Adaptation Planning at Adaptation Planning Lab (APL)

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ONE BAY Resilient Communities Working Group Meeting

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About APL

- The Adaptation Planning Lab (APL) at the University of Florida primarily investigates adaptive strategies in response to climate change from the empirical and theoretical perspectives.
- APL has been involving numerous faculty members and graduate students in a variety of research projects funded by national and state sponsors.
- APL strives to shed insight on developing efficient and adaptive strategies in an era of changing and somehow unpredictable climate.

Research Themes at the APL

Exposure Analysis to SLR

[Economic Loss]

Vulnerability Analysis

Social Behaviors

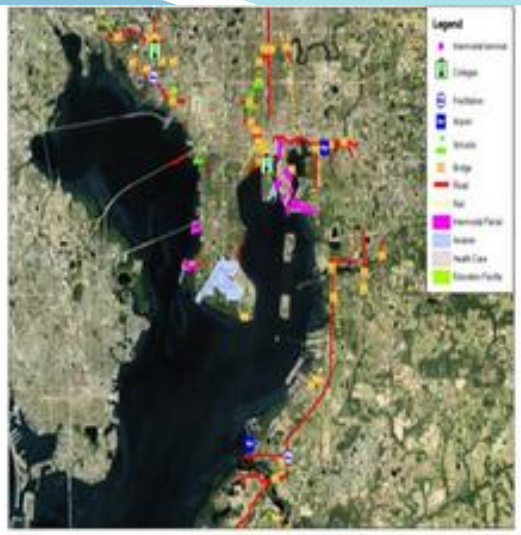
[Population Dynamics]

Adaptation Strategies

[Cost/Benefit analysis]

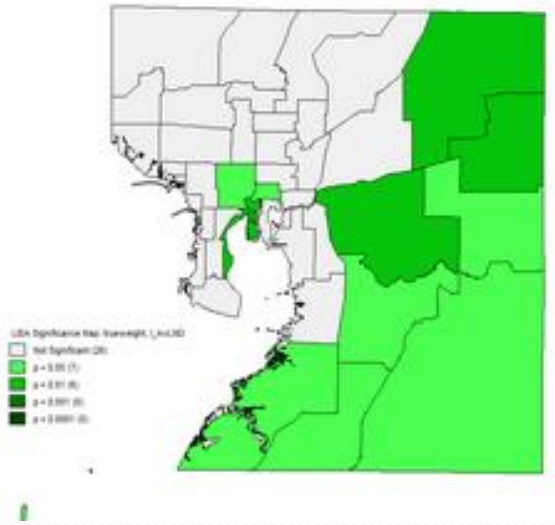
Coastal Resiliency

Research Projects

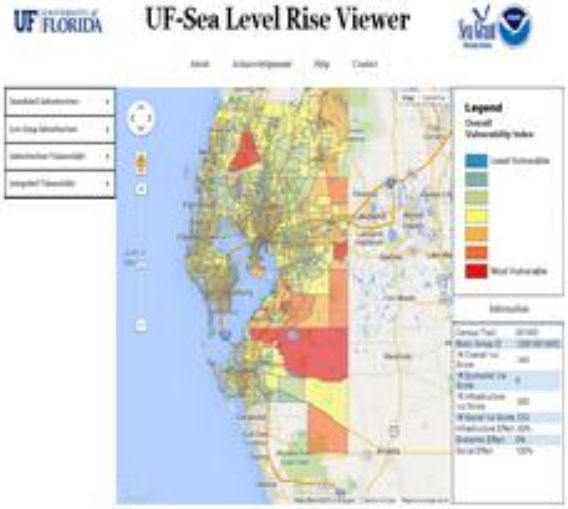


Development of Sea Level Rise Adaptation Planning Procedures and Tools Using NOAA Sea Level Rise Impacts Viewer

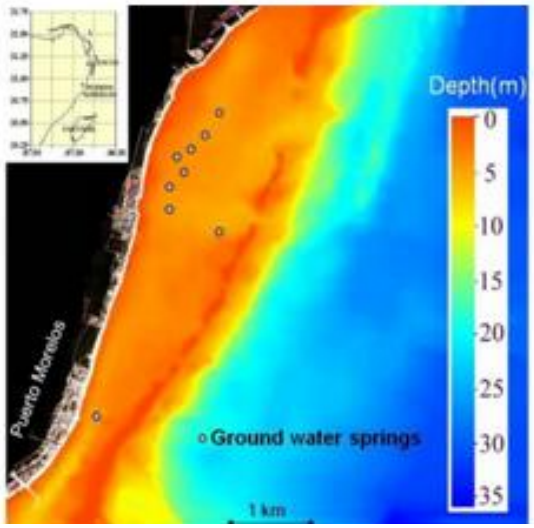
A Parameterized Climate Change Projection Model for Hurricane Flooding, Wave Action, Economic Damages, and Population Dynamics



A spatial temporal econometric model to estimate costs and benefits of sea level rise adaptation strategies

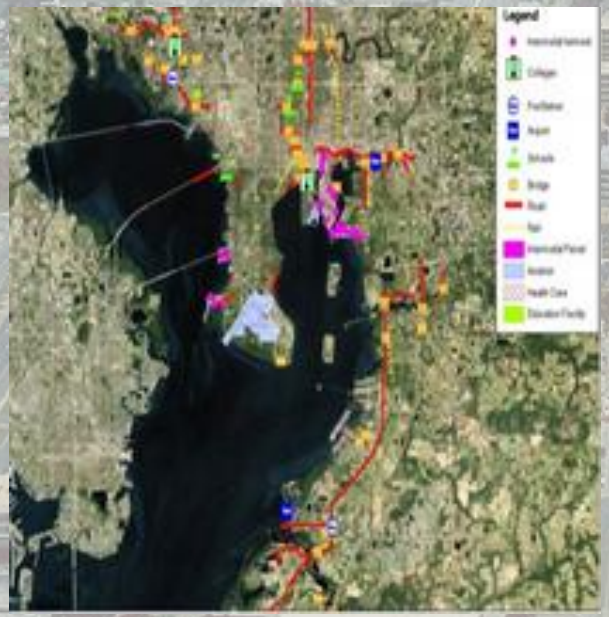


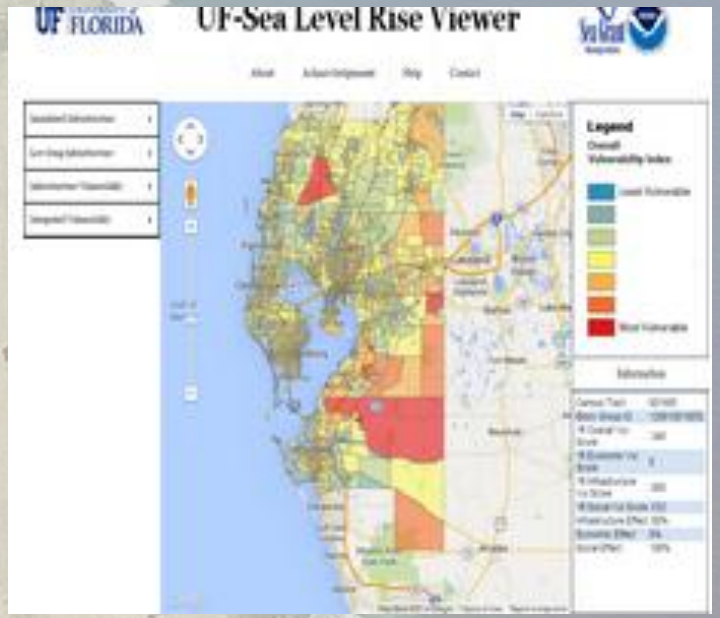
UF-Sea Level Rise Viewer



Planning for hydrologic and ecological impacts of sea level rise on sustainability of coastal water resources

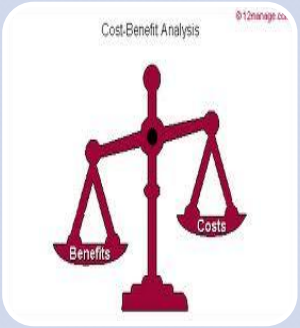
Vulnerability Analysis





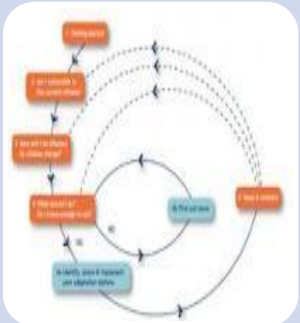
Goals

Estimate system vulnerabilities, Identify optimal adaptation



Conduct cost-benefit analysis of different adaptation strategies

Establish a policy kit for local planners for adaptation planning



Develop a regional adaptation planning procedure and decision-support tools

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Comparison between Different Dimensions

- Social Impacts:
  - Human vulnerability to hazards, based on population attribtes and the built environment, measured by The Social Vulnerability Index (SoVI®) 2005-09, including 42 socioeconomic variables representing income, age, urban and rural, special needs, race, gender, employment, and migration, etc.
- Economic impacts:
  - Employment, wages, and the number of establishments (or businesses) exposed to a hazard are strong indicators of a community's overall economic impact.
- Infrastructure:
  - Critical infrastructure and key resources

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Vulnerability Indicator Processing

Social Vulnerability

It shows areas of high human vulnerability to hazards, based on population attributes (e.g., age and poverty) and the built environment, produced by the Hazards and Vulnerability Research Institute at the University of South Carolina.

Component	Cardinality	Name	% Variance Explained	Dominant Variables	Component Loading
1	+	Race (Black), Class, Poverty	17.45	QBLACK	0.736
				QFHH	0.853
				QCVLUN	0.692
				QPOVTY	0.766
				QED12LES	0.667
				QNOAUTO	0.647
				QFAM	-0.794
2	-	Wealth	15.69	QASIAN	0.692
				PERCAP	0.730
				QRICH200K	0.810
				POPDENS	0.607
				MDGRENT	0.790
				MDHSEVAL	0.852
				QURBAN	0.563
3	+	Age (Elderly)	12.98	MEDAGE	0.914
				QAGEDEP	0.774
				PPUNIT	-0.672
				QRENTER	-0.623
				QSSBEN	0.801
4	+	Ethnicity (Hispanic)	9.34	QHISP	0.687
				QFEMLBR	-0.669
				QEXTRCT	0.598
				QNOHLTH	0.728
5	+	Special Needs	6.73	QNRRES	0.628
				QMOHO	-0.454
				HOSPTPC	0.586
6	+	Ethnicity (Native American)	4.94	QNATAM	0.798
				QESL	-0.488
				QNOAUTO	0.489
7	+	Service Employment	4.45	QSERV	0.821
		Cumulative Variance Explained	71.56		

http://webra.cas.sc.edu/hvri/docs/sovi0610_factorsb.pdf

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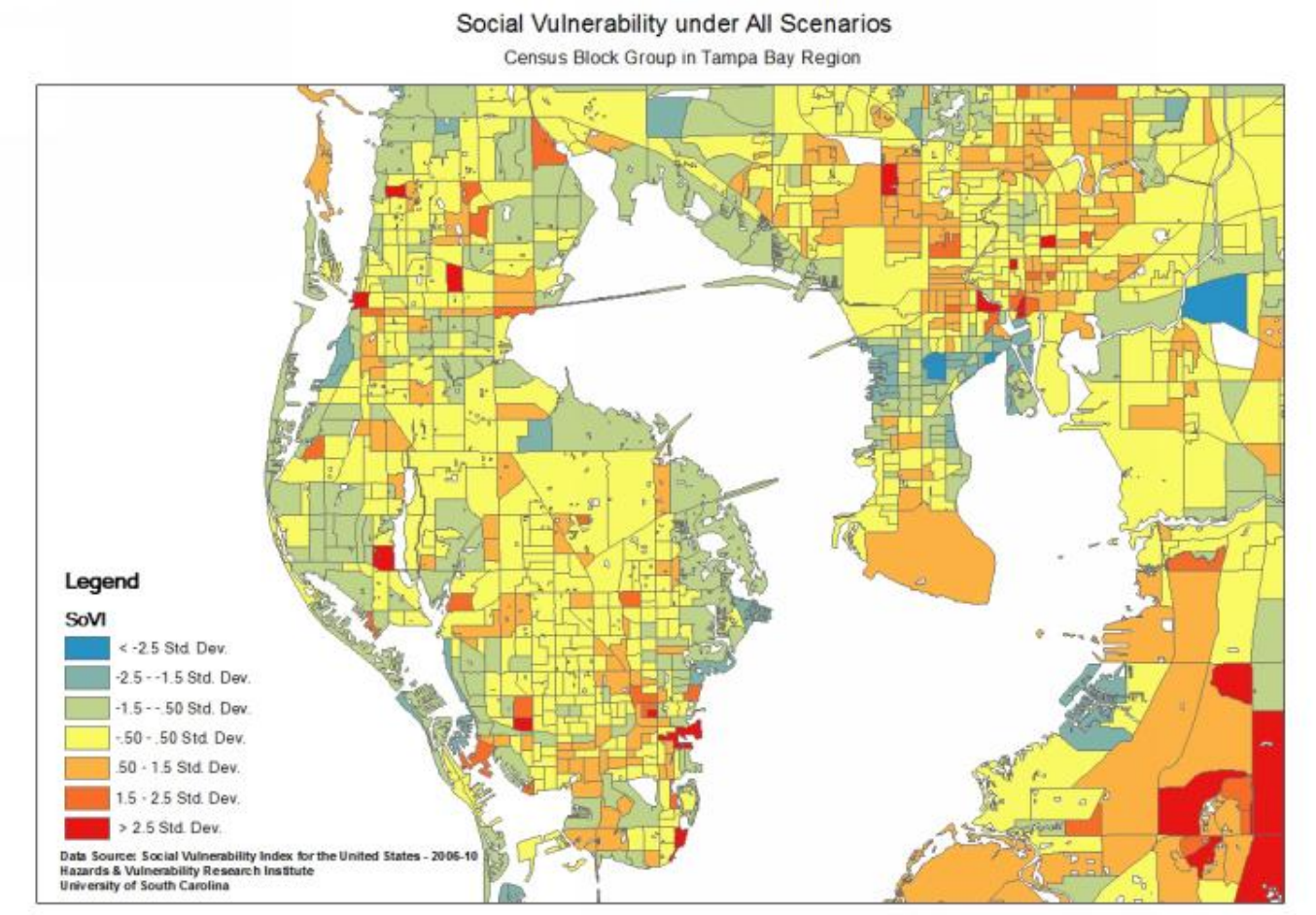
Social Vulnerability



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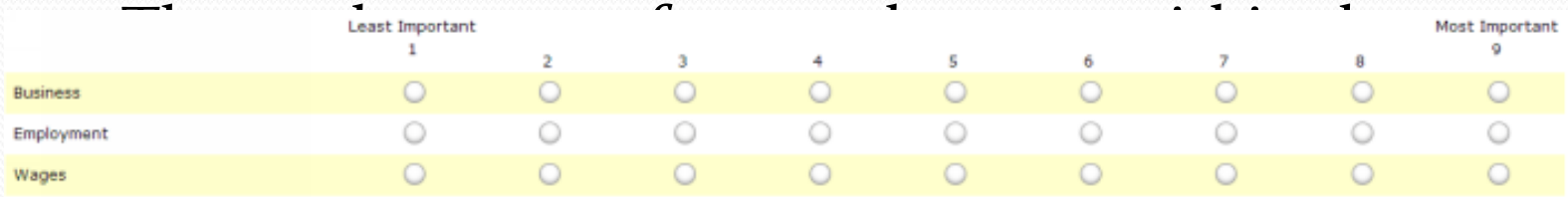
Economic Vulnerability Indicators

- Business:
  - Number of businesses within the area
- Employment:
  - Number of employment within the area
- Wages:



	Least Important 1	2	3	4	5	6	7	8	Most Important 9
Business	○	○	○	○	○	○	○	○	○
Employment	○	○	○	○	○	○	○	○	○
Wages	○	○	○	○	○	○	○	○	○

Economy indicators weight

- Paired Wilcoxon Signed Ran[illegible] Test
  - Wages mean rank 1.54
  - Business mean rank 2.02
  - Employment mean rank 2.4[illegible]
- Wage ≈ business < employment
- Select number of employment as the economic indicator

Test Statistics[c]

