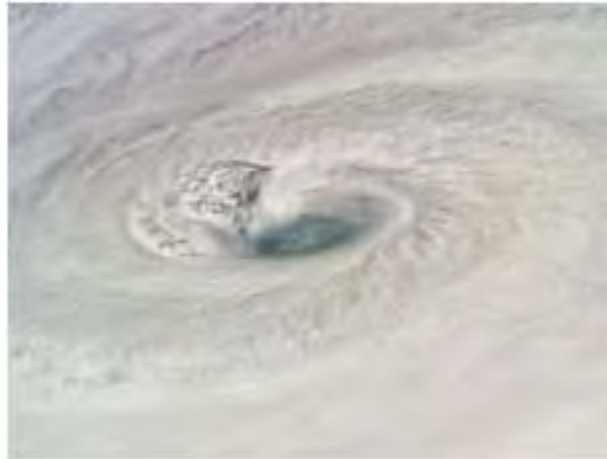


Financial Adaptation to Sea Level Rise and Storm Surge



The COAST Approach and Issues to Consider in Portland, Maine



Muskie School of Public Service

University of Southern Maine
Portland, Maine

Environmental Finance Center Network

The EFCN is the only university-based organization creating innovative solutions to managing costs of environmental protection and improvement. It consists of ten EFCs serving states within EPA's ten regions. By sharing and integrating information, tools and techniques, the EFCs work together and with the public and private sectors to promote a sustainable environment, bolstering efforts to address difficult how-to-pay issues.



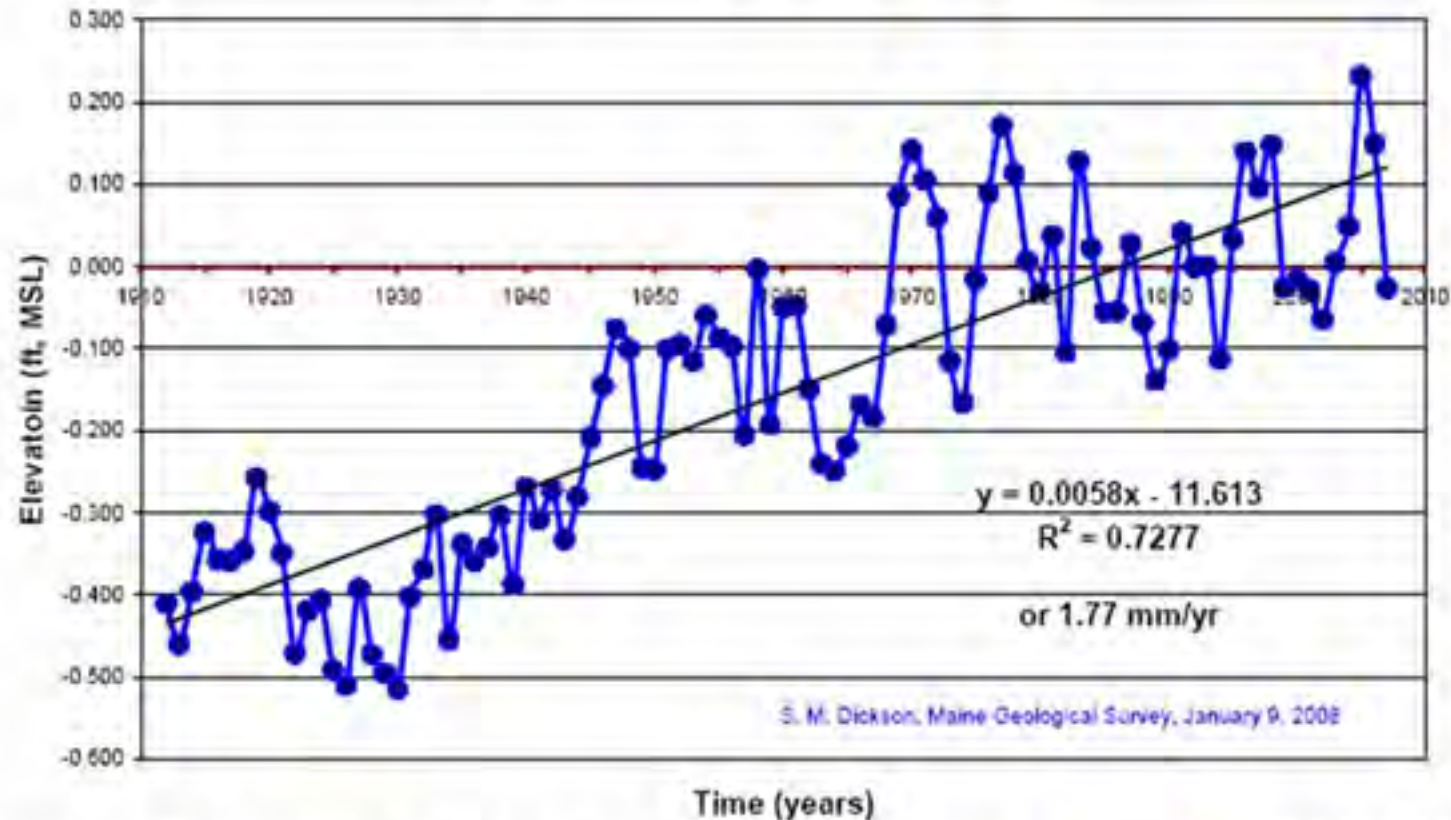
Global sea-level rise

Metres



Source: Cazenave and Llovel, 2009.

Portland Sea Level

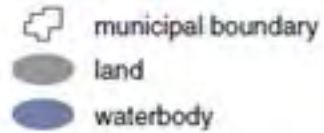
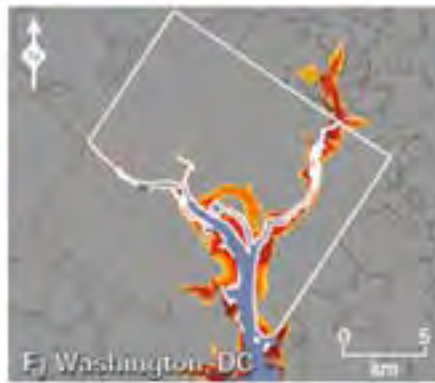
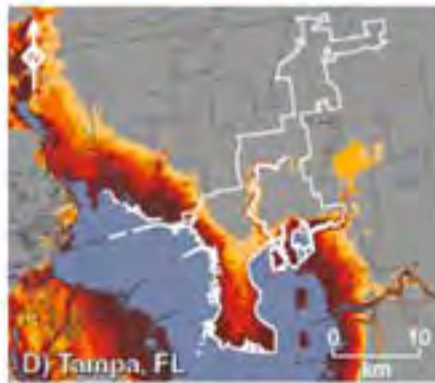
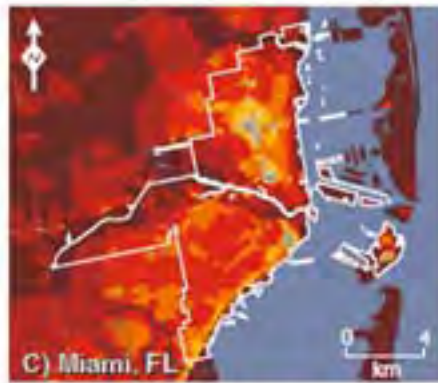
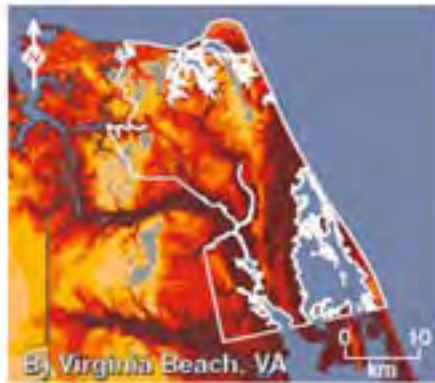


