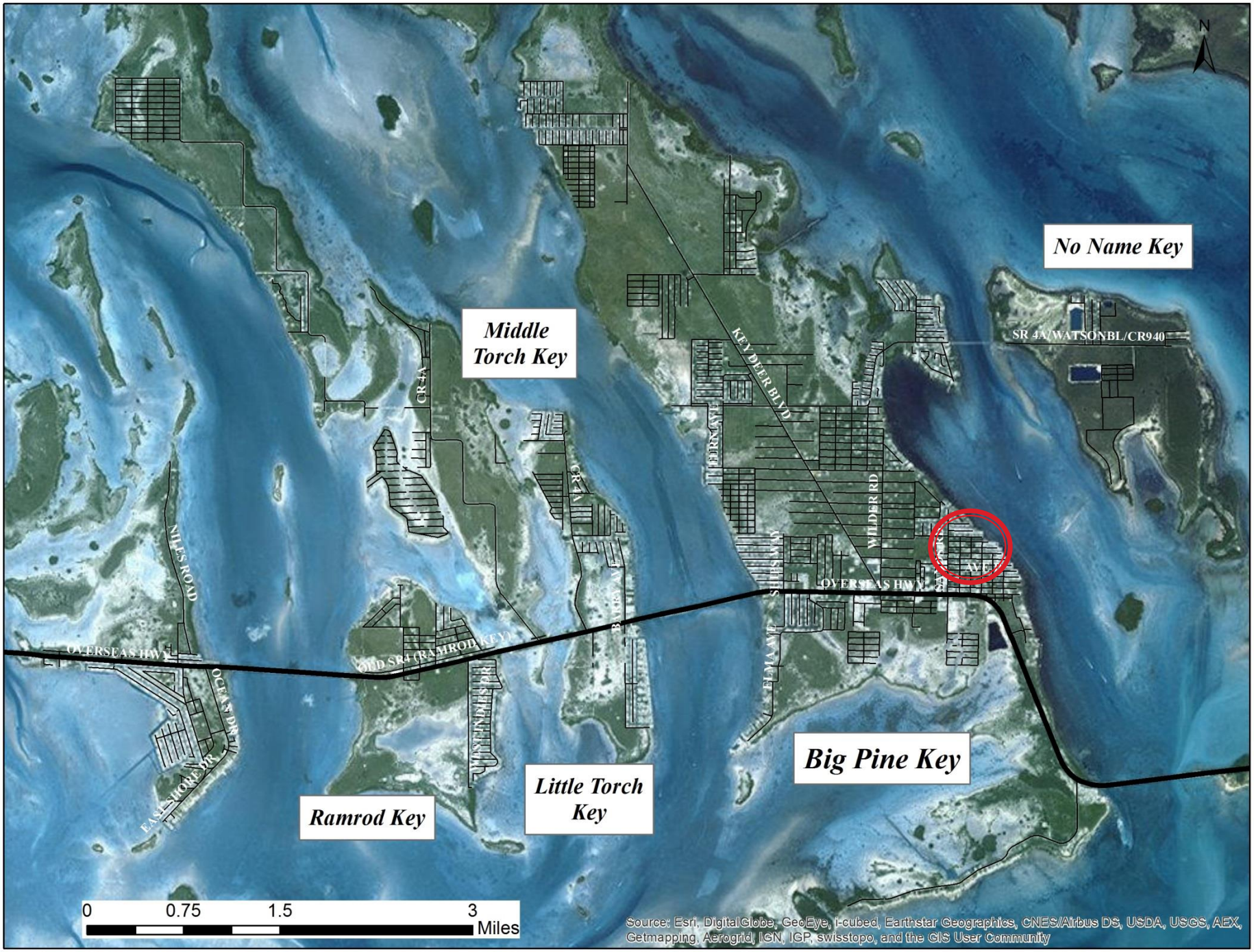
FDOT Contract# BDK75 977-63
September 2013
Final Report

Prepared by
Alexis Thomas
Dr. Russell Watkins
The GeoPlan Center
Department of Urban & Regional Planning
University of Florida