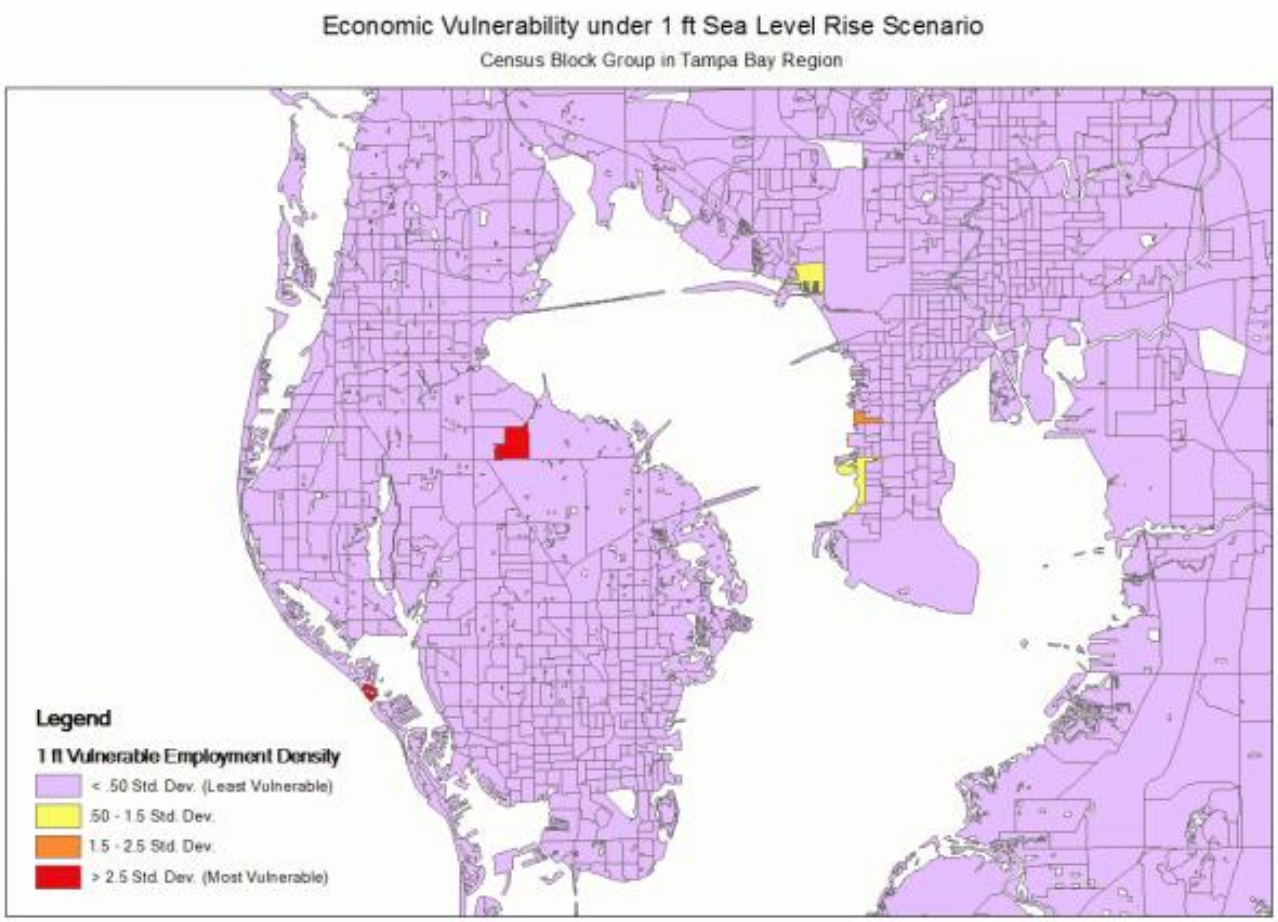
	Employment - Business	Business - Wages	Wages - Employment
Z	-2.066[a]	-1.883[a]	-3.337[b]
Asymp. Sig. (2-tailed)	.039	.060	.001

a. Based on negative ranks.

b. Based on positive ranks.

c. Wilcoxon Signed Ranks Test

Economic Vulnerability



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Critical Infrastructure

- Get expert opinion in comparing infrastructure importance from different perspectives: Infrastructure maintenance repair cost, emergency importance, and relocation difficulties
- Infrastructure Types include critical infrastructures listed in “Critical Facilities” published by Florida Division of Emergency Management (2012)
  - Emergency Operation Center
  - Health care facilities
  - Principal transportation facilities
  - Intermodal Distribution Centers
  - Policy and fire department

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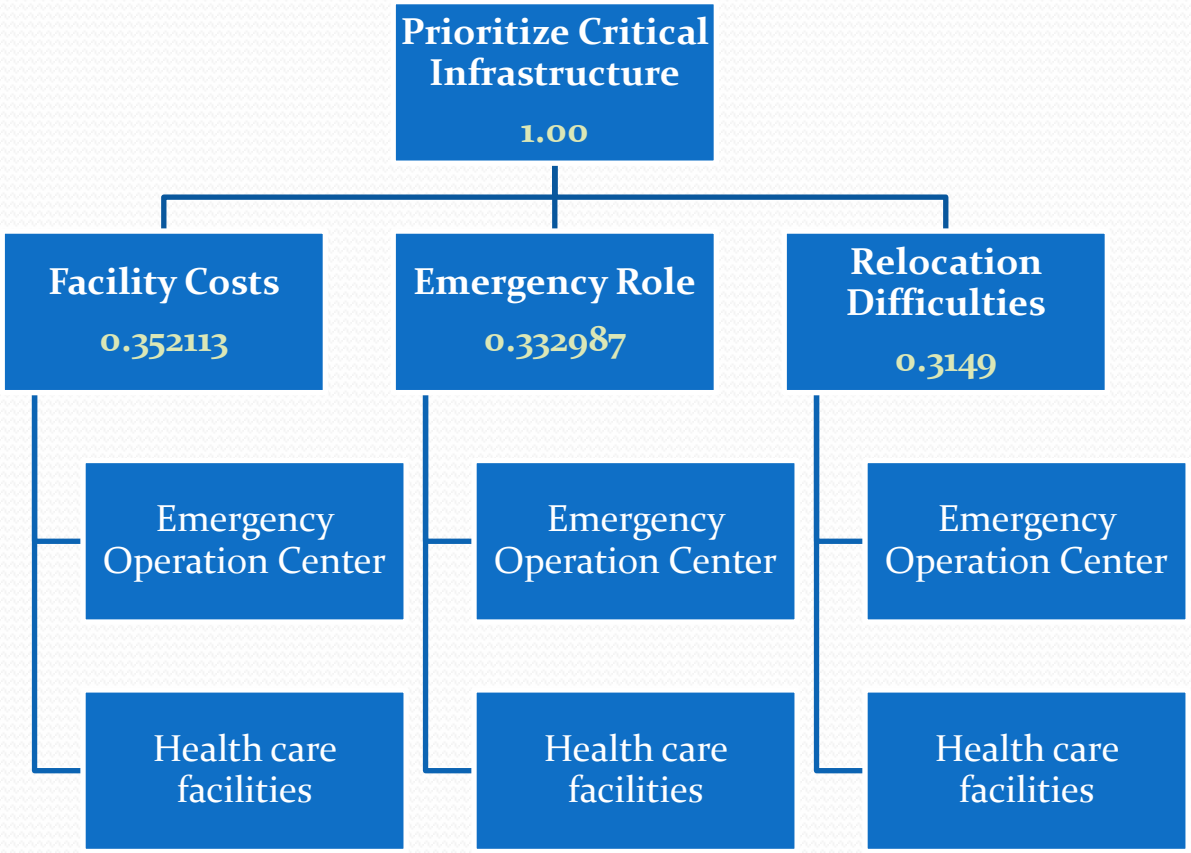
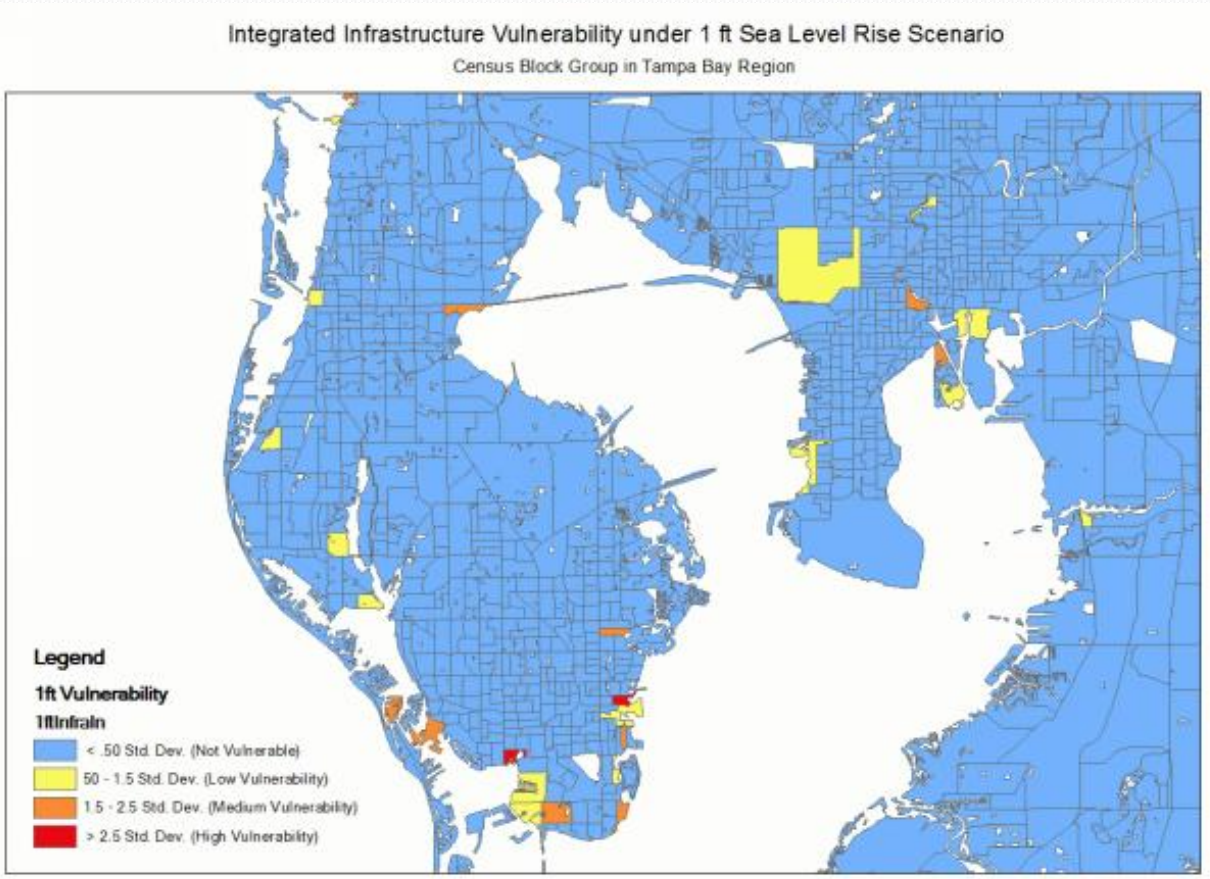
AHP Method


Prioritize Critical Infrastructure
1.00
Facility Costs
0.352113
Emergency Role
0.332987
Relocation Difficulties
0.3149
Emergency Operation Center
Emergency Operation Center
Emergency Operation Center
Health care facilities
Health care facilities
Health care facilities

Infrastructure Vulnerability



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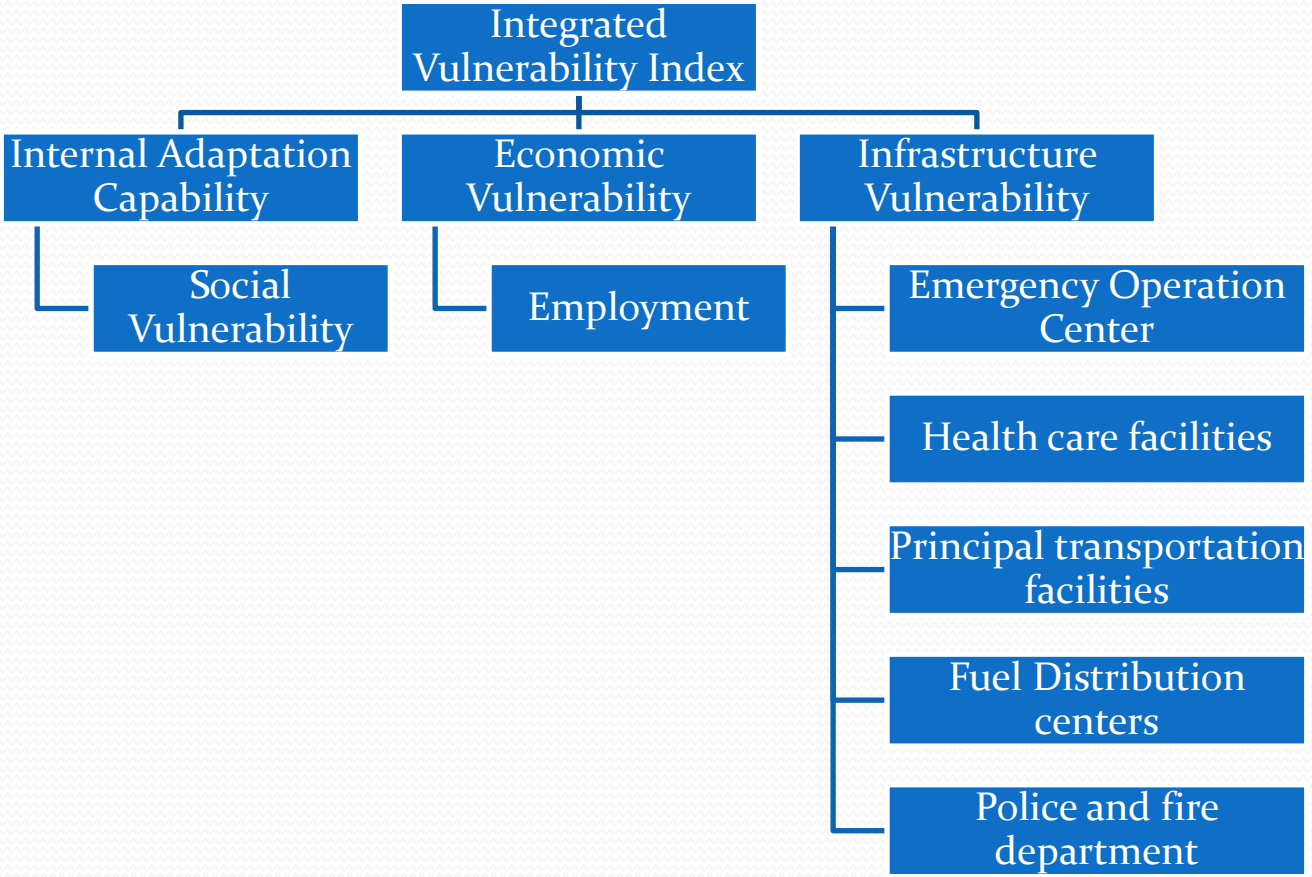
Computing Integrated Vulnerability Index



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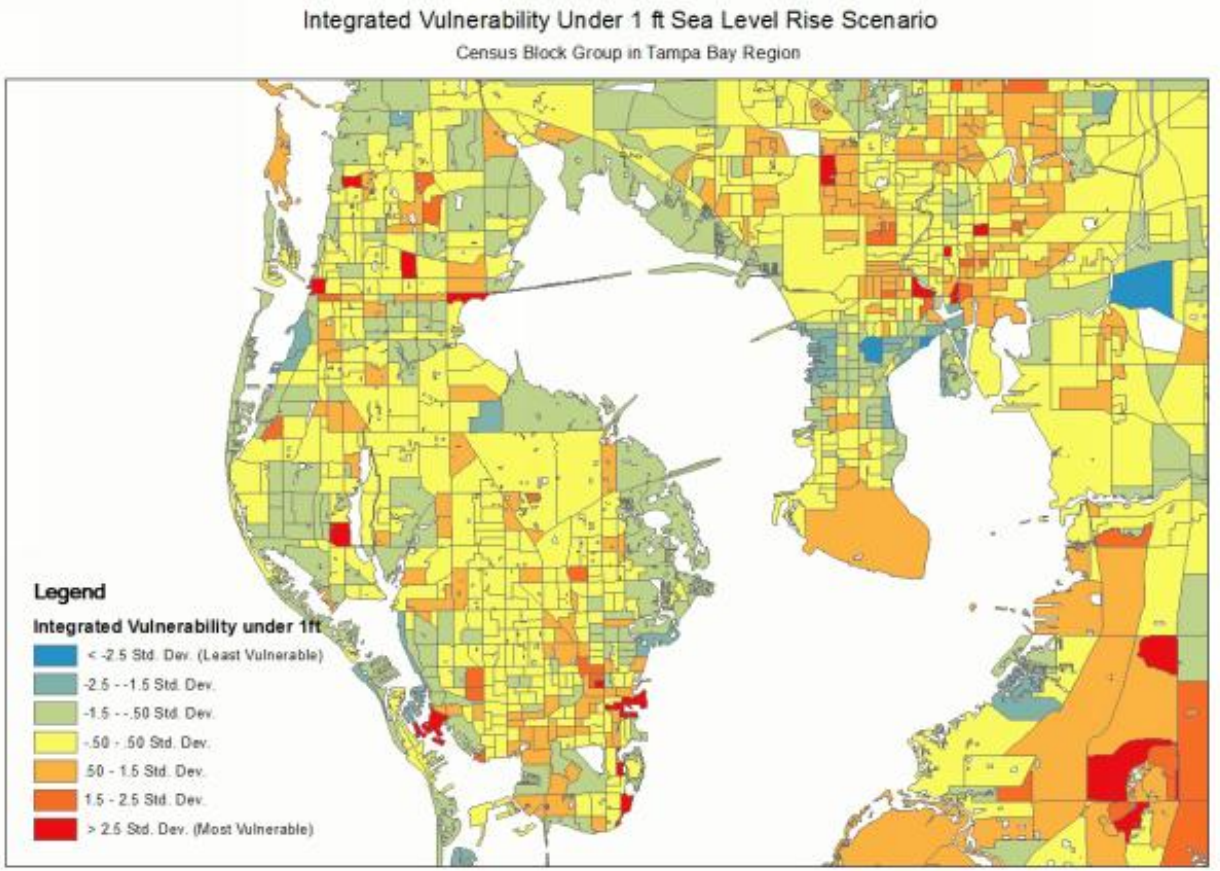
Integrated Vulnerability