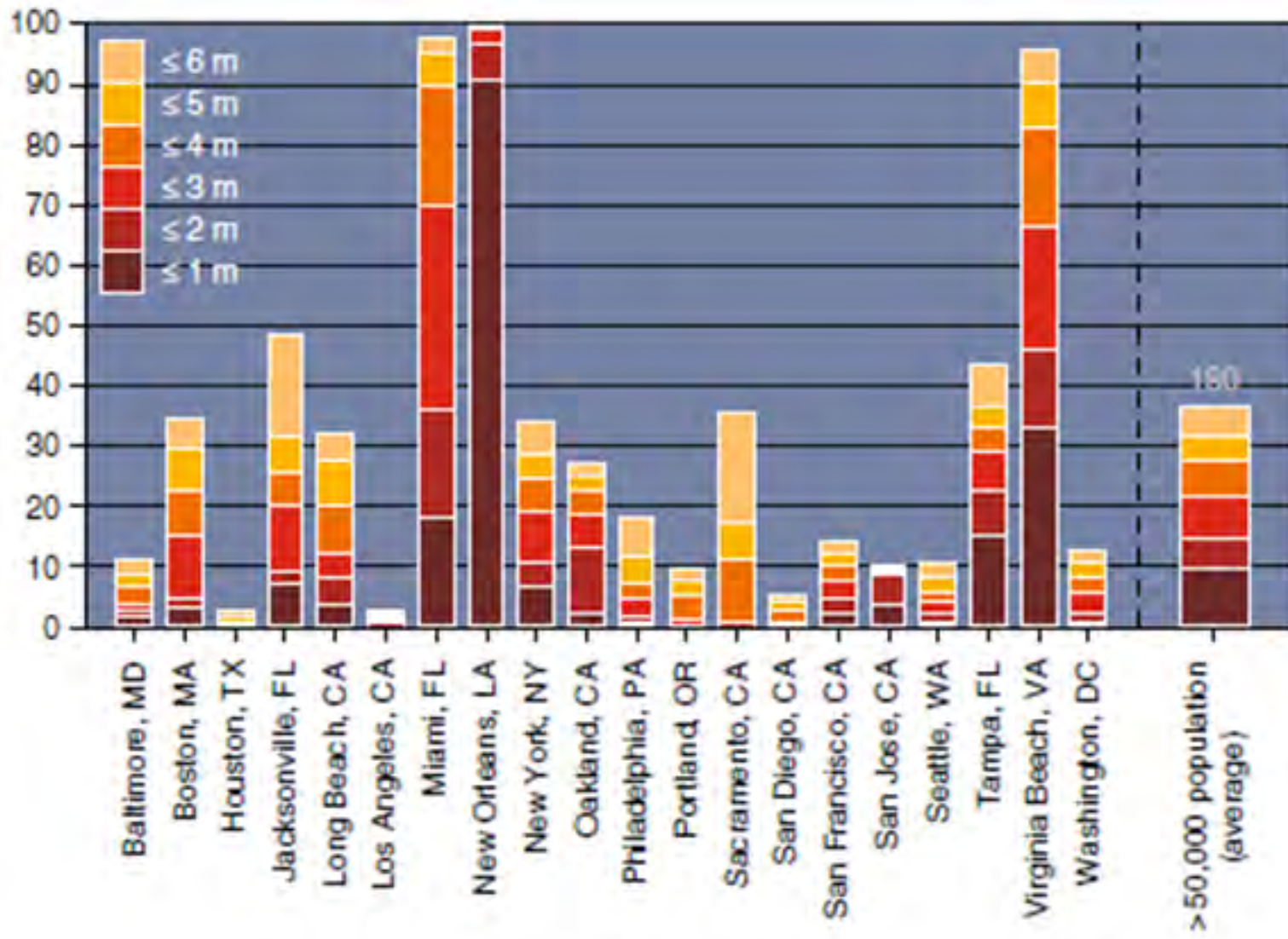
Portland Tide gauge = global ocean over last century **1.8 mm/yr** (IPCC, 2007).
In Maine, this is the fastest in past 3000 years
Satellite altimetry (1993-2003) = global sea level **3.1 ± 0.7 mm/yr** (IPCC, 2007)

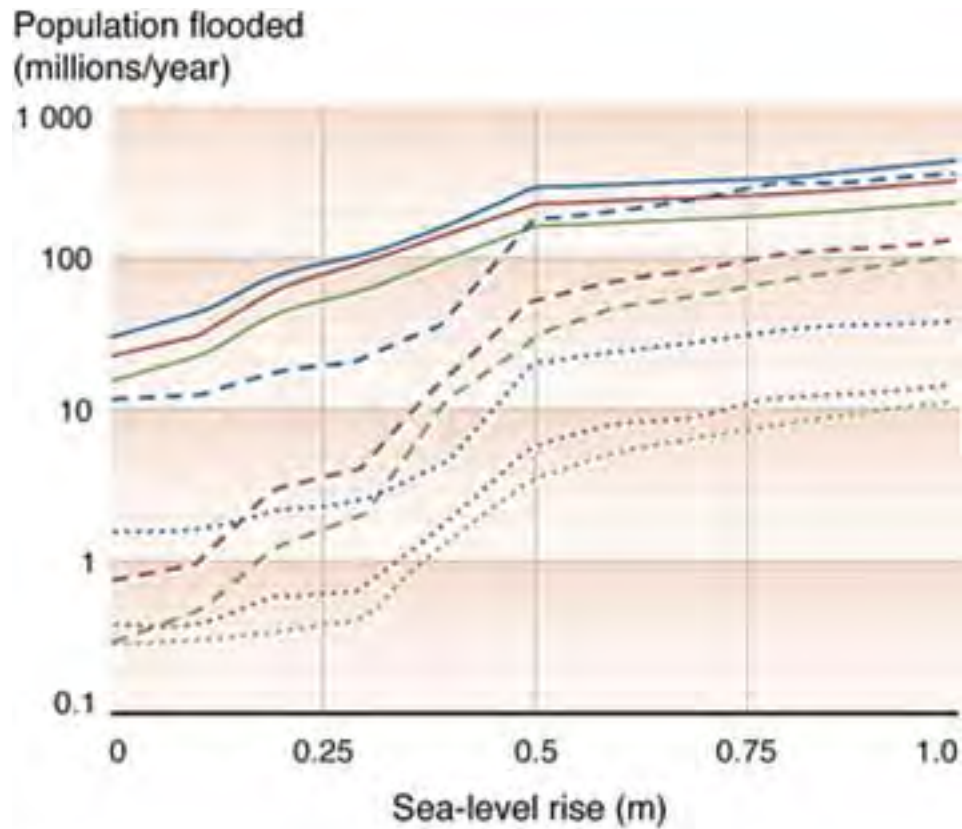




Weiss et al., *Climatic Change*, March 2011







Scenario	Degree of protection		
	constant	evolving	enhanced
A1/B1: <i>population 8 billion, highest GDP/capita</i>			
A2: <i>population 14 billion, lowest GDP/capita</i>			
B2: <i>population 10 billion, intermediate GDP/capita</i>			