Funded by
Florida Department of Transportation

http://sls.geoplan.ufl.edu/documents-links/

**General planning assessment tool requires additional data for use in site-level decisions*

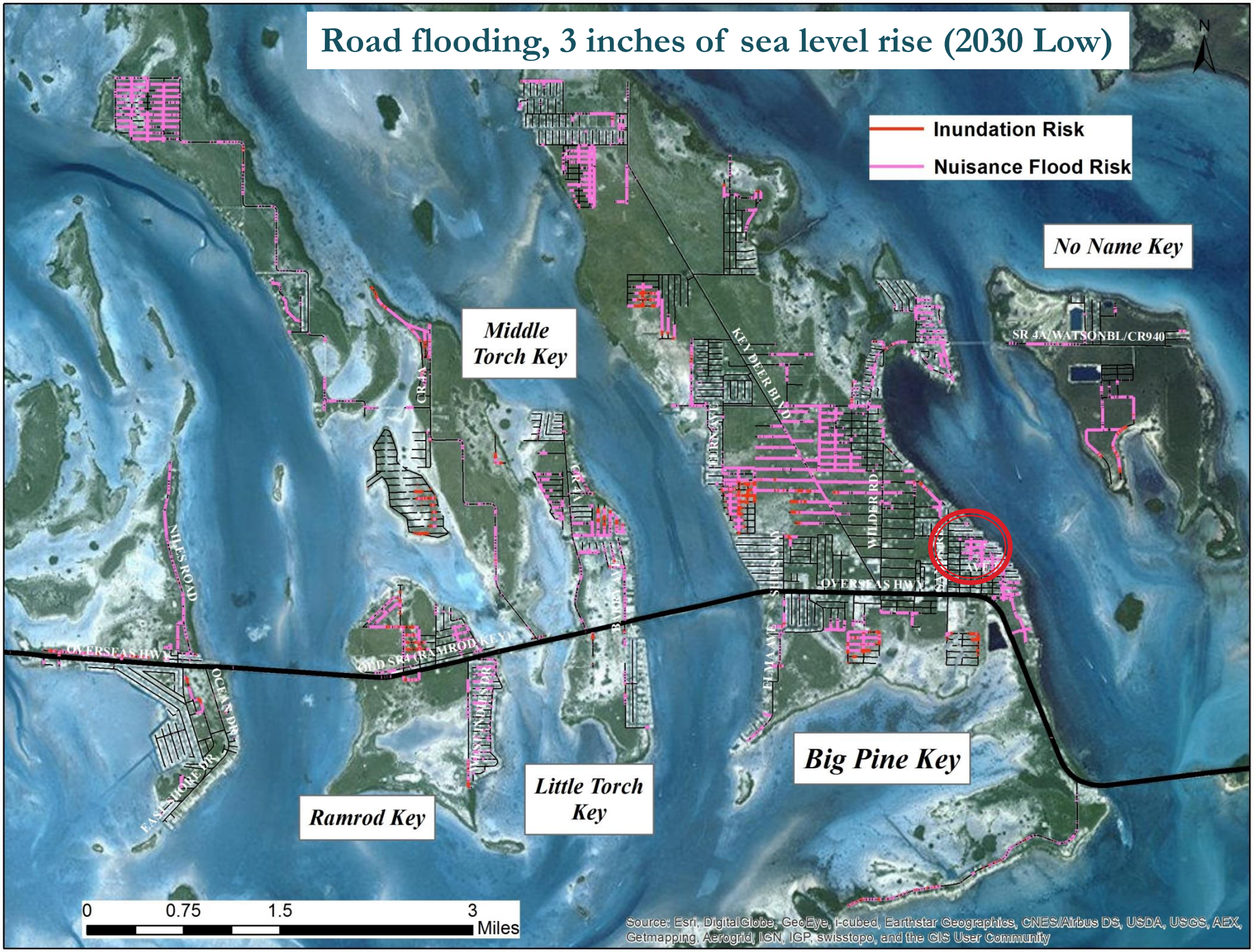


N
No Name Key
Middle Torch Key
Big Pine Key
Little Torch Key
Ramrod Key
SR 4A/WATSONBL/CR940
KEY DEER BLVD
CR 4A
FERN AVE
WILDER RD
SHIBS WAY
OVERSEAS HWY
AVE
BARRY AVE
ELMA AVE
OLD SR4 (RAMROD KEY)
NILES ROAD
OCEAN DR
EAST SHORE DR
0
0.75
1.5
3
Miles
Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