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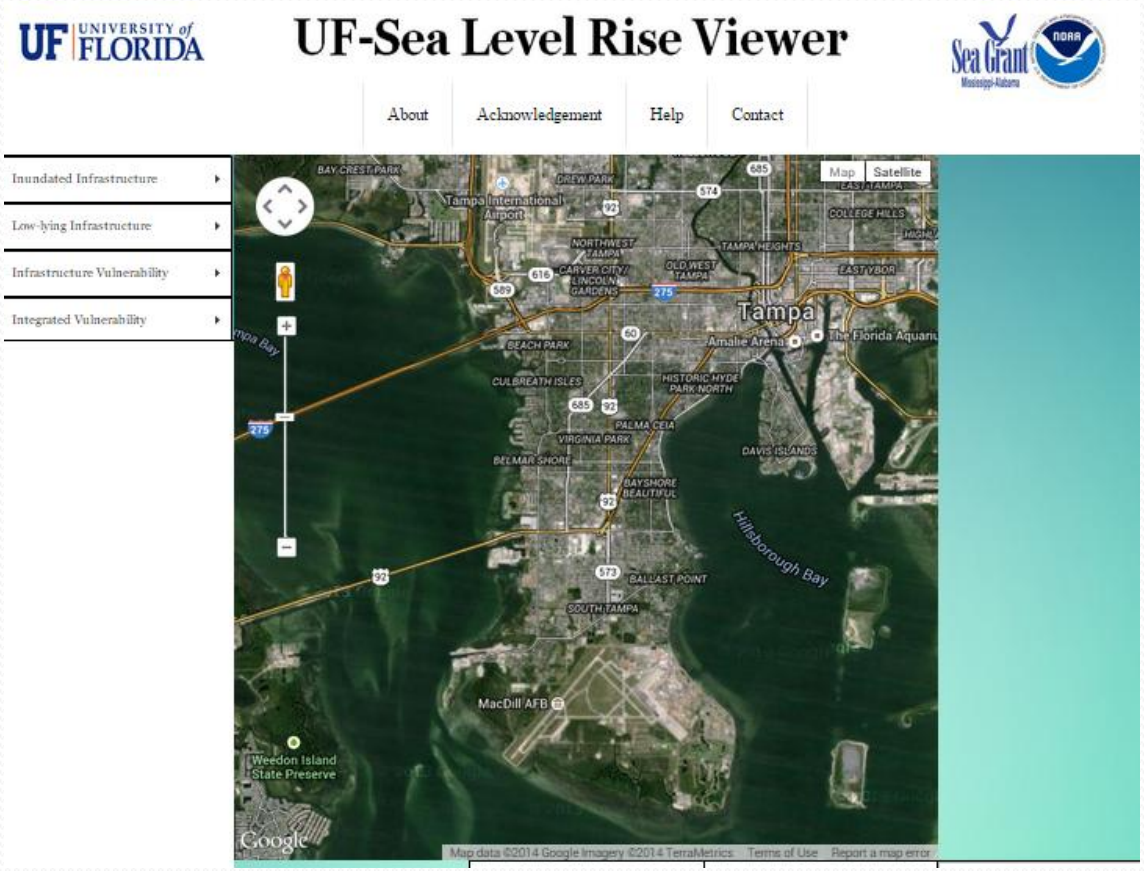
UF SLR Viewer



UF Sea Level Rise and Coastal Flooding Viewer:
http://plaza.ufl.edu/dengyujun11/SLR7.0.html

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Major Findings

- With no sea level rise or low sea level rise, social vulnerability is the most influential components in determining the overall vulnerability
- As sea level rises, the influence of employment and infrastructure will become more significant.
- Although social, economic, and infrastructure are weighted equally in the integrated vulnerability calculation, the influences of social, economic, and infrastructure differ by location and time due to the difference in level of exposure

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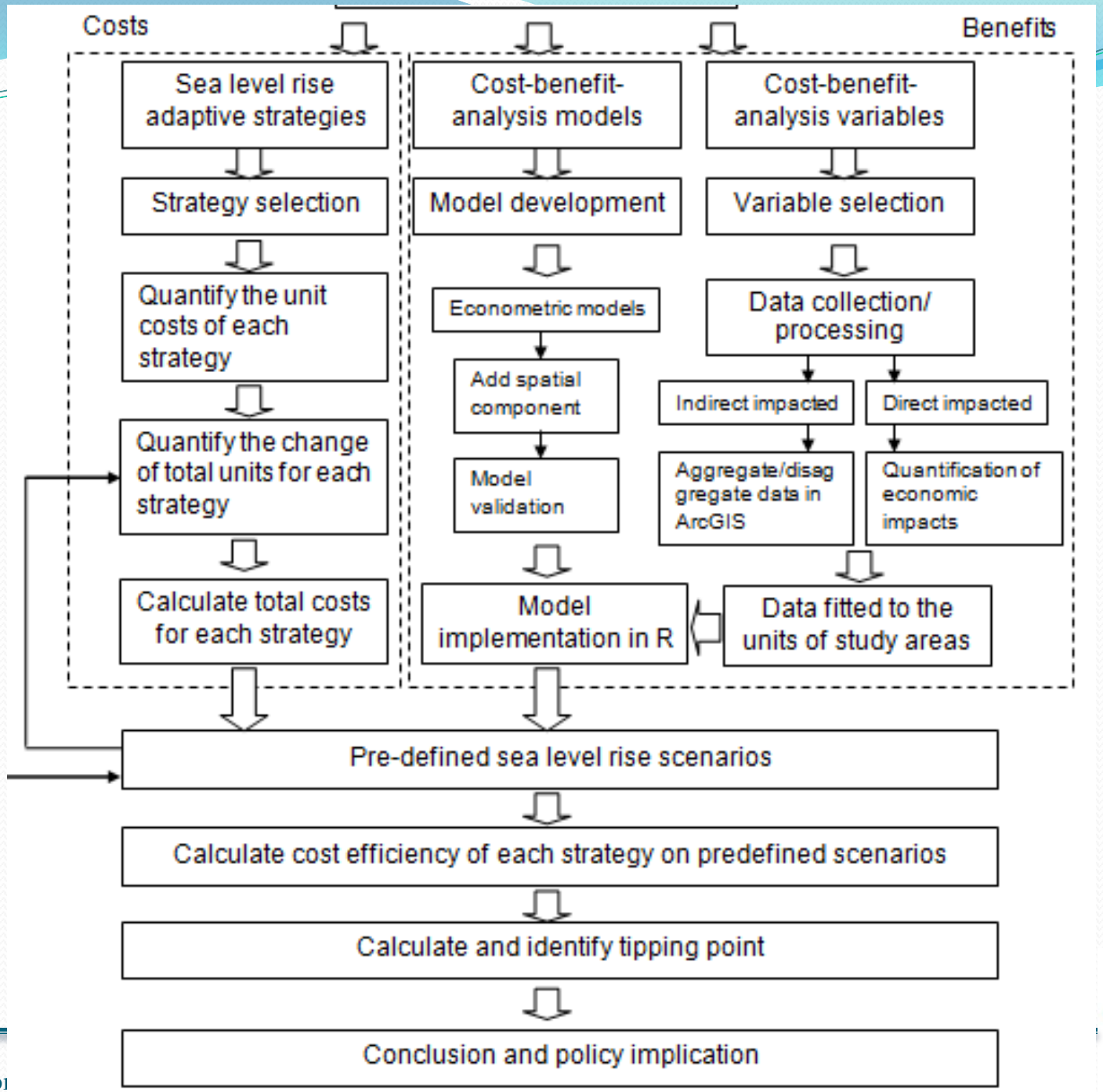
Adaptation Strategies to SLR [Cost/Benefit Analysis]

Research Objectives

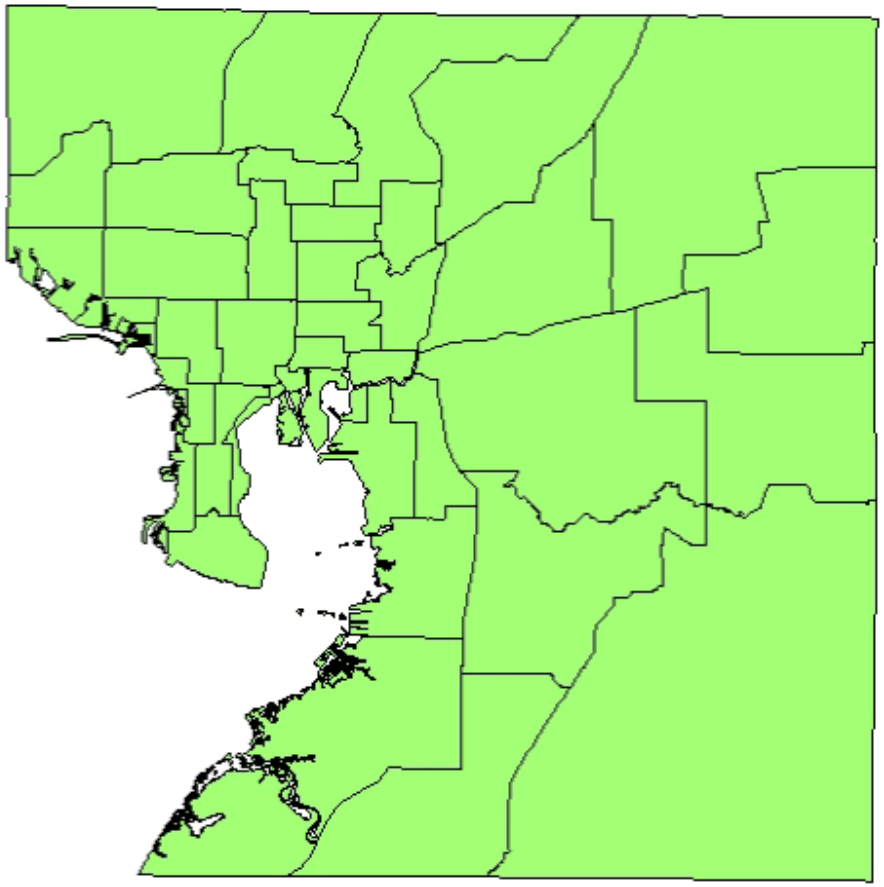
- Whether adaptation of sea level rise adaptive strategies is more cost-efficient than no action? If it is, which adaptive strategies are more cost-efficient than others?
- How to better capture the indirect economic impacts of sea level rise and its adaptation strategies ?
- What is the best time (tipping point) to take adaptation actions?

Research flow chart



Case study area-Hillsborough County, FL

- A good case to study sea level rise adaptation
  - Densely populated (1,229,226 as of 2010)
  - Large amount of wetlands
  - Experience hurricanes and frequent storm surges
- The County is divided into 39 EAZs. The delineation of EAZ is based on Evacuation Analysis Zone created by Tampa Bay Regional Planning Council



Quantification of Benefits

Benefit quantification for variables without spatial pattern:

- Travel time delay
- Building damages
- Change of wetland ecosystem services

Travel time delay

- Transportation network congestion delays the users' travel time which is considered to have monetary values.
  - First of all, the delayed travel time has opportunities cost that can be utilized to do other things rather than spending times in traffic queues.
  - Secondly, the delayed travel time can actually have economic cost if the travelers are late for work.
- Florida Standard Urban Transportation Modeling Structure (FSUTMS) is developed to serve as the standard transportation model for the State of Florida. The FSUTMS models are developed based on Cube software, a transportation modeling software.

Results

1 foot 2 feet 5 feet

Sea level rise	1 foot	2 feet	5 feet
Total travel time delay per day (in million $)	1.12	1.61	1.92
Total value of travel time delay per year (in million $)	409	577	701

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Wetland services

- The value of wetland products can be captured by market with monetary values. However, the values of their services are greatly underestimated since the market cannot directly assign values to those services.
- The calculation is based on the average value for different ecosystem services provided by Gulf of Mexico Ecosystem Service Valuation Database (http://www.gecoserv.org/).

Type	Beach value	Freshwater value	Mangrove value	Marine open water	Salt water value
Value	195,838	61,959	125,991	2,913	28,629

Unit: dollar per ha

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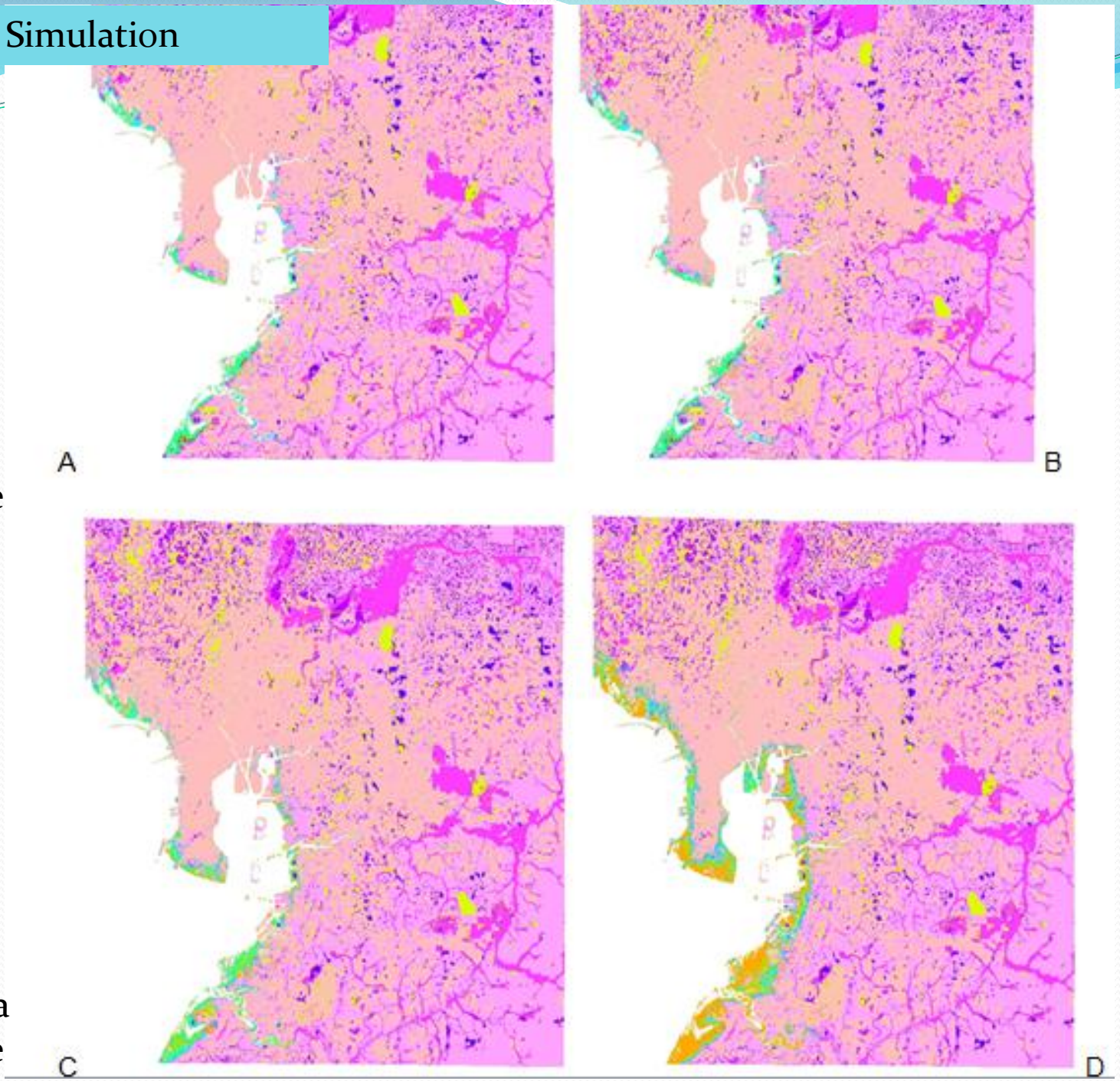
SLAMM Simulation