-- Nicholls et al. 2006, *Philos. Trans. R. Soc. Lond.*



Jerry and Marcy Monkman



Norbert Psuty



- More frequent flooding
- More coastal erosion
- Wetland inundation and loss



Michael Dwyer























Impact of Sea Level Rise on Portland, ME









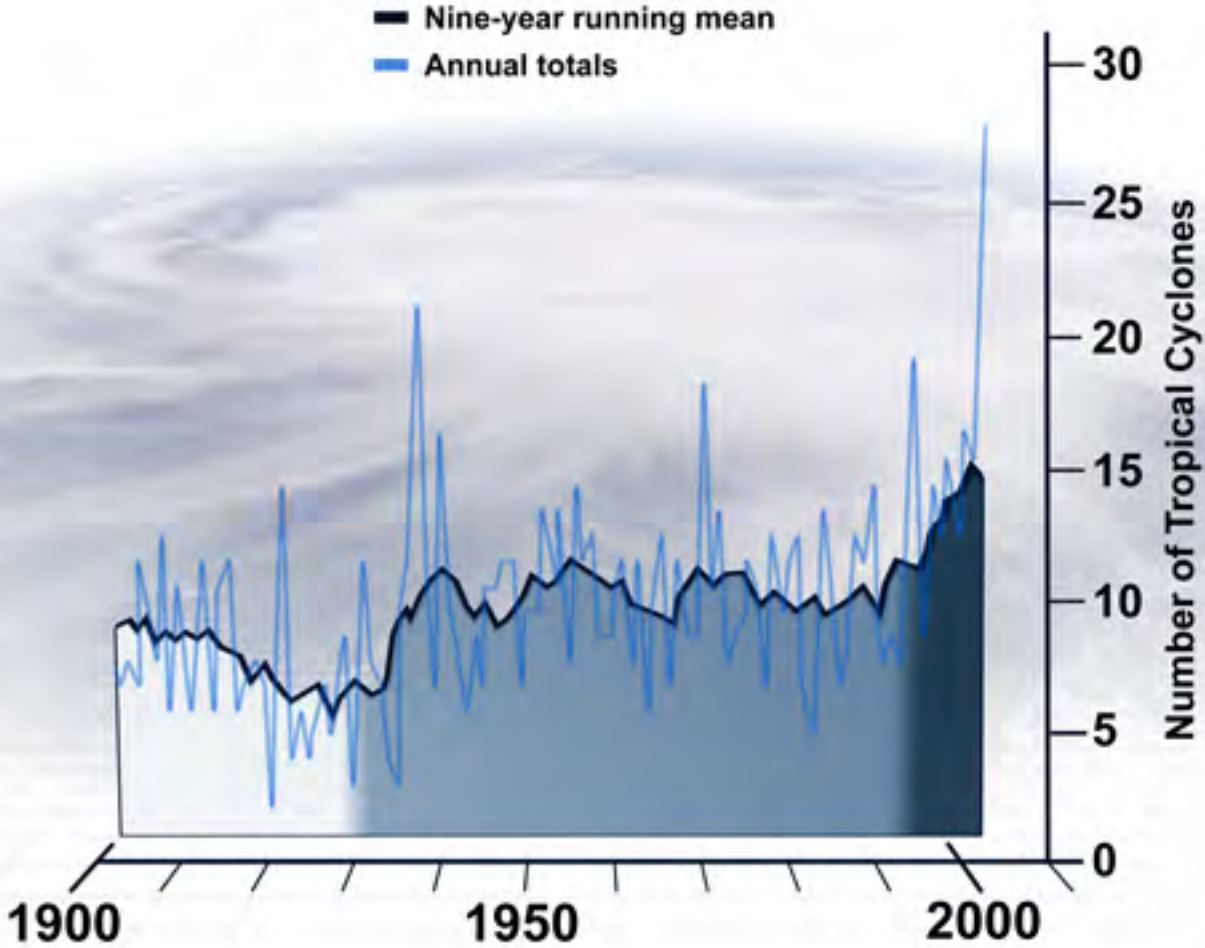
Impact of Sea Level Rise on Portland, ME





(R. Obrey.)
Whole Foods 1/9/10 at high tide

Frequency of Atlantic Storms



Climate Change >> Sea Level Rise >> Storm Surge



Patriot's Day Storm 2007: York Beach



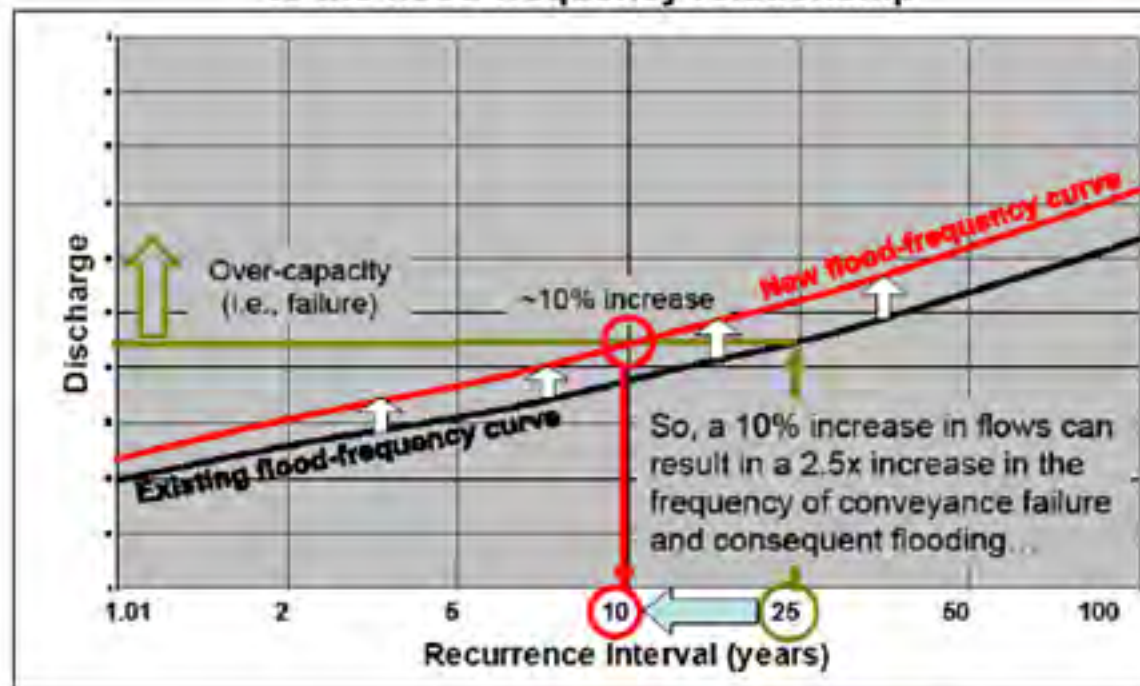
New England Environmental Finance Center