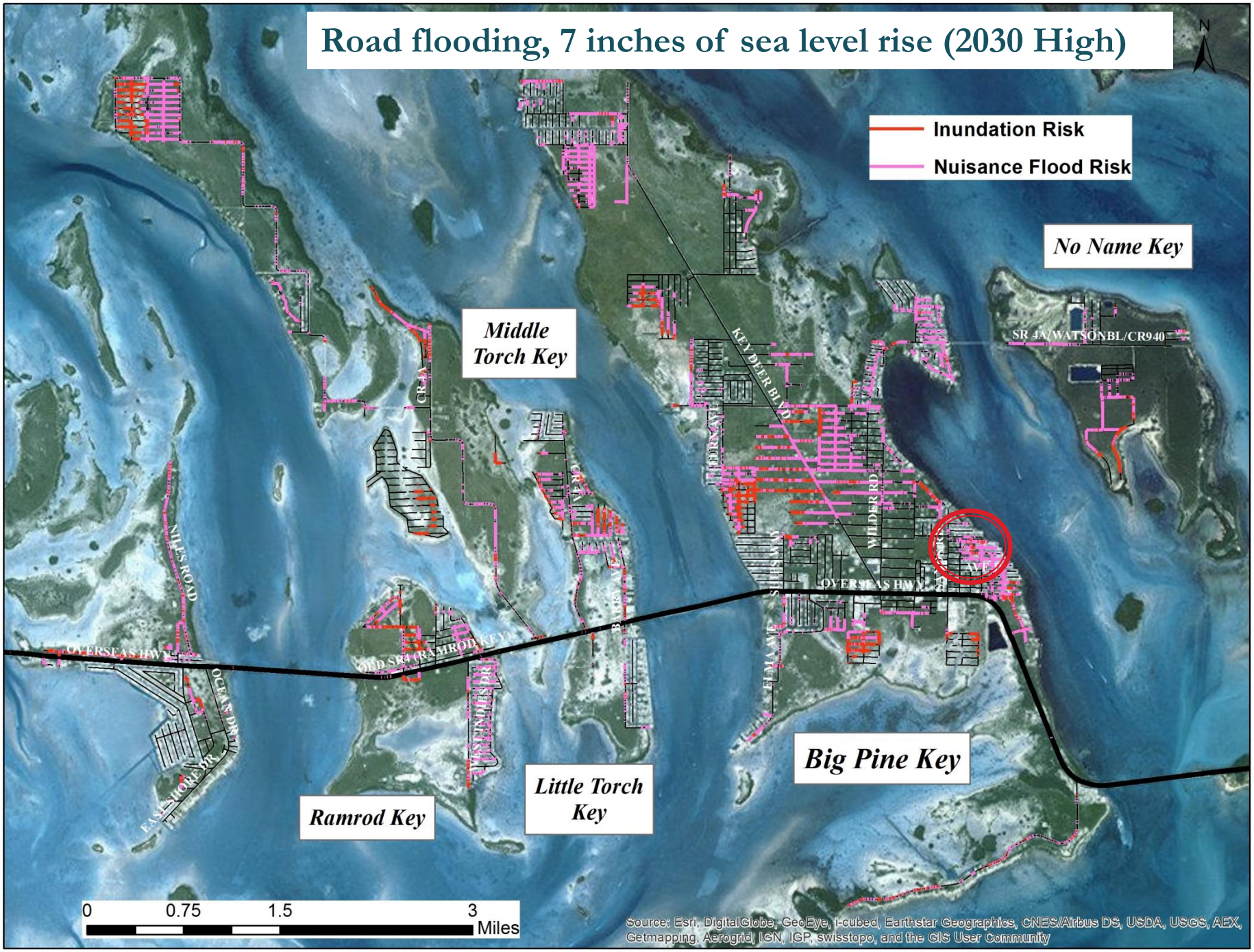
September 29, 2015

Photo credit: Greg Corning, provided by Monroe County staff

Road flooding, 3 inches of sea level rise (2030 Low)



Road flooding, 7 inches of sea level rise (2030 High)