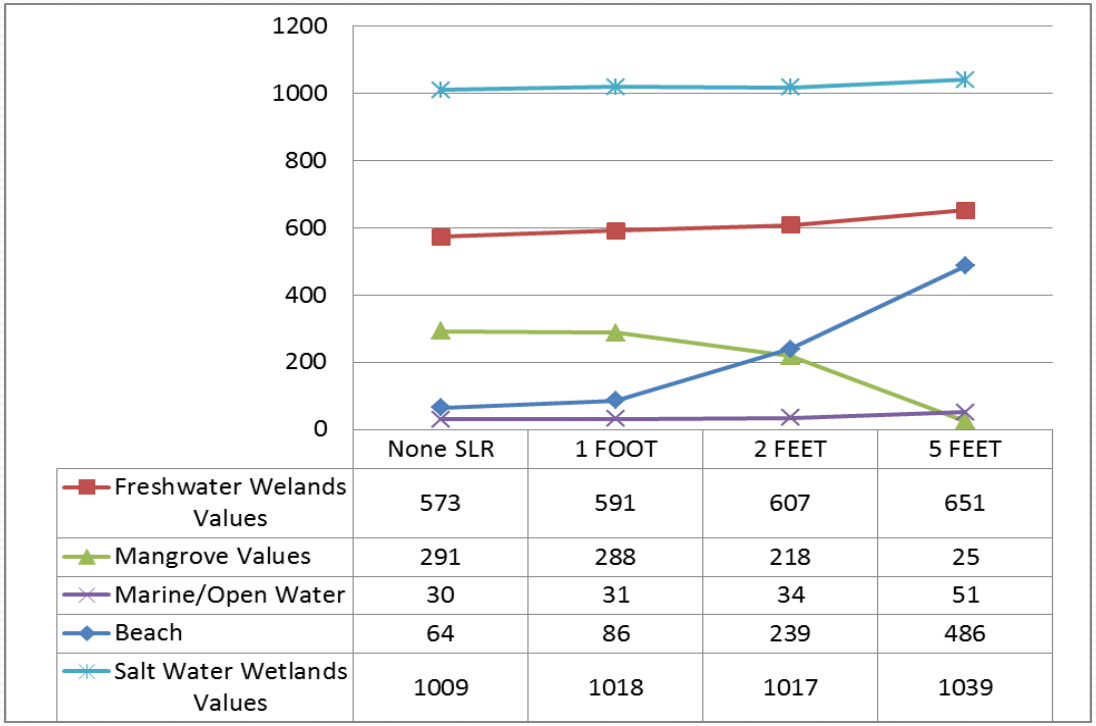
No sea level rise

1 foot sea level rise

2 feet sea level rise

5 feet sea level rise

Results



	None SLR	1 FOOT	2 FEET	5 FEET
Freshwater Welands Values	573	591	607	651
Mangrove Values	291	288	218	25
Marine/Open Water	30	31	34	51
Beach	64	86	239	486
Salt Water Wetlands Values	1009	1018	1017	1039

Total values of five major types of wetlands (value in millions)

Sea level rises	1 foot	2 feet	5 feet
Total value	$2,014	$2,115	$2,252
Value loss	-$47	-$148	-$285

Unit in million dollars

Building damages

- As sea level rises, costal buildings are vulnerable to both inundation and frequent flooding cause by sea level rise. However, quantification of coastal building damages is complicated because of the limited data and knowledge.
- Hazus model is employed to calculate building damages. It is a risk assessment tool to use various models to estimate potential losses from different natural hazards, including earthquakes, floods, and hurricanes.

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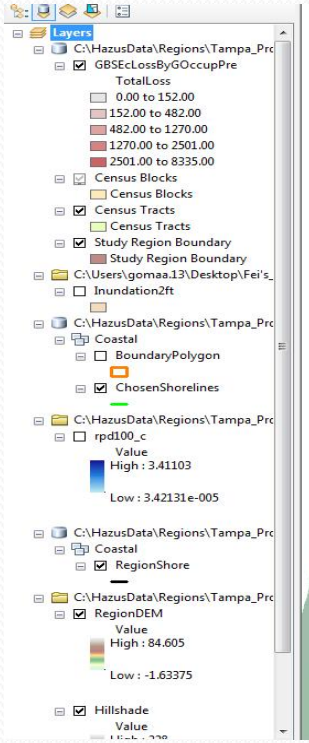
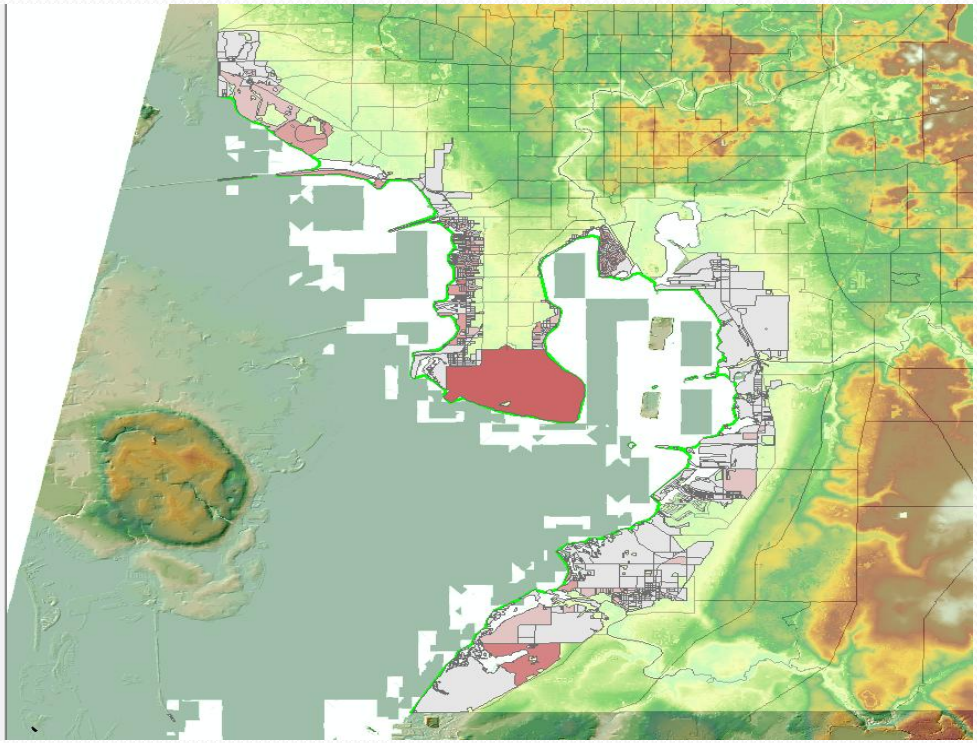
Results





Sea level rise	1 foot	2 feet	5 feet
Values of building damages	$3,381	$4,128	$5,319

Unit in million dollars

Spatial econometric models

- Spatial econometric models are always employed to capture spatial effects, which are represented by spatial dependence: spatial interaction and spatial error.

$$y=\rho W_1 y+X\beta+\varepsilon$$

$$\varepsilon=\lambda W_2 \varepsilon+\mu$$

- Where, y is dependent variable; X is independent variable; ρ and λ are spatial coefficients; W is weight matrix specifying the relations between spatial units; ε and μ are error terms.

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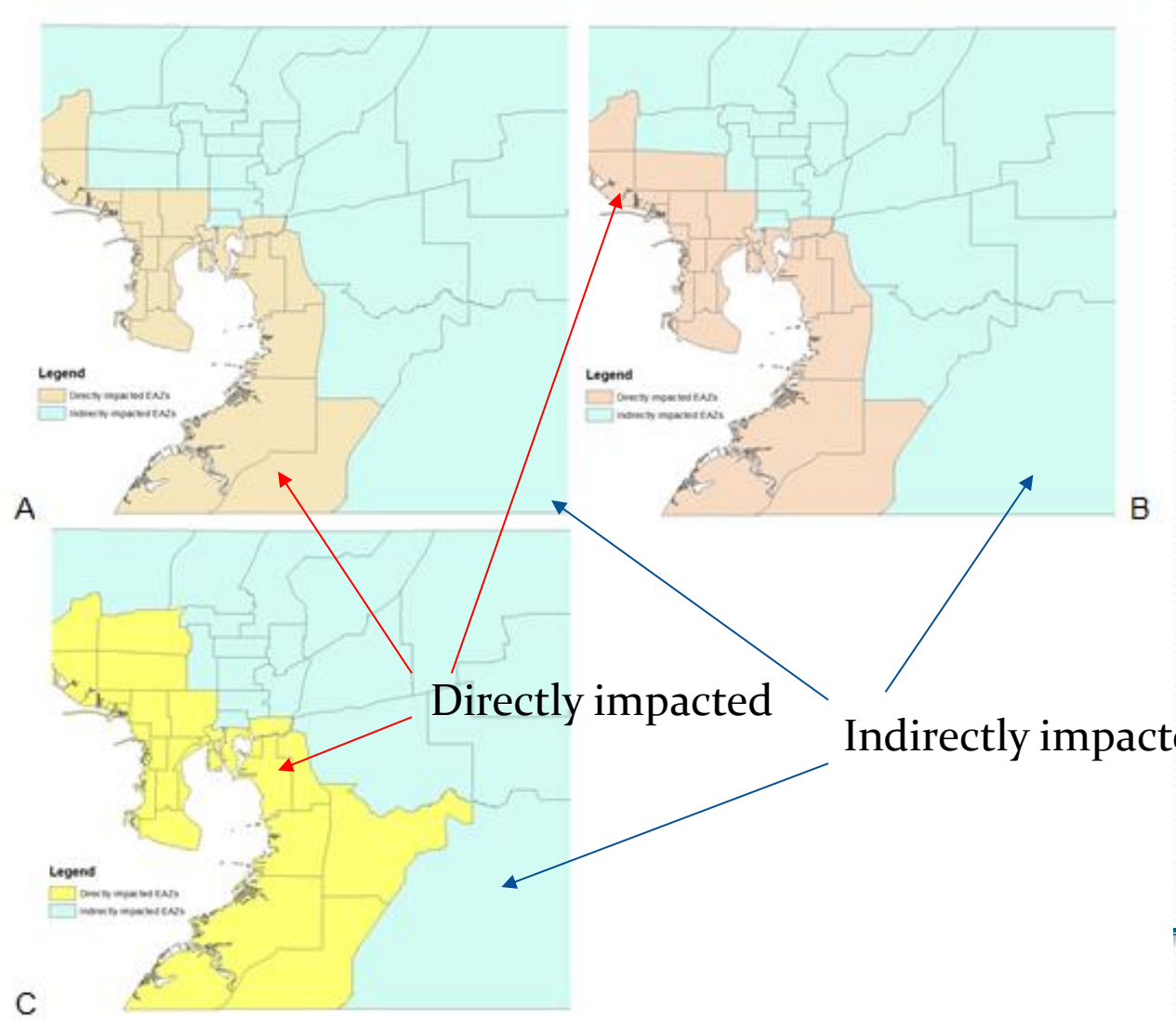
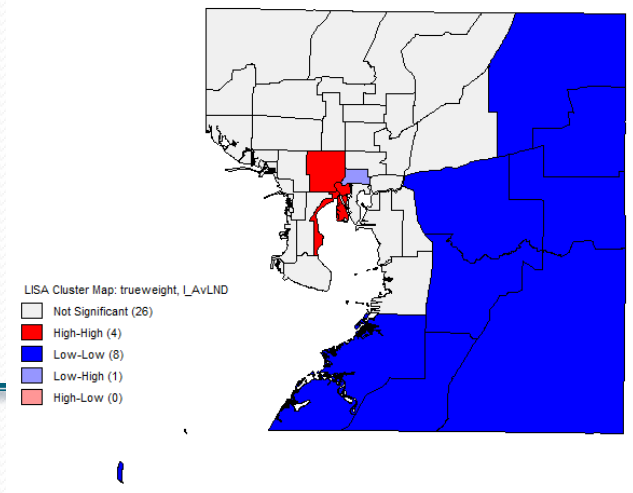
Area categorization

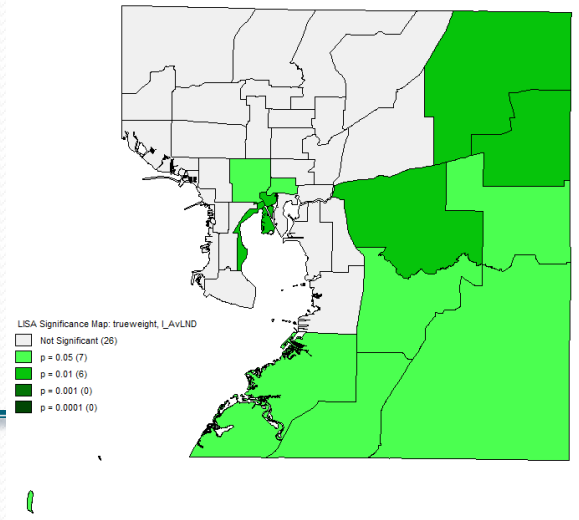


Quantification for the Loss of Land Value

- Average land value per square kilometer for each EAZ is selected to represent property value since it is shown with significant spatial autocorrelation.

Moran' I statistic	Expectation	Variance	Standard deviation	P-value
0.526230637	-0.0263158	0.007478512	6.3894	8.326e-11





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Model Results

$$AvLND = \rho\omega \bullet AvLND + \alpha \bullet PopDens + \beta + \varepsilon$$

Variable	Coefficient	Std.Error	z-value	Probability
W_AVLND	0.5997456	0.08026037	7.472501	0.0000000
POPDENSo	17194.12	1978.786	8.689228	0.0000000
CONSTANT	-1.393851e+007	4900879	-2.844083	0.0044541

Sea level rise	1 foot	2 feet	5 feet
Direct loss	2,217	2,481	4,345
Indirect loss	4,189	10,292	11,391
Total loss	6,406	12,773	15,736

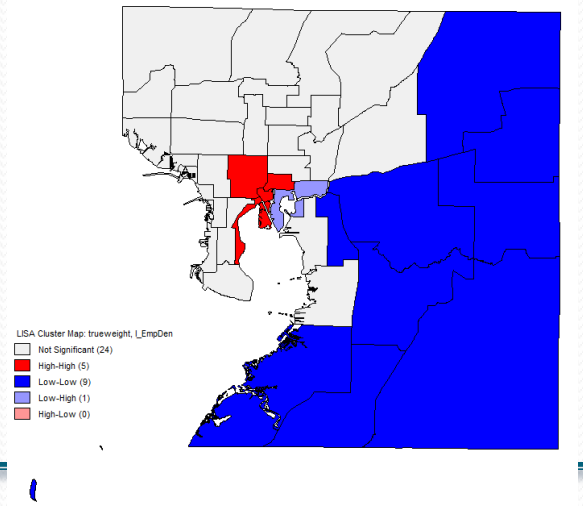
Quantification of Loss of Business

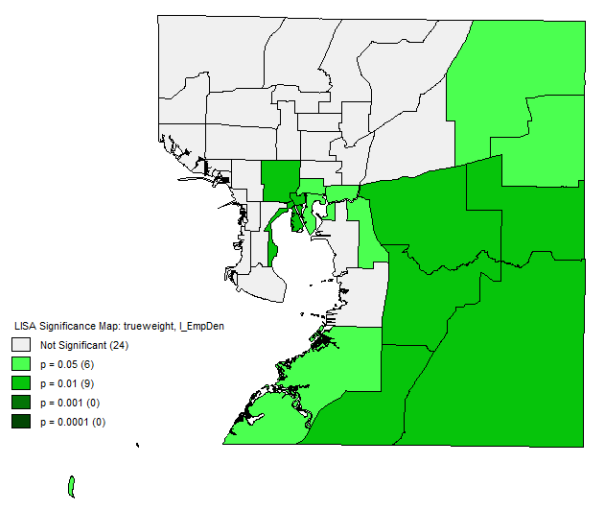
- This study estimates business loss by linking the employment to business revenue. Since existing literatures suggest a close relationship between the percentage of payroll to gross revenue, this study uses the expenditure on payrolls to proximate the business revenue (Harris 1999).
- Total business revenue=(Total number of employment * average personal income)/30%.

Model of employment density

- After testing different representation of employments, the density variable turns out to have significant spatial dependence.