FLOOD FREQUENCY CHANGES

10% increase in flow = 2.5 times chance of failure

Consequences of “modest” changes
to the flood-frequency relationship



Source: Derek Booth

Planners and Climate Change Action: An Approach for Communities

by Samuel B. Merrill

Robert M. Sanford

Mark B. Lapping

Planners and others engaged in community development take seriously their responsibility to protect the public's health, welfare, and safety. In a new way, though, global climate change compels local officials to contend with the local and the global at the same time. For example, a planner for a coastal community undoubtedly will have to confront the necessity of removing and relocating critical infrastructure—roads, wastewater treatment plants, or schools, for example—from lands that could likely be inundated by rising sea levels. The planner must recognize also that changes in the growing season and water shortages due to droughts in other regions may make local agricultural land more important than ever before. Similarly, lands once deemed marginal may become exceedingly valuable.

Likewise, there is a temporal aspect of global climate change that ought to be recognized. If a major road is to be relocated, planners and policymakers will

have to contend with shifts in land values and recognize that placement of infrastructure due to relocation will mean other land use changes will also occur. Businesses and firms located along an existing road that will likely be lost to rising sea levels will also need to be relocated. This important change will trigger any number of smaller adjustments, both private and public. It is possible that entire downtowns will be lost and new commercial and service centers will have to be established. This, in turn, will bring about changes in residential development and the everyday patterns of life. Nearly all communities—and not just those located on the coast or in river valleys—will be faced with challenges. But in facing them, time is truly of the essence and a failure to seize the moment could have consequences of unimagined proportions.

This essay is a brief overview of responsibilities local officials must face to ensure that their towns are adequately prepared for the coming challenges. It provides some of the arguments that underlie planners' obligations and suggests a means to categorize necessary responses over time.

CHANGE IS UPON US

Dealing with new or even "fringe" topics is what planners have always done; it is their job to articulate pathways and opportunities that may arise from events and changes not routinely recognized. This role arose in matters of public health—the cholera epidemic of 1836, for example, and the need to keep sewage away from drinking water. In many ways, this public health need will continue well into the future. In Maine, awareness of the overlap between planners and climate change is not new. Back in 1995, for example, planners at the U.S. Environmental Protection Agency (EPA) and the Maine State Planning Office issued a document, *Anticipatory Planning for Sea Level Rise along the Coast of Maine*, which articulated a variety of topics and issues to be faced if sea levels climb an anticipated average of 66 cm before the end of the current century. Now, however, documents of this type—and efforts by local planners to implement recommendations from them—need to become much more commonplace and mainstream.



The Effects of Climate Change on Economic Activity in Maine: Coastal York County Case Study

by Charles S. Colgan

Samuel B. Merrill

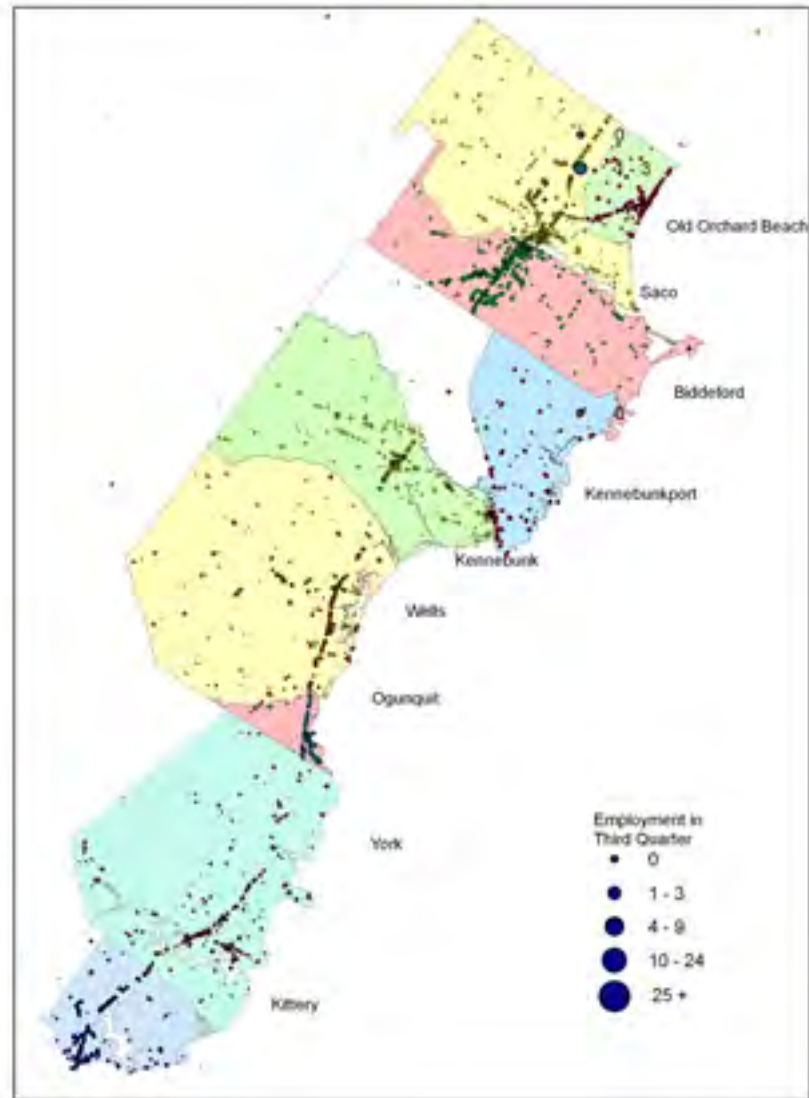


Climate change can have significant ramifications for Maine's economy. If short-term projections for the next century are accurate, at minimum sea level rise will become increasingly noticeable in association with more severe and destructive coastal storms. Charles Colgan and Samuel Merrill evaluate risk estimates by presenting a case study of the projected consequences of sea level rise and coastal storm damage on the economy of the state's most vulnerable area, York County's coastal communities.