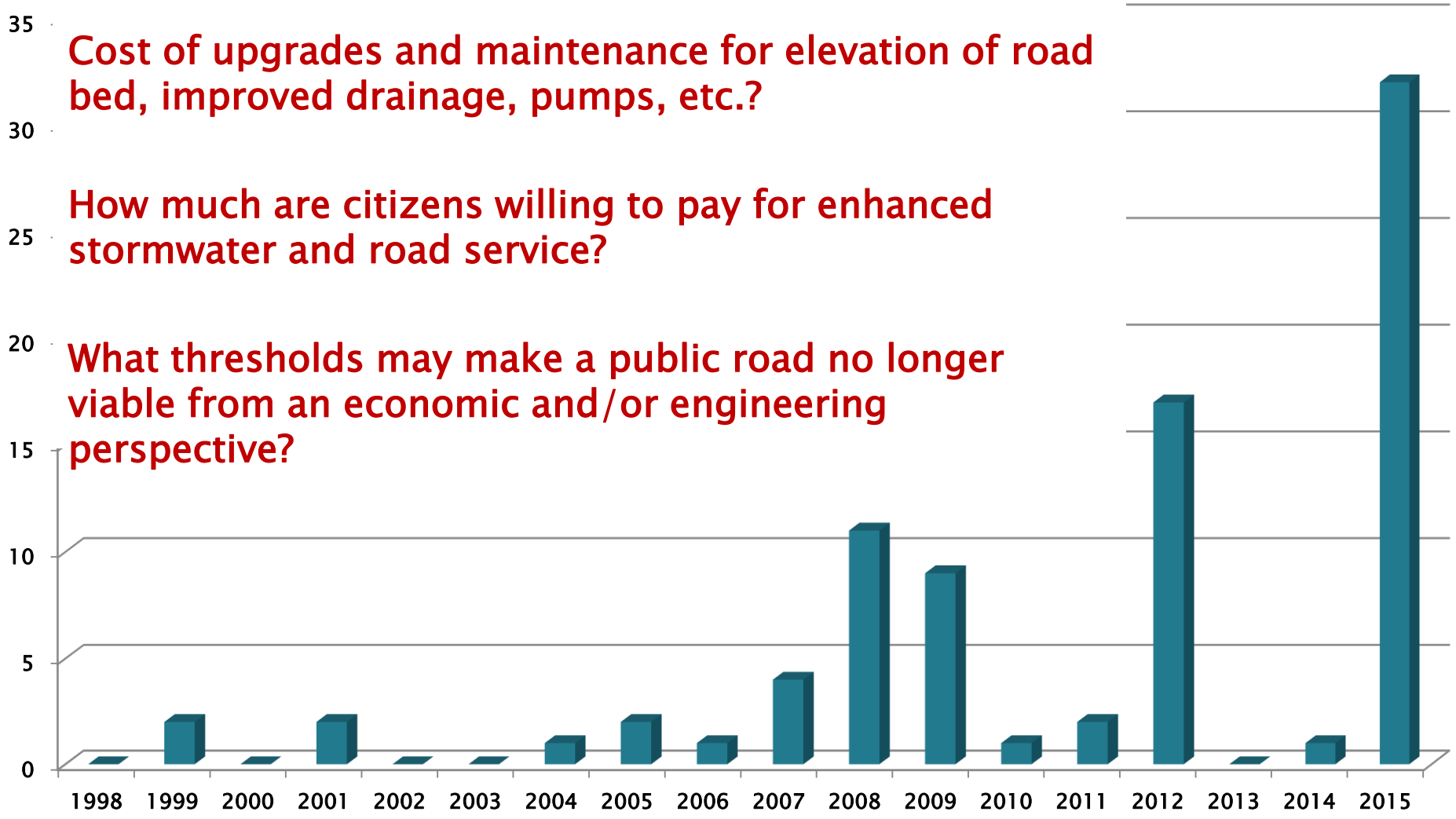
Modeling: More Accurate by the Day Policy Framing: Much More Difficult

What is an appropriate level of service for maintaining stormwater and roads under sea level rise?

Cost of upgrades and maintenance for elevation of road bed, improved drainage, pumps, etc.?

How much are citizens willing to pay for enhanced stormwater and road service?

What thresholds may make a public road no longer viable from an economic and/or engineering perspective?



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GREENKEYS!
A PLAN TO CREATE A SUSTAINABLE FLORIDA KEYS
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