Moran' I statistic	Expectation	Variance	Standard deviate	P-value
0.540344467	-0.026315789	0.006963554	6.7906	5.584e-12





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Model results

$$EmpDens = \rho\omega gEmpDens + \alpha gPopDens + \beta + \varepsilon$$

Variable	Coefficient	Std.Error	z-value	Probability
W_EMPDEN	0.5926498	0.07449083	7.95601	0.0000000
POPDENSo	1.559869	0.160632	9.710822	0.0000000
CONSTANT	-1318.593	393.0426	-3.354834	0.0007942

Rising sea levels	1 foot	2 feet	5feet
Direct employment loss	25,341	25,633	50,523
Indirect employment loss	-65,316	219,849	365,746
Total employment loss	-39,975	245,482	416,269
Total business loss (million $)	-$6,103	$37,480	$63,555

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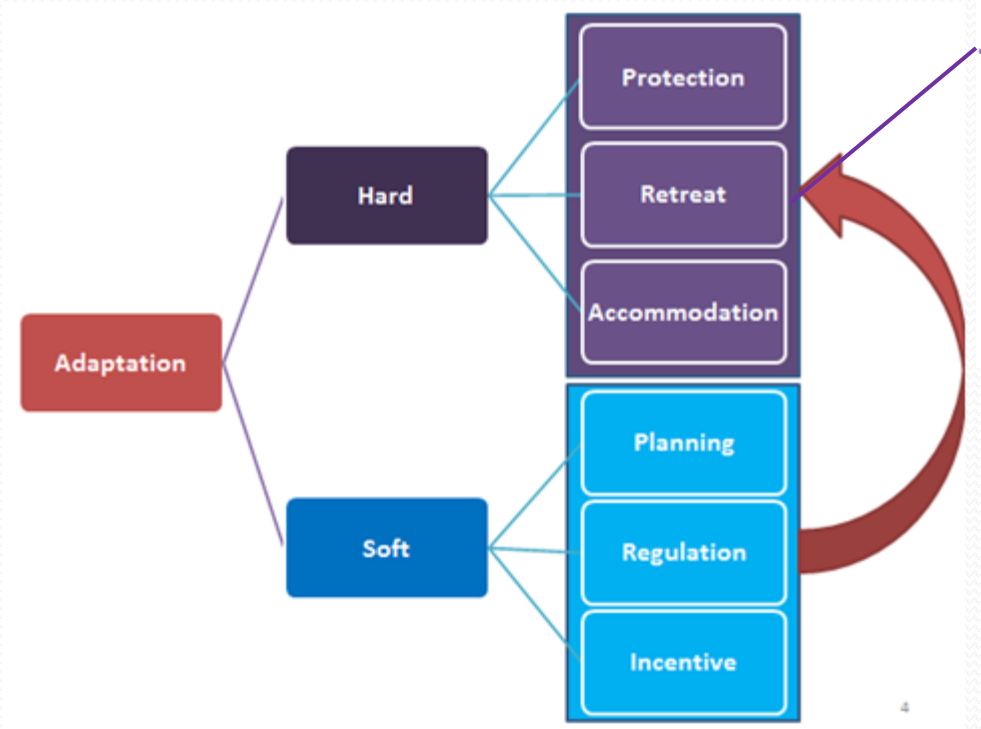
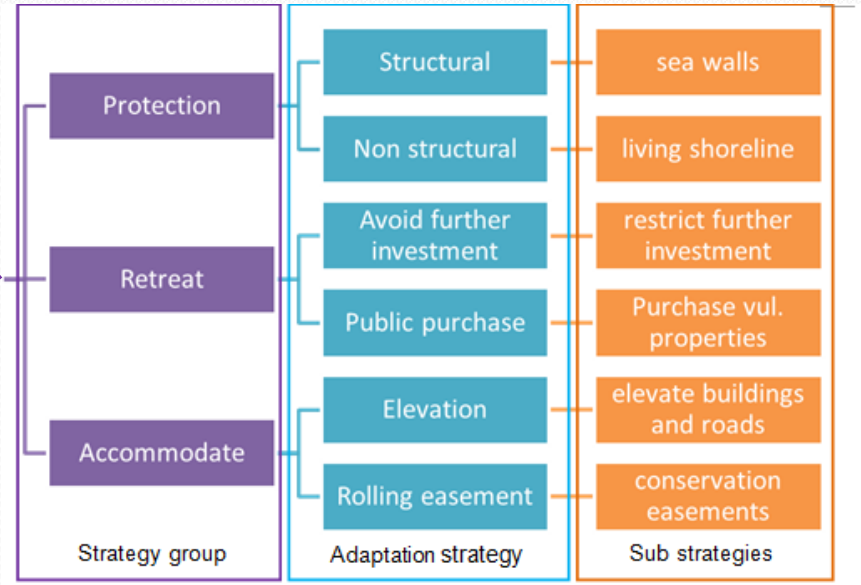
Quantification of Cost for adaptation strategies

Strategy framework





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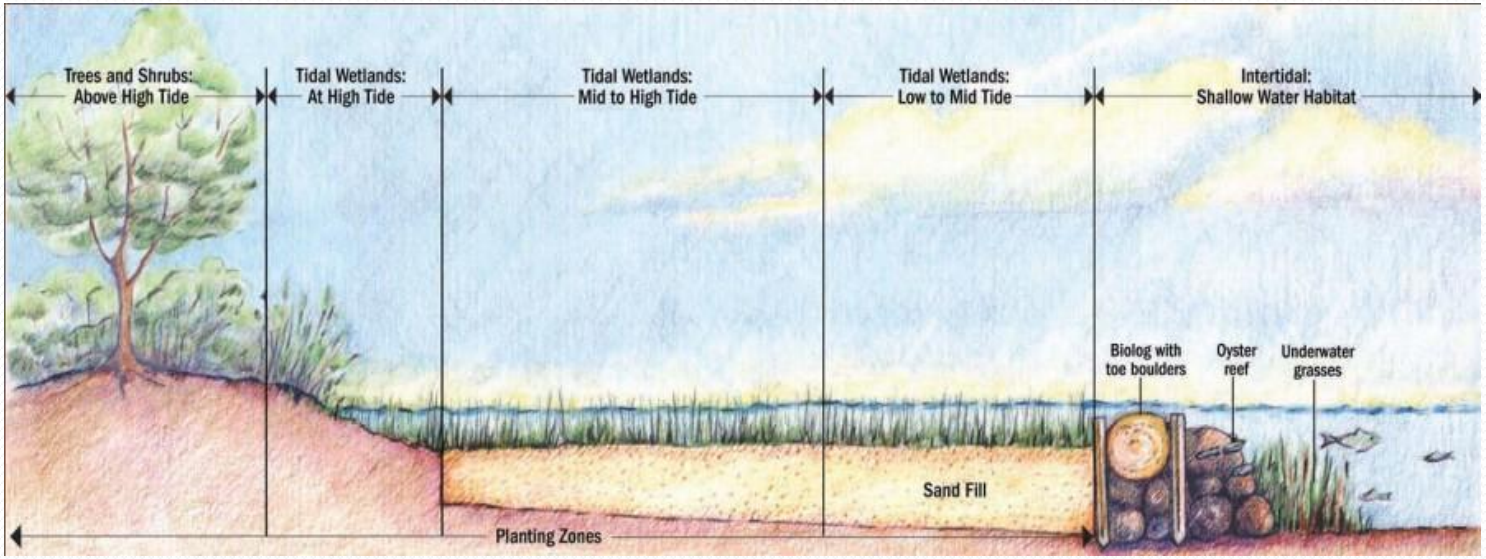
Constructing sea walls

- Building sea walls is a straightforward adaptation strategy to protect built-up environment but can damage natural systems.

Adaptation scenarios	Scenario 1	Scenario 2	Scenario 3
Total costs (in million $)	3,737	2,206	1,533

Establishing living shoreline

- The coastal areas of Hillsborough County are dominated by wetlands rather than recreational beaches. Therefore, living shoreline can fit the



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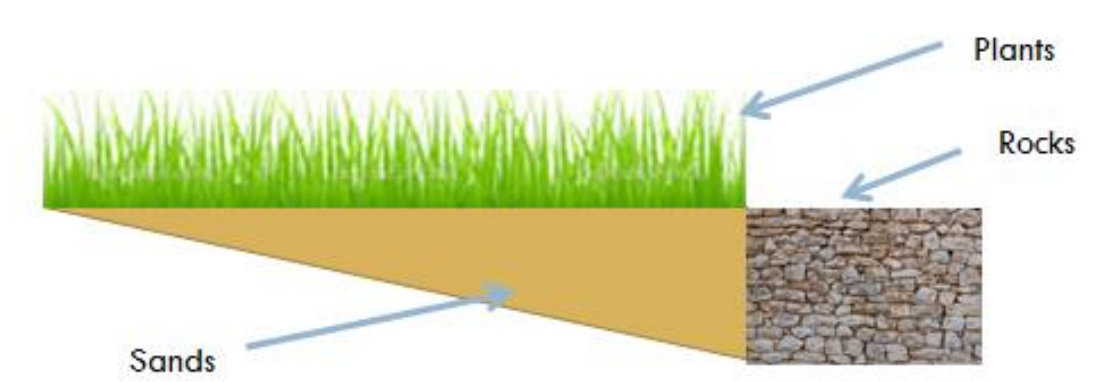
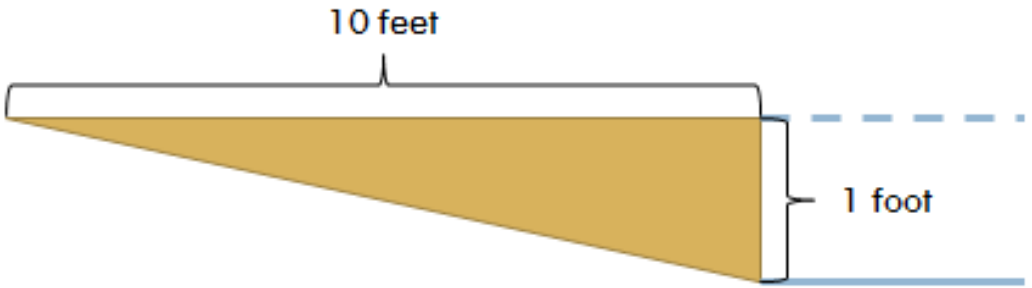
Calculation





	Scenario 1	Scenario 2	Scenario 3
Total costs (in millions $)	3,085	1,846	866

Conservation easement

- Conservation easement is one type of rolling easement which enables coastal society to gradually adapt to rising sea levels while enabling ecosystems to migrate inland.
- World Resources Institute suggests that each acre protected with a conservation easement costs on average $2,000 (World Resources Institute 2002) in the year 2002.

	Scenario 1	Scenario 2	Scenario 3
Total cost (in millions)	$113	$83	$78

Structural elevation

- This specific strategy involves the elevation of vulnerable buildings as well as the elevation of vulnerable roads.

Scenarios	Scenario 1	Scenario 2	Scenario 3
Total adaptation costs (in millions)	$9,115	$4,215	$3,048

Avoid further investment

- This strategy is the retreat response for sea level rise. That is, employing policies and zoning ordinances to avoid further development in these vulnerable areas to minimize risks and prepare for an eventual retreat and clear the way for wetland migration.

Public purchase

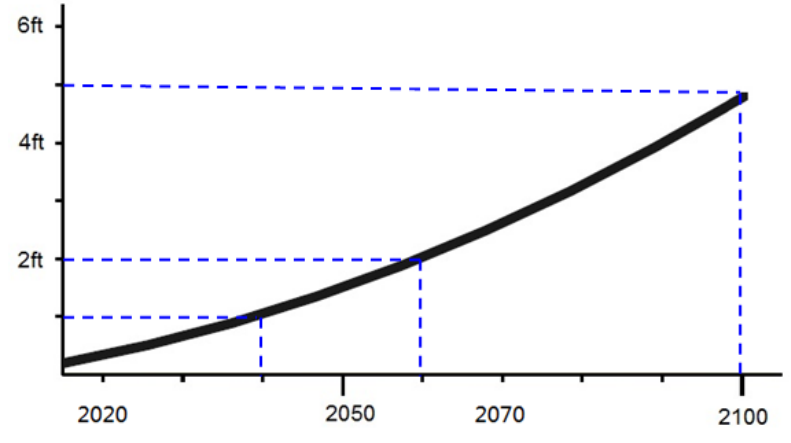
- The purchase is a typical property acquisition strategy, which asks local government to determine the most vulnerable properties and raise funds to purchase the property and assist the owners at risk to relocate.

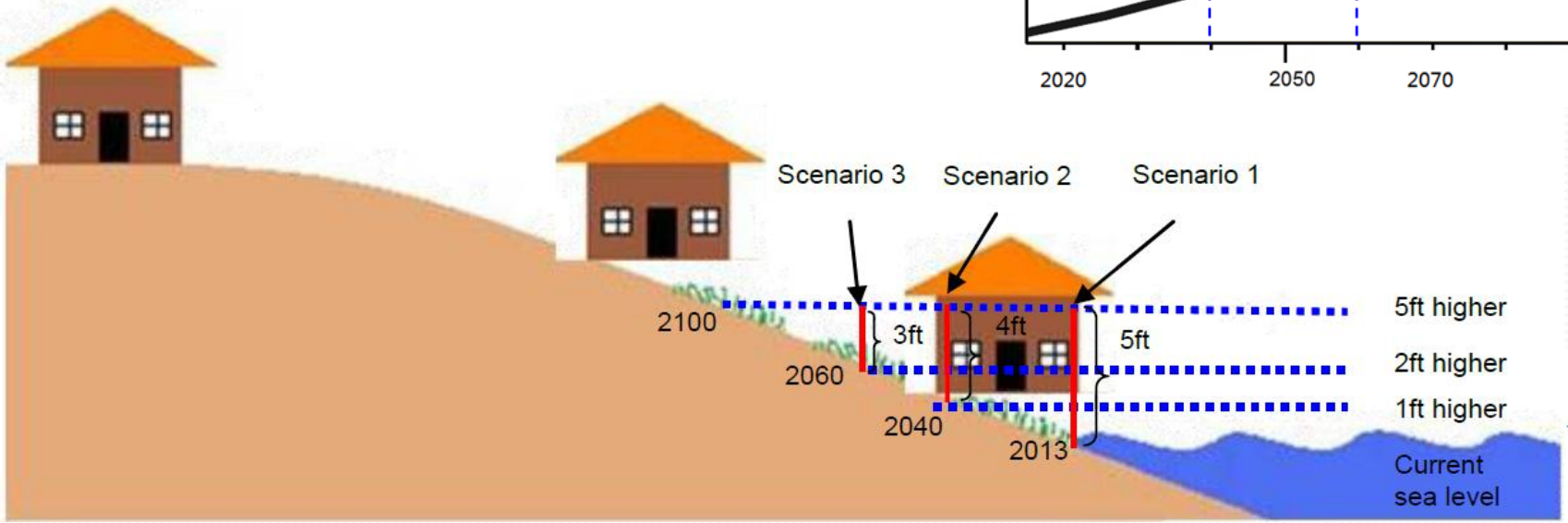
Scenarios	Scenario 1	Scenario 2	Scenario 3
Investment avoidance	0	0	0
Public purchase	$3,729,475,919	$2,481,457,430	$2,217,021,826

Action time points

- Action time points are defined as the year when a sea level rise adaptation strategy is implemented.

3 action scenarios





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Cost efficiency under Scenario 1

Strategies	Sea wall	Living shoreline	Elevat-ion	Easem-ent	Public purchase	Avoidance
Total benefits	$86,533	$87,103	$79,234	-$82,119	-$82,119	-$86,675
Total costs	$3,737	$3,086	$9,116	$113	$3,729	$0
B/C ratio	23	28	9	-728	-22	NA
Net benefits	$82,795	$84,017	$70,119	-$82,23	-$85,849	-$86,675

Unit in million $

Cost efficiency under Scenario 2

Strategies	Sea wall	Living shoreline	Elevat-ion	Easem-ent	Public purchase	Avoidance
Total benefits	$80,702	$81,178	$67,183	-80,67	-$80,677	-$80,821
Total costs	$2,207	$1,846	$4,216	$83	$2,481	$0
B/C ratio	37	44	16	-976	-33	NA
Net benefits	$78,49	$79,332	$62,96	-$80,75	-$83,158	-$80,821