New England Environmental Finance Center

Employment Locations in York County Coastal Communities 2007

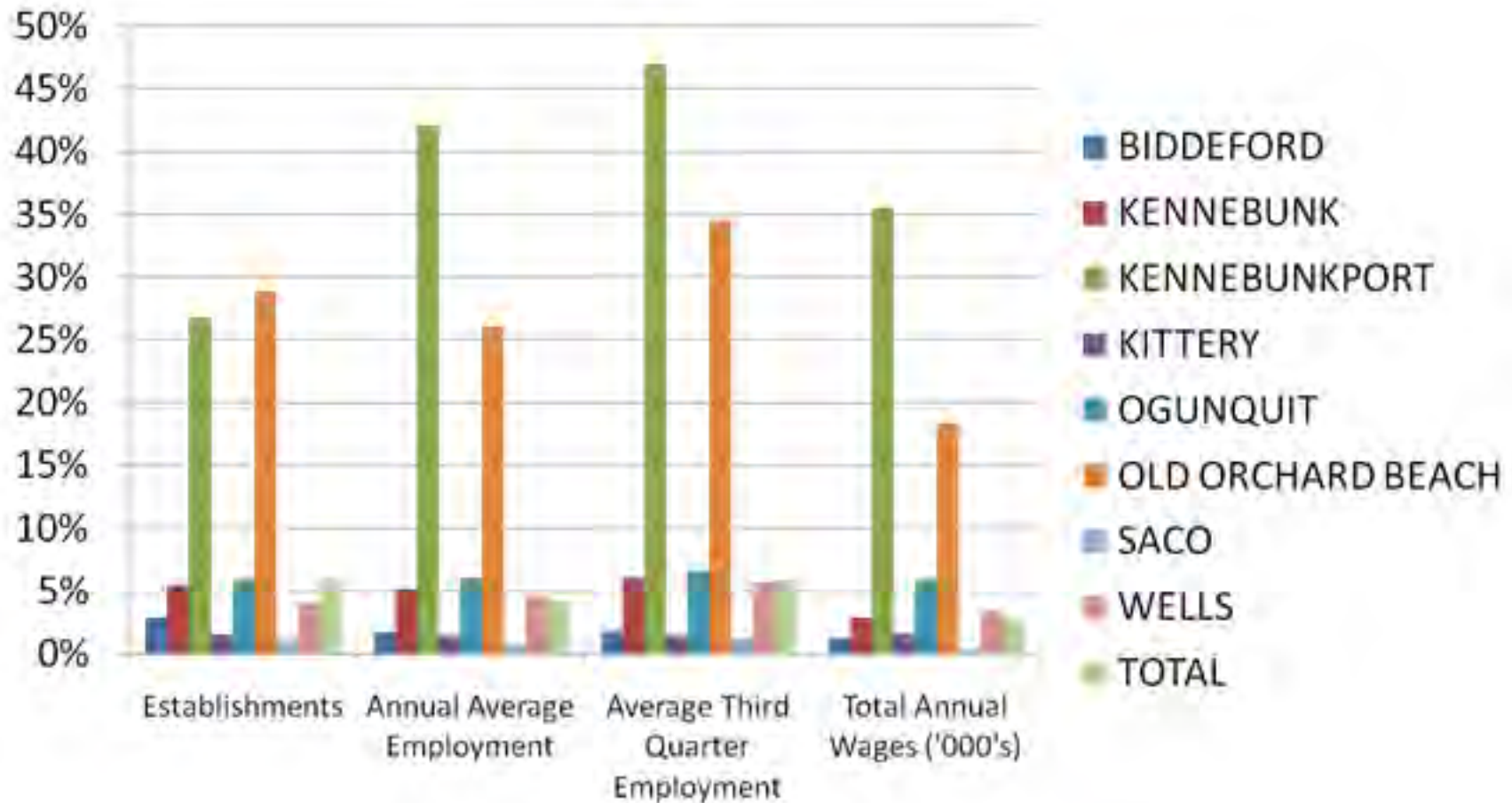


Source: Maine Department of Labor Quarterly Census of Employment and Wages

Old Orchard Beach: Employment At Risk by Different Size Storms

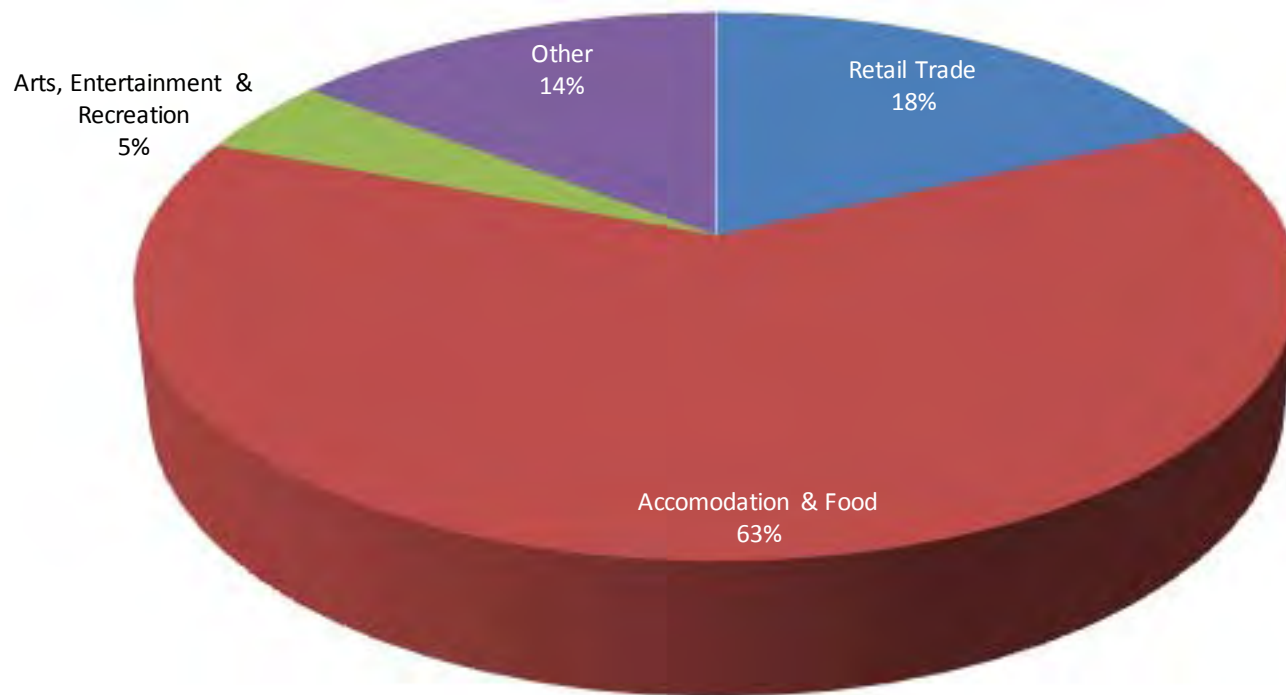