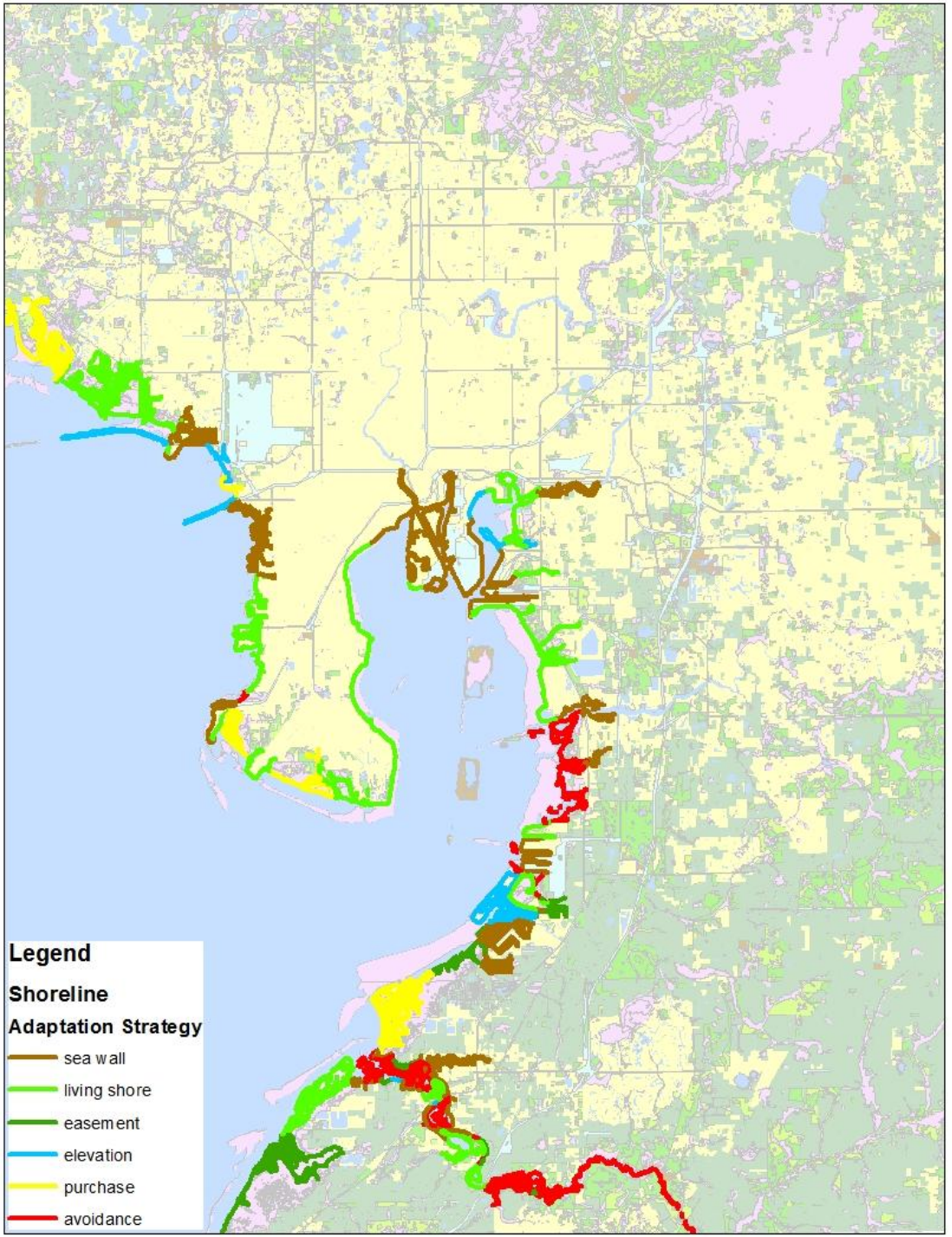
Unit in million $

Cost efficiency under Scenario 3

Strategies	Sea wall	Living shoreline	Elevat-ion	Easem-ent	Public purchase	Avoidance
Total benefits	$30,099	$30,373	$28,892	-$28,604	-$28,604	-$28,686
Total costs	$1,533	$867	$3,049	$78	$2,217	$0
B/C ratio	20	35	9	-366	-13	NA
Net benefits	$28,566	$29,506	$25,843	-$28,682	-$30,821	-$28,686

Unit in million $

Strategy assignment



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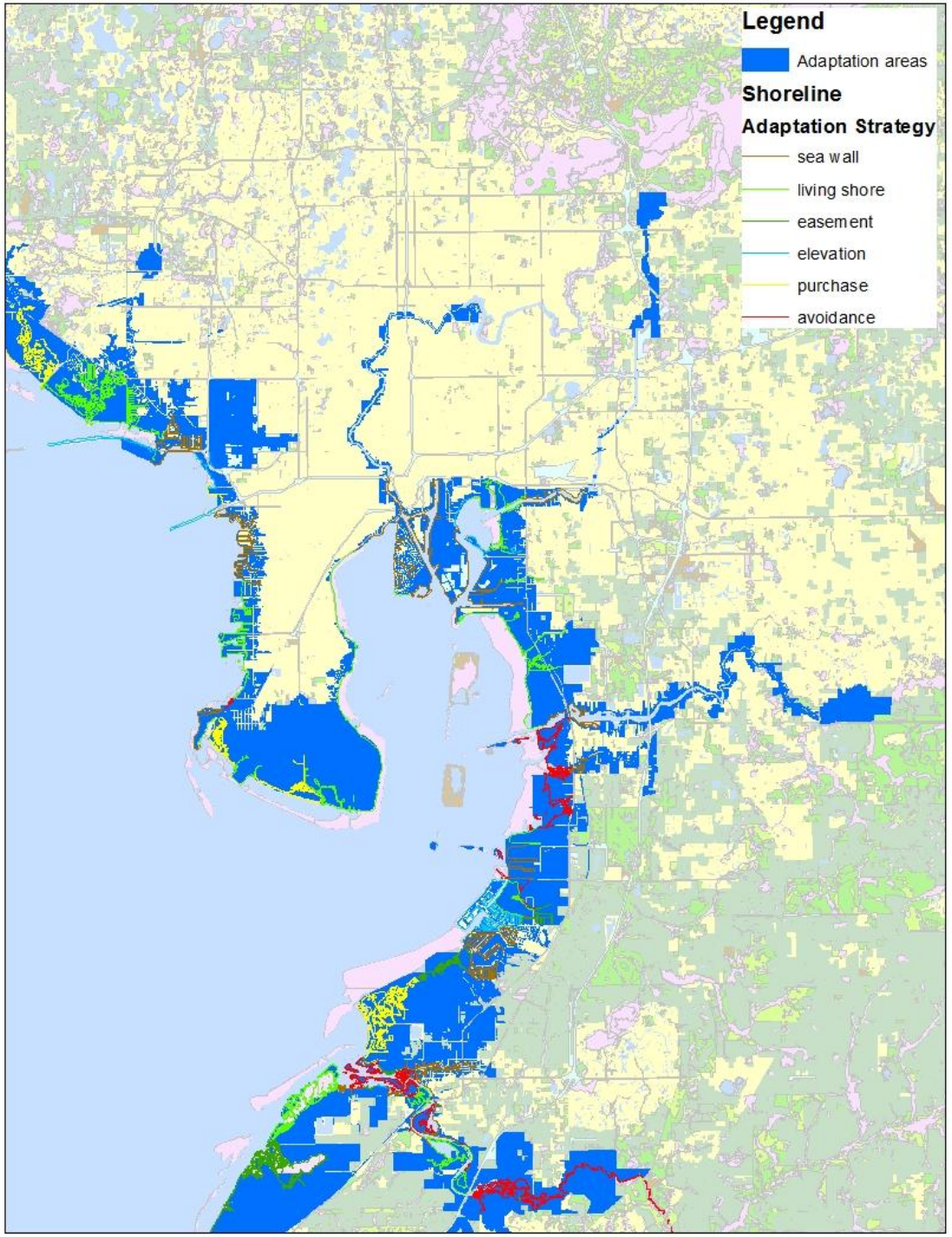
Planning areas



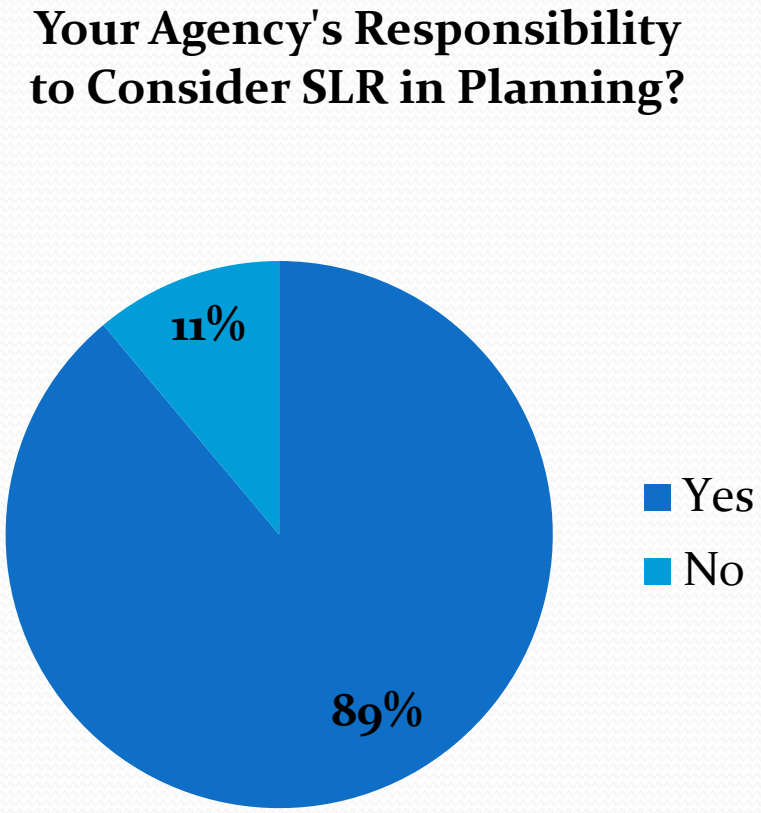
Social Behaviors
[Population Dynamics]

Sample Survey Results

Sea Level Rise Planning Status in Tampa Bay Region

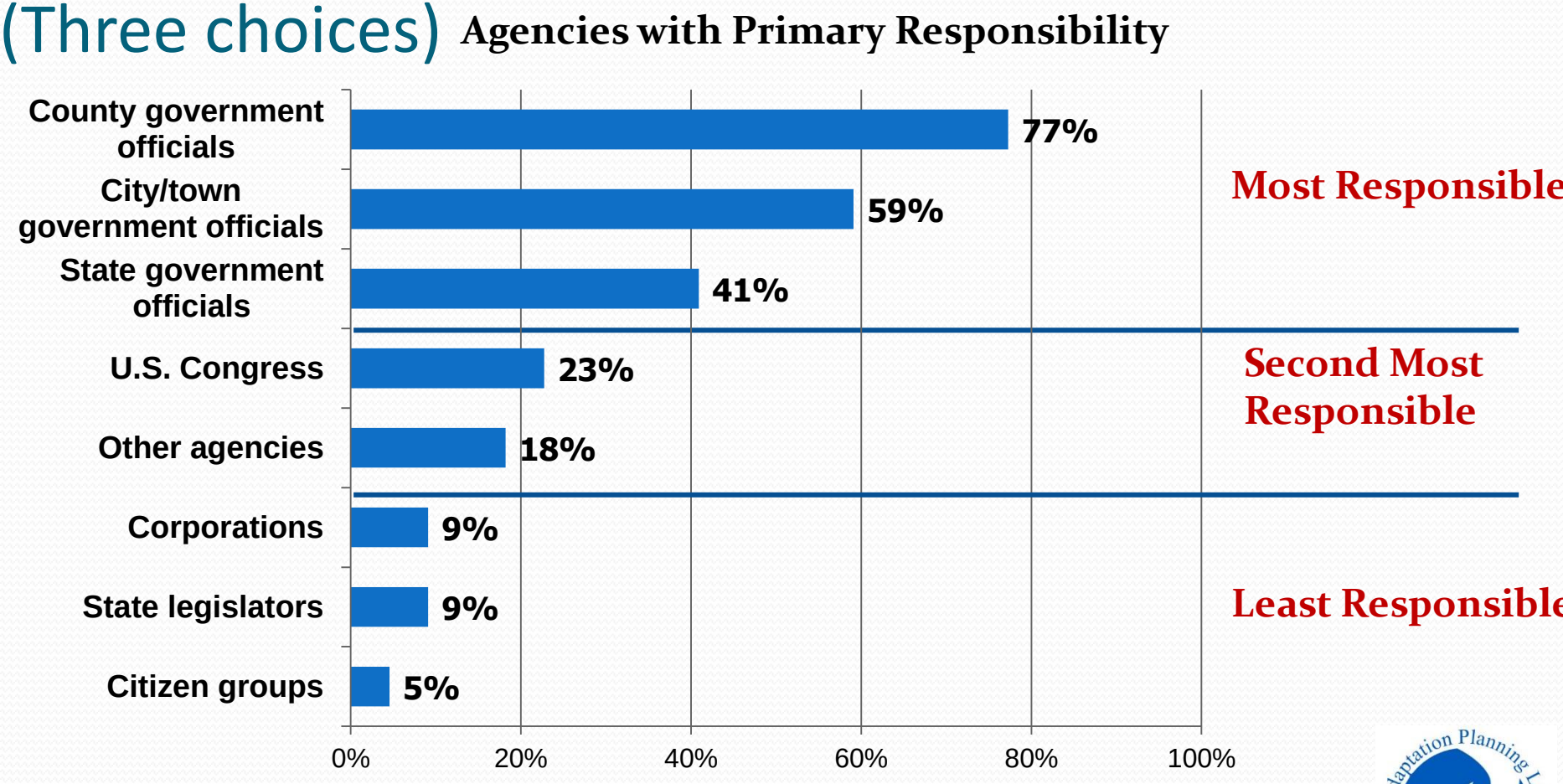
Responsibility, Funding, Planning Scenario

Who is Responsible for SLR Planning



- Exception
  - An Attorney (Citizen groups)
  - One Planning/Zoning Employees (City/County/State Government Officials)

Agencies with Primary Responsibility for SLR Adaptation Planning (Three choices)

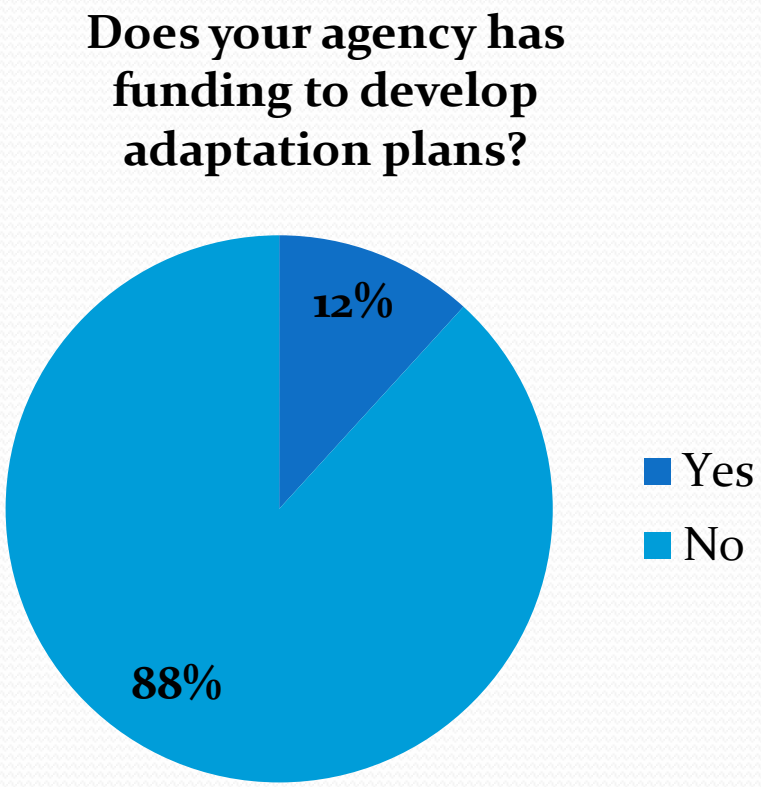


Other agencies: Department of Environment Protection, Water Management District Regional Planning Council

Implications for SLR Decision Support Tool Development

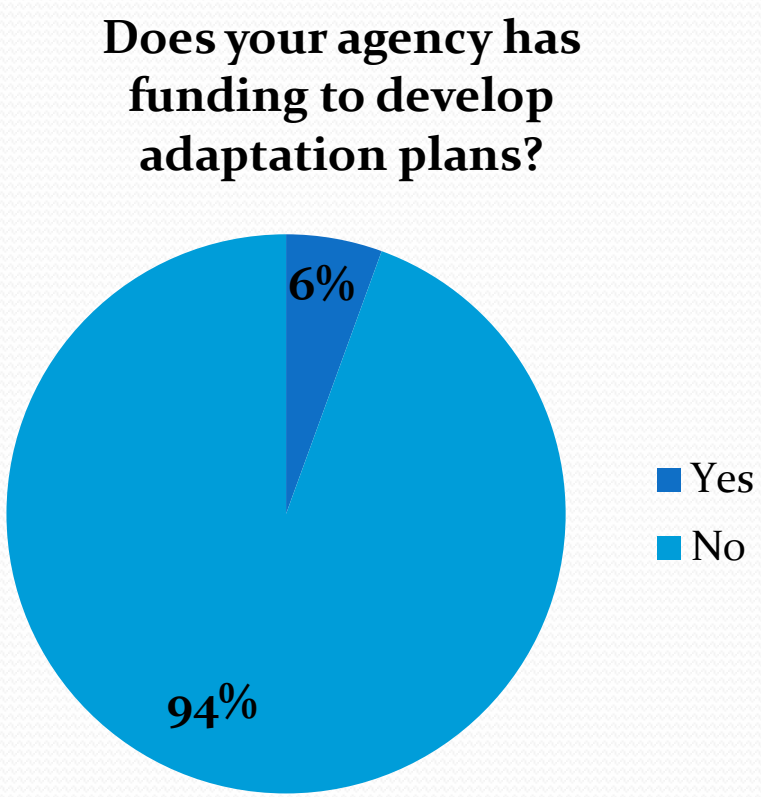
- Almost all of the agencies think they should take some responsibility to take sea level rise into planning practice.
  - City, County Planners, zoning, land use development managers
  - Private engineering firms
  - Environmental protection department
  - Transportation planning and management department
  - Local government officials
- **Multidisciplinary** and **Multi-agencies** nature
- County government officials, city government officials, and state government officials are rated as the top three most responsible ones for sea level rise adaptation planning
- Adaptation for sea level rise will focus at **local** levels, with **county** planning and governments as the most possible primary responsible agencies.

Funding for Adaptation Plan Development



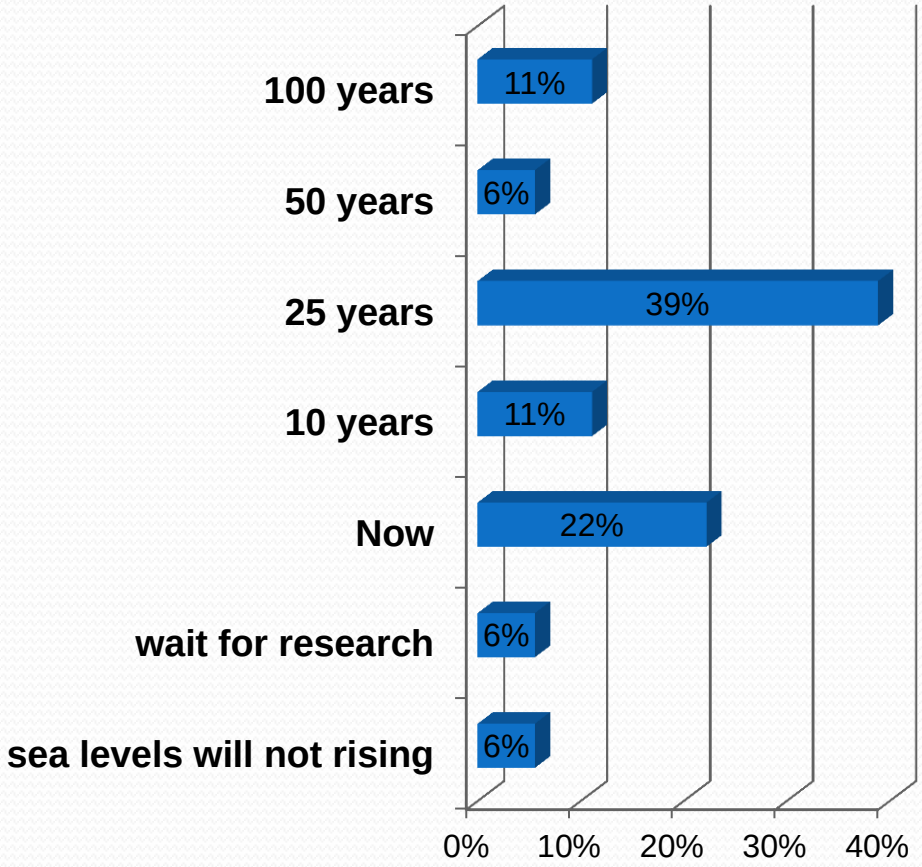
- Budget Range
  - EPA Tampa Bay Estuary Program – about $50,000 for coastal habit impact assessment
  - Hernando County – Part of the County Comprehensive Plan Update

Funding for Implementation of Adaptation Plan



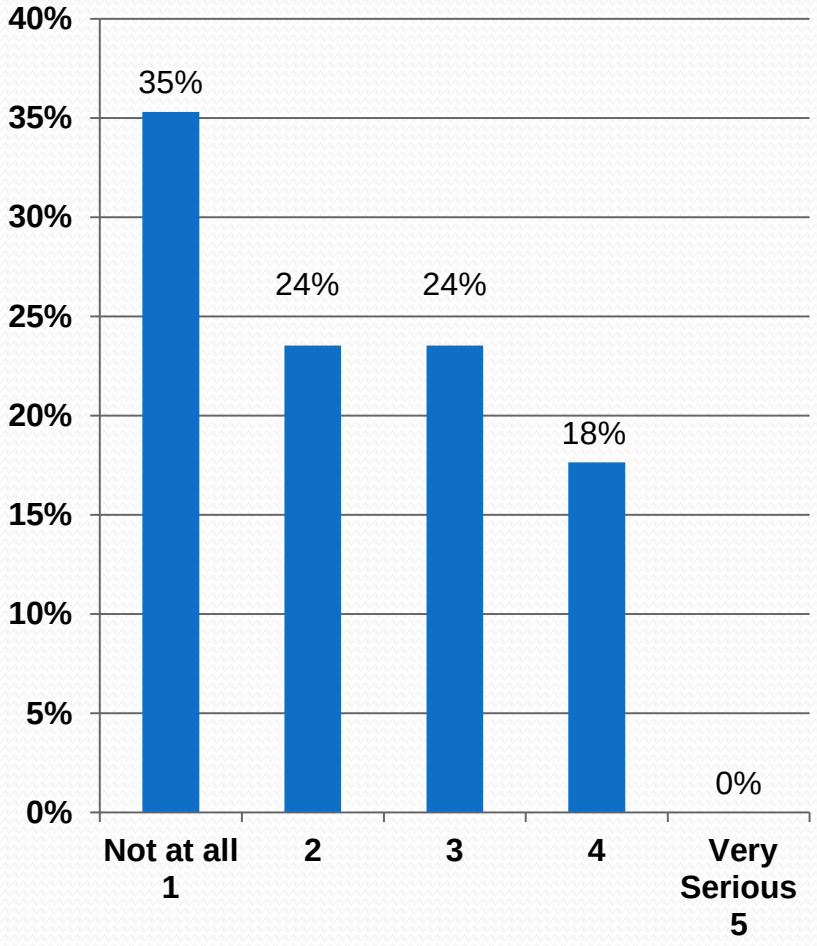
- Budget Range
  - EPA Tampa Bay Estuary Program – About $50,000 to implement high-priority habitat restoration or protection projects

SLR Adaptation Planning Scenarios



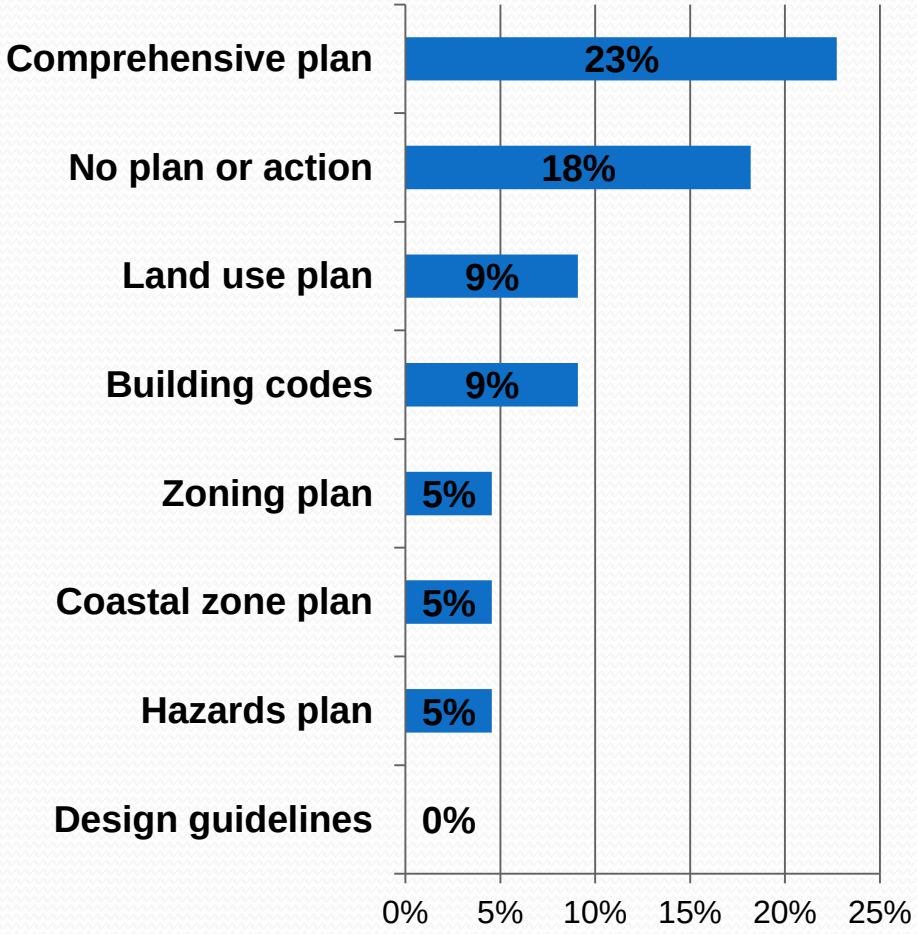
- Majority of the respondents (90%) believe sea level rise is rising
- Most of them (70%) think sea level rise will start to have impacts in Tampa Bay region in no more than 25 years

Threat of Sea Level Rise on Future Planning



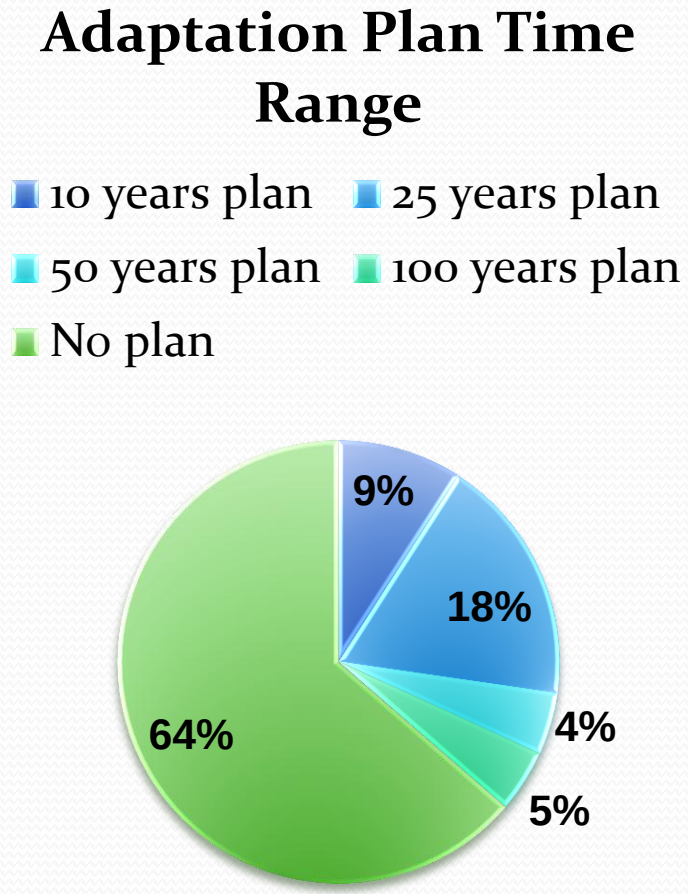
- However, over half of the agencies do not consider sea level rise as a very serious issue for future planning

Current Adaptation Planning Practice



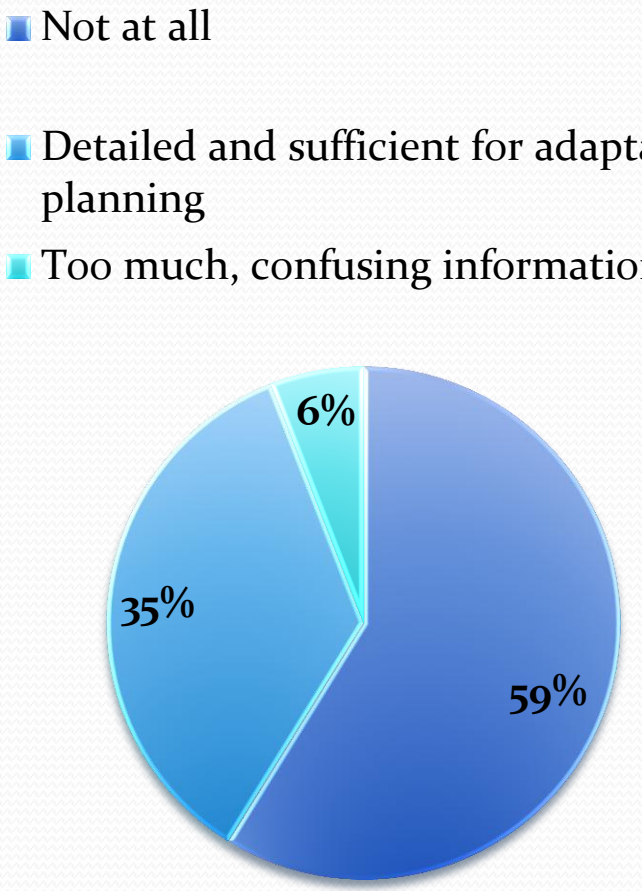
- About one-fifth of the agencies do not have any plan or action
- One-fifth of the agencies include sea level rise in their ***comprehensive plan***
- Ten percent include SLR in their building codes or land use plan
- Other plans that include sea level rise are coastal zone plan, hazards plan, zoning plan, Comprehensive Conservation and Management Plan, and Land Development Code - Flood Prevention & Protection Areas.

Current Adaptation Planning Practice



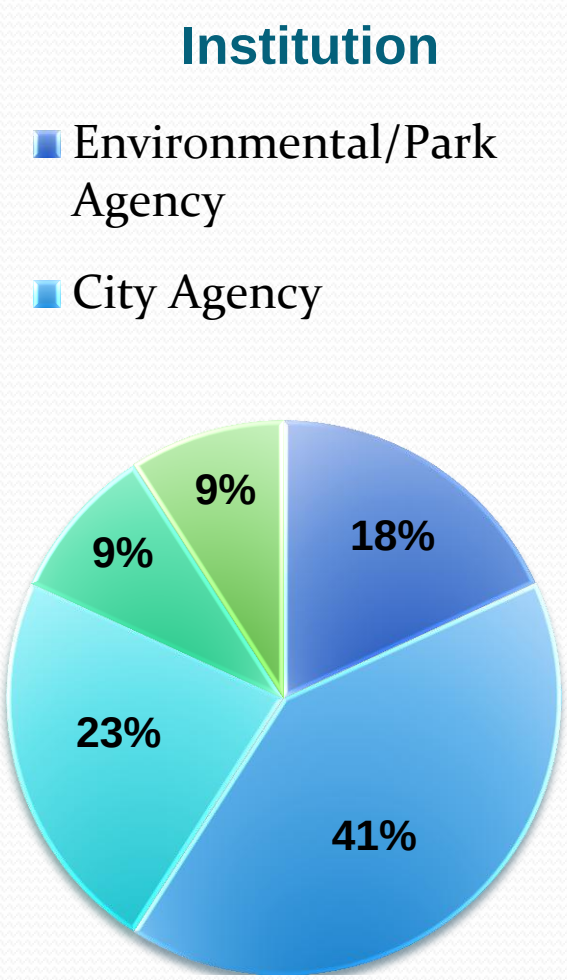
- Majority of the agencies do not have adaptation plan with a specific planning time range at the moment.
- Among the agencies with adaptation plans, the most common adaptation plan time range is 25 years.

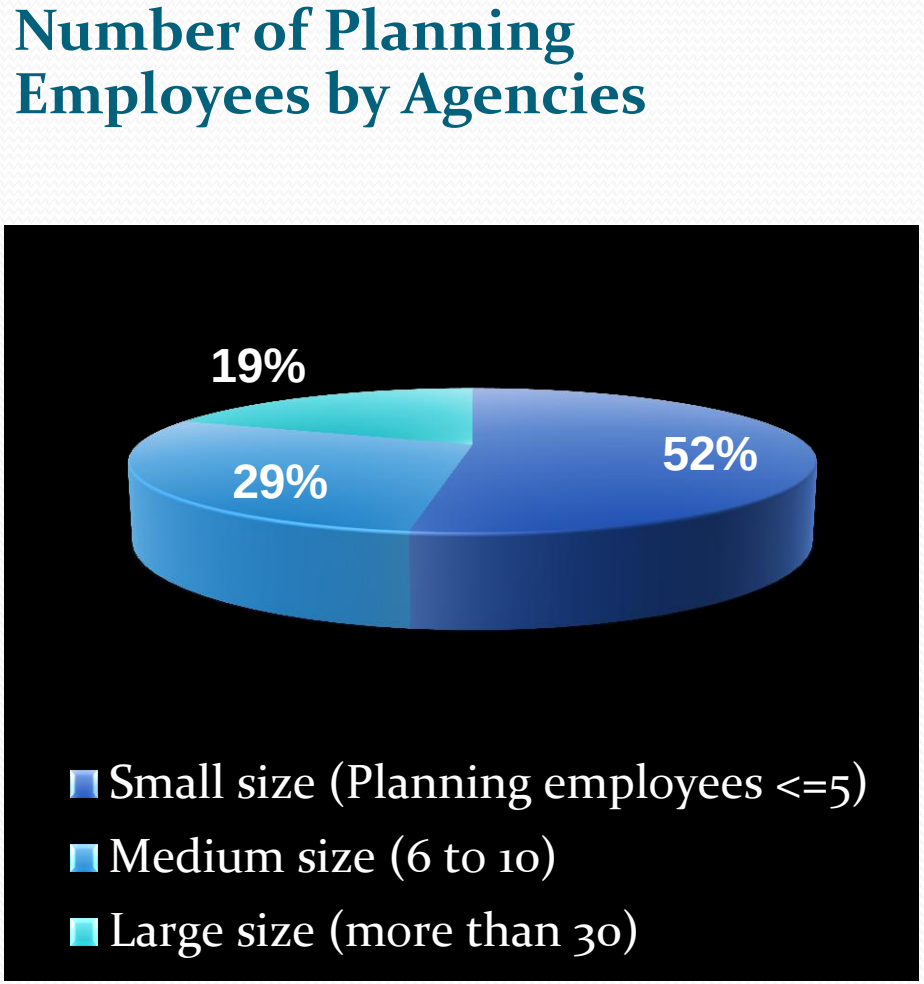
Is there sufficient information to support sea level rise planning and adaptation?