Percent of Town Economy in At Risk Employers

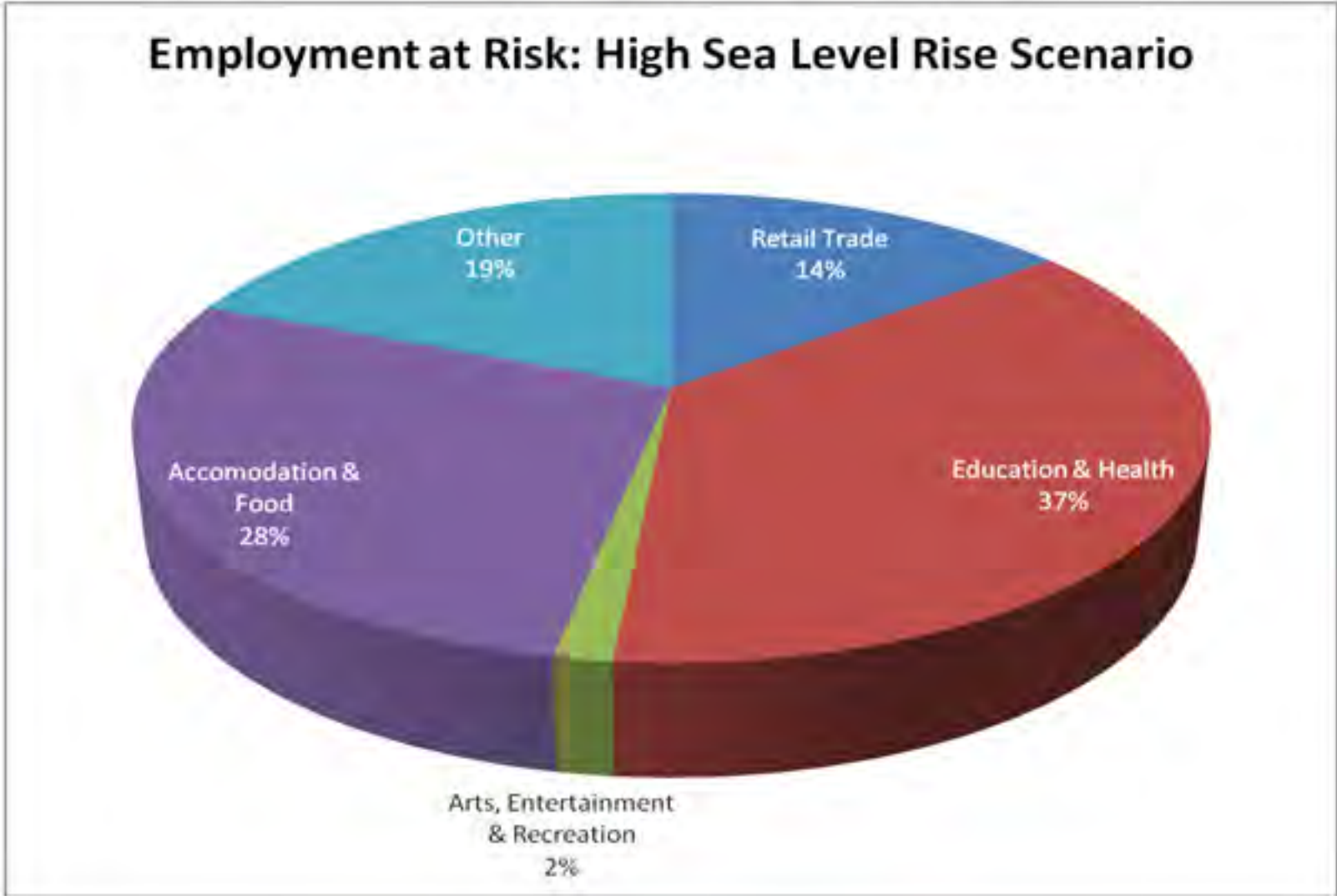


Within the SLOSH Model Zone, the biggest threat is to Establishments Related to Tourism

Industry of Employment: SLOSH Model Risks



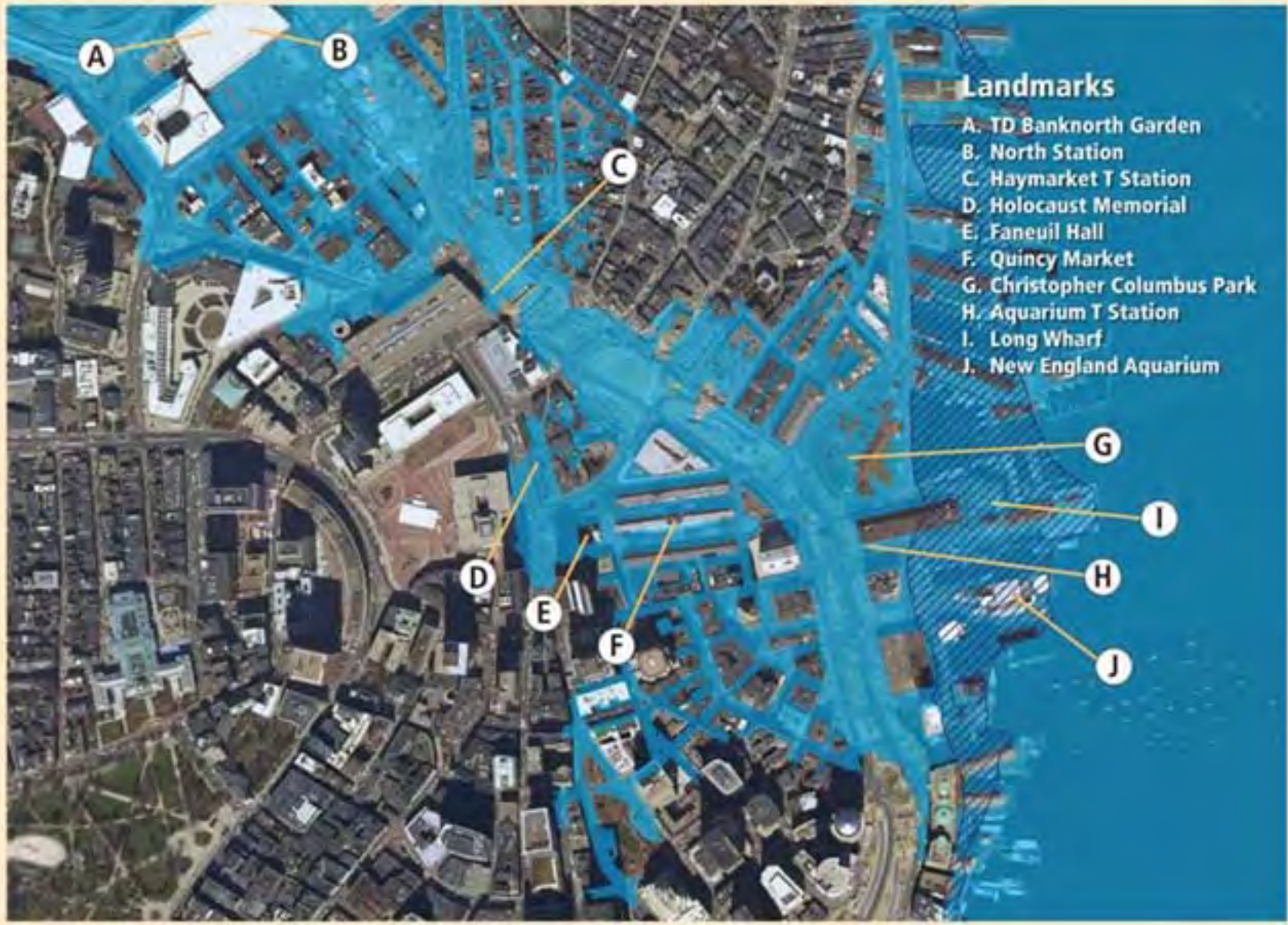
In the High Sea Level Rise Scenario, the Industries at Risk Substantially Expand



Employment at Risk Within SLOSH Model Predictions

	Establishments	Annual Average Employment	Average Third Quarter Employment	Total Annual Wages ('000's)
BIDDEFORD	24	183	209	\$4,511
KENNEBUNK	32	274	341	\$5,338
KENNEBUNKPORT	67	524	812	\$11,835
KITTERY	7	121	119	\$7,026
OGUNQUIT	13	88	167	\$1,817
OLD ORCHARD BEACH	103	470	977	\$7,345
SACO	7	49	85	\$813
WELLS	19	176	260	\$3,700
TOTAL	272	1,885	2,971	\$42,385

Coastal Flooding in Boston under Present and High Emission Sea Levels



■ Current 100-year flood zone
■ Projected 100-year flooded area (higher-emissions scenario)





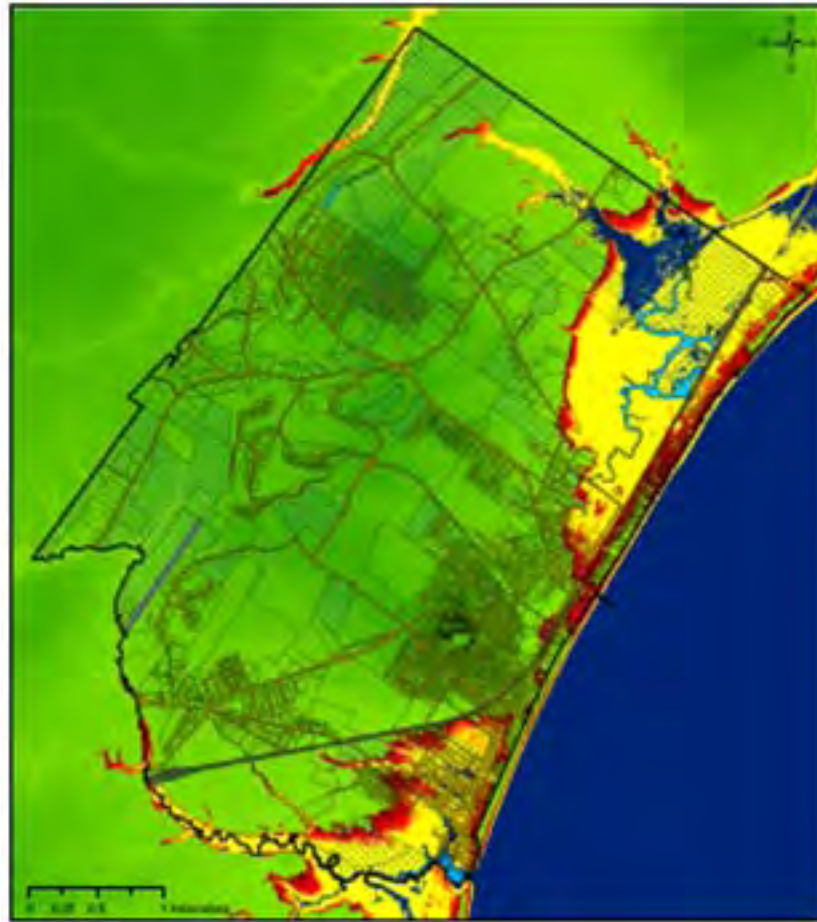
Source: NECIA/UCS, 2007 (see: www.climatechoices.org/ne/)

Ways to Frame Climate Adaptation

- **Be honest. Respect feelings and beliefs. Empower citizen involvement when possible.**
- **Make it local.**
- **Make it concrete, not abstract.**
- **Make it now, not later.**
- **Talk about trade offs between risks and benefits, and the benefits of adapting sooner rather than later.**
- **Frame adaptation within the context of local attitudes towards climate change. (There are other reasons than climate change to take many adaptive actions).**

From **“Climate Skeptics Embrace Cleaner Energy.”**

<http://www.nytimes.com/2010/10/19/science/earth/19fossil.html?ref=us>



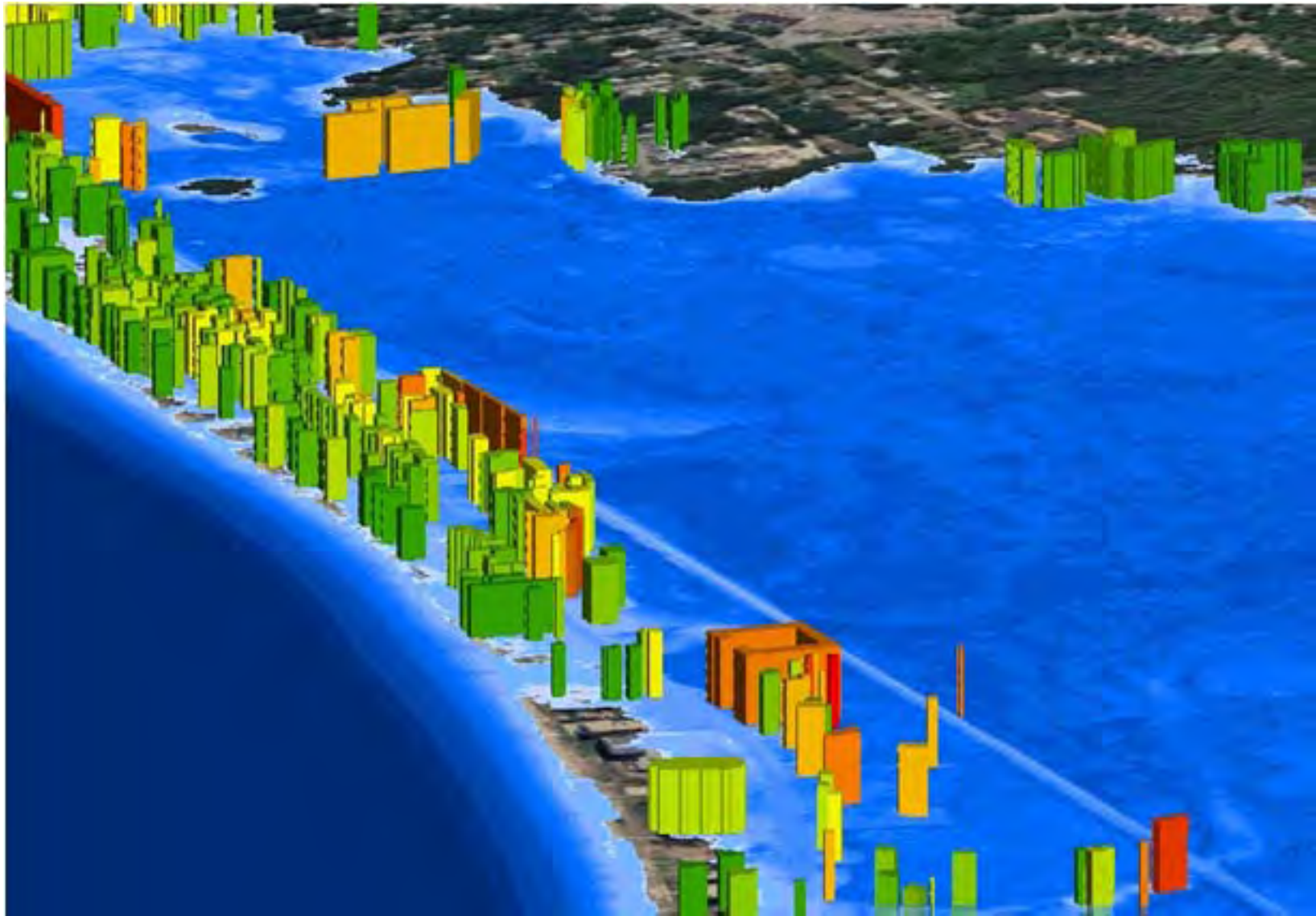


New England Environmental Finance Center

**DAMAGE FUNCTIONS
FOR SINGLE FAMILY RESIDENTIAL
STRUCTURES WITH BASEMENTS**

Structure Depth-Damage

Table 1 Structure One Story, With Basement		
Depth	Mean of Damage	Standard Deviation of Damage
-8	0%	0
-7	0.7%	1.34
-6	0.8%	1.06
-5	2.4%	0.94
-4	5.2%	0.91
-3	9.0%	0.88
-2	13.8%	0.85
-1	19.4%	0.83
0	25.5%	0.85
1	32.0%	0.96
2	38.7%	1.14
3	45.5%	1.37
4	52.2%	1.63
5	58.6%	1.89
6	64.5%	2.14
7	69.8%	2.35
8	74.2%	2.52
9	77.7%	2.66
10	80.1%	2.77
11	81.1%	2.88
12	81.1%	2.88
13	81.1%	2.88
14	81.1%	2.88
15	81.1%	2.88
16	81.1%	2.88



New England Environmental Finance Center

Expected costs and damages, 2010 - 2050

SLR Scenario	Adaptation	Residual Damages	Adaptation Cost	Total Damages and Costs
		(\$ million)	(\$ million)	(\$ million)
No SLR	No Action	680	0	680
	50 yr flood	3.4	52.4	55.8
	100 yr flood	0	60	60
Low	No Action	899.3	0	899.3
	50 yr flood	28.3	52.4	80.7
	100 yr flood	0	60	60
High	No Action	1016.6	0	1016.6
	50 yr flood	67.8	52.4	120.2
	100 yr flood	37.6	60	97.6

Input: a range of adaptation options

- Revetments



Pea Patch Island, DE (Delaware River)

Input: a range of adaptation options

- Revetments
- Geotextile tubes





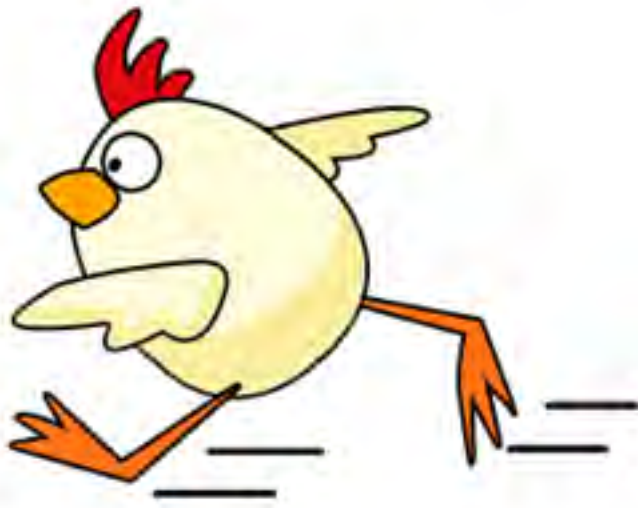


New England Environmental Finance Center

Sea Isle City, NJ

Geotextile Tubes





“Facing the bluntness of reality is the highest form of sanity and enlightened vision.”

- Chogyam Trungpa Rinpoche

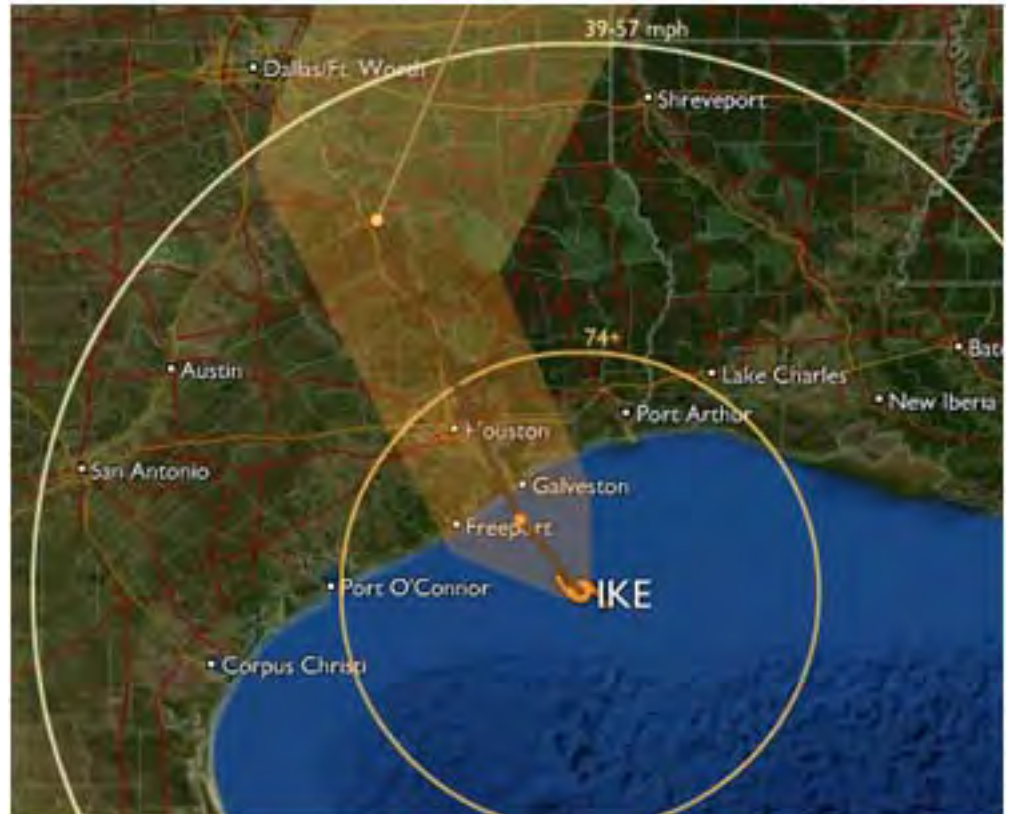
Input: a range of adaptation options

- Revetments
- Geotextile tubes
- Sea walls





New England Environmental Finance Center



Input: a range of adaptation options

- Revetments
- Geotextile tubes
- Sea walls
- Jetties