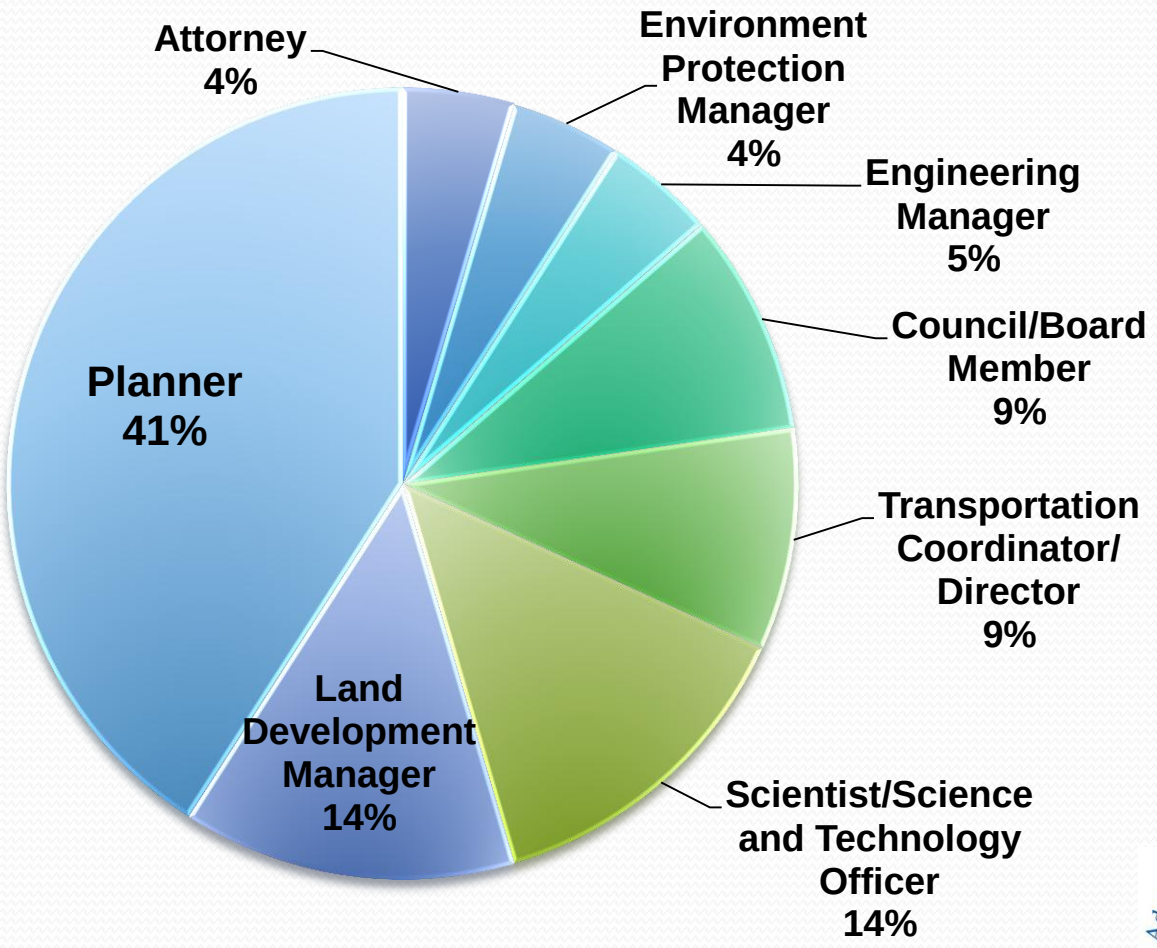
- Majority of the respondents think there is not adequate information and tools to support sea level rise planning and adaptation.
- Although it may not be the reason for no action or no plan (half of the agencies with no plan think there is detailed and sufficient information for adaptation planning), agencies with plans and actions do need more information to further support their planning and adaptation practice

Who are getting involved in SLR planning?





Profession



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User Group Implications

- Users dominated by city/county agencies.
- Planners is the major user group.
- Multiple agencies participation is involved.
  - Diversity of agencies, department
  - Diversity of positions (planners, senior professionals, managers, directors, council members)

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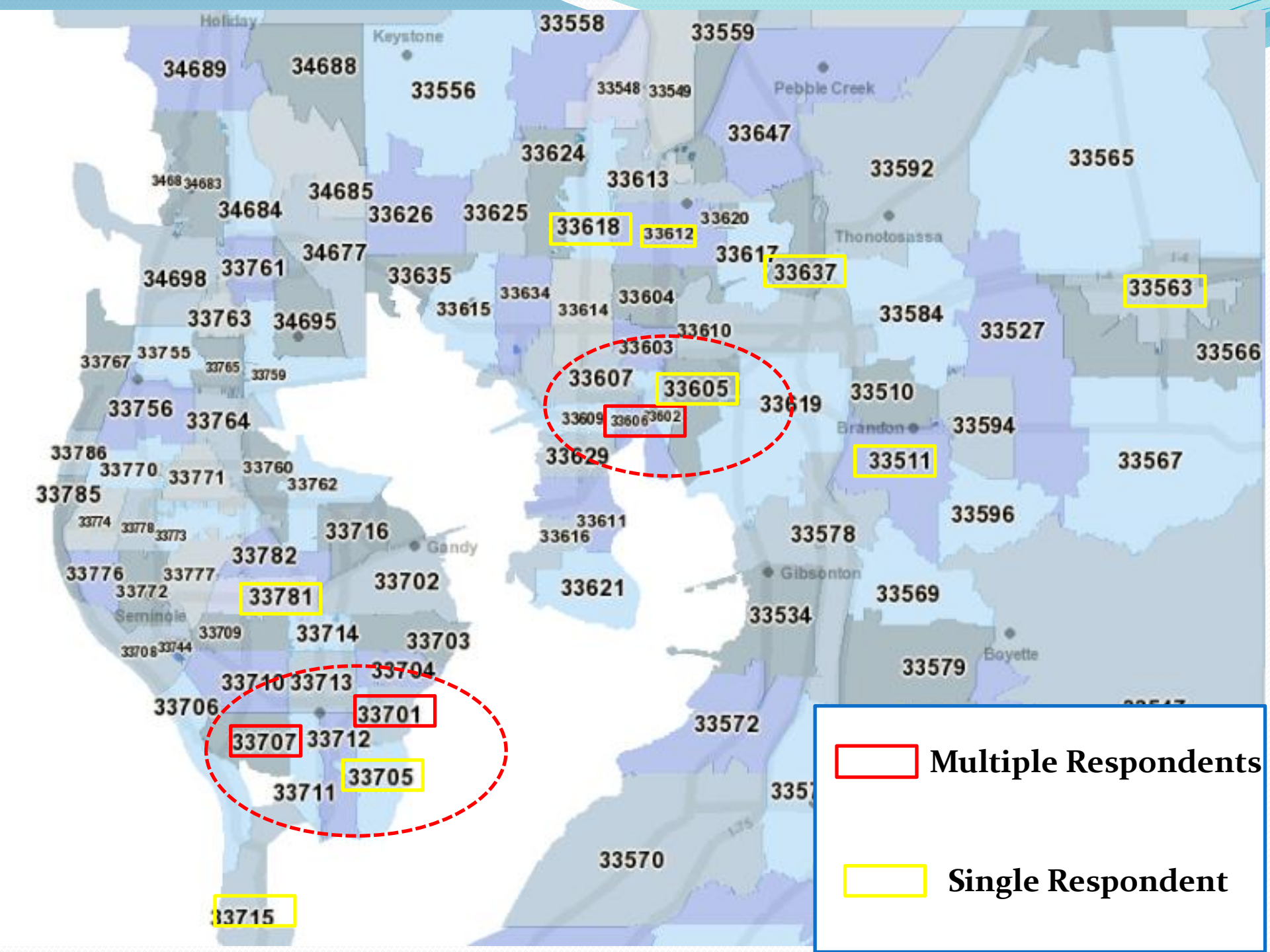
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Pebble Creek
Thonotosassa
Brandon
Gibsonton
Boyette
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Seminole
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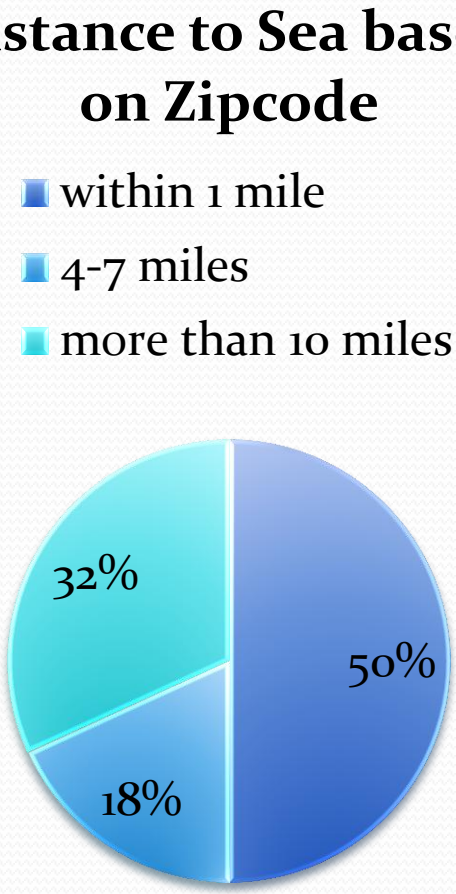
Multiple Respondents
Single Respondent

User Group Implications



- Participators in sea level rise adaptation planning
  - Spatially wide spread, inland concerns about sea level rise also
  - Near costal area more concerned

Adaptation Scenarios

- Highly related with the location of the jurisdiction

Distance to Sea (miles)	Build dikes, seawalls etc.	Build up marsh areas and non-structural- Shore nourishment	Discourage building new structures in areas at risk from sea level rise	Allow beaches and wetlands to naturally migrate inland	Purchase land at risk of sea level risk and frequently flooded properties.	Elevate buildings in area at risk	Elevate infrastructures and facilities at risk	Change building codes and regulations to reduce risk in flood prone areas
1	8	9	10	9	8	6	6	7
1	8	9	7	1	4	6	6	10
1	5	5	7	7	7	7	7	7
1	8	6	9	8	8	9	6	9
1	4	5	10	6	5	7	7	9
1	1	1	5	5	1	5	5	7
1	7	6	7	6	7	7	7	7
1	3	6	10	5	3	1	4	9
1	10	10	1	1	1	1	1	5
1	1	2	5	3	9	3	3	6
Mean	5.5	5.9	7.1	5.1	5.3	5.2	5.2	7.6
Median	6	6	7	5.5	6	6	6	7

Other (6): Transfer of Development Rights Program from high risk to low risk areas

Adaptation Scenarios

Distance to Sea (miles)	Build dikes, seawalls etc.	Build up marsh areas and non-structural- Shore nourishment	Discourage building new structures in areas at risk from sea level rise	Allow beaches and wetlands to naturally migrate inland	Purchase land at risk of sea level risk and frequently flooded properties.	Elevate buildings in area at risk	Elevate infrastructures and facilities at risk	Change building codes and regulations to reduce risk in flood prone areas
6.8	4	5	10	7	9	3	2	6
4.45	1	1	10	1	1	10	5	10
5.2	8	4	8	6	3	3	3	7
Mean	4.33	3.33	9.33	4.67	4.33	5.33	3.33	7.67
Median	4	4	10	6	3	3	3	7

Distance to Sea (miles)	Build dikes, seawalls etc.	Build up marsh areas and non-structural- Shore nourishment	Discourage building new structures in areas at risk from sea level rise	Allow beaches and wetlands to naturally migrate inland	Purchase land at risk of sea level risk and frequently flooded properties.	Elevate buildings in area at risk	Elevate infrastructures and facilities at risk	Change building codes and regulations to reduce risk in flood prone areas
12.5	2	4	8	6	2	4	6	8
12.5	1	1	10	6	1	7	8	9
12.5	1	1	10	6	1	7	8	9
16.8	1	3	8	6	1	3	5	5
19.8	8	8	8	8	3	3	10	3
Mean	2.6	3.4	8.8	6.4	1.6	4.8	7.4	6.8
Median	1	3	8	6	1	4	8	8

Adaptation Scenario

- Near Sea (< 1miles)
  - Most Feasible:
    - Discourage building new structures in areas at risk from sea level rise
    - Change building codes and regulations to reduce risk in flood prone areas
  - Least Feasible:
    - Allow beaches and wetlands to naturally migrate inland (Doing nothing scenario)
- Medium distance (4-7 miles)
  - Most Feasible:
    - Discourage building new structures in areas at risk from sea level rise
    - Change building codes and regulations to reduce risk in flood prone areas
  - Least Feasible:
    - Elevate infrastructures and facilities at risk
- Long Distance (>10 miles)
  - Most Feasible:
    - Discourage building new structures in areas at risk from sea level rise
    - Elevate infrastructures and facilities at risk
    - Change building codes and regulations to reduce risk in flood prone areas
  - Least Feasible:
    - Purchase land at risk of sea level risk and frequently flooded properties.

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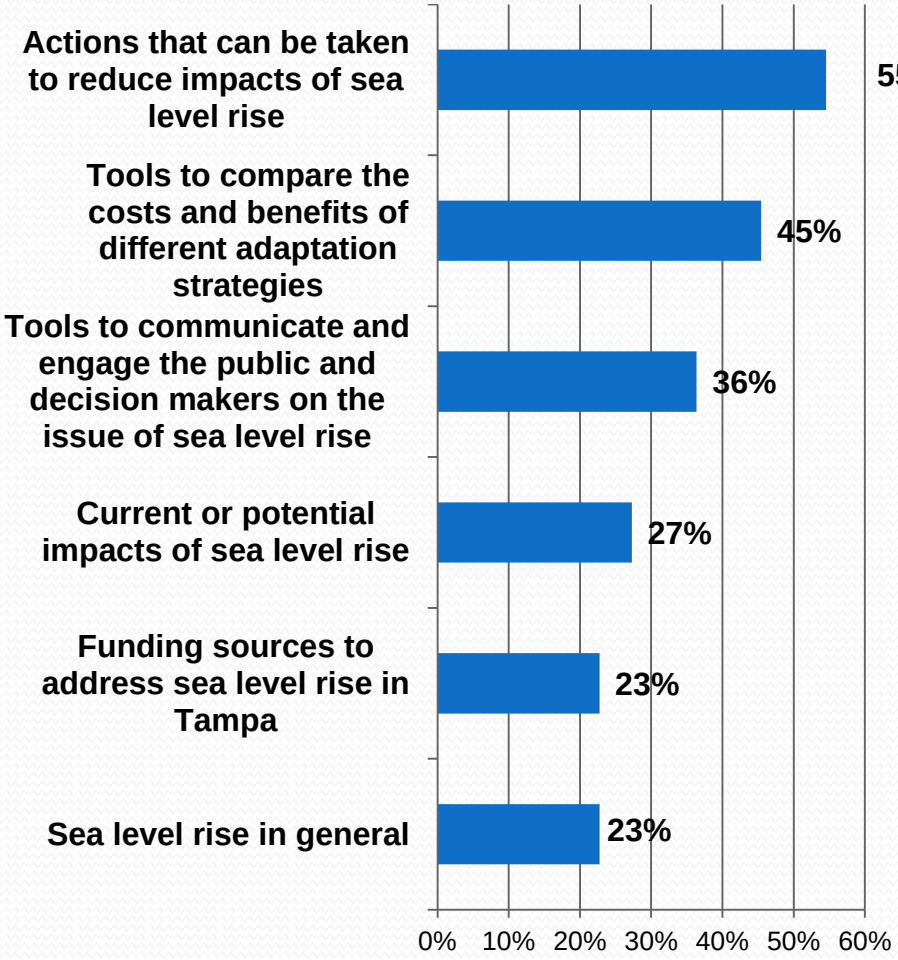
Research Needs



- research need to be further explored to support adaptation planning Ranking
  - Actions that can be taken to reduce impacts of sea level rise (Policy toolkit)
  - Tools to compare the costs and benefits of different adaptation strategies (adaptation Evaluation)
  - Tools to communicate and engage the public and decision makers on the issue of sea level rise (education)

Future Research

- Changes in environmental conditions will necessitate the movement of people from coastal areas—the very places that have been attractive forces for development in these Gulf States since the 1800s (Mulkey 2007). These shifts in population and development activities are expected to impact local economic activities affecting land uses and economic growth in these coastal states in the long run. So we have two major research questions.

- What are the impacts of inundation due to sea level rise on local residents and businesses?
- How to predict the population relocation if the primary residences of affected population are permanently inundated due to sea level rise?

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Thanks!!

http://tampaslr.wordpress.com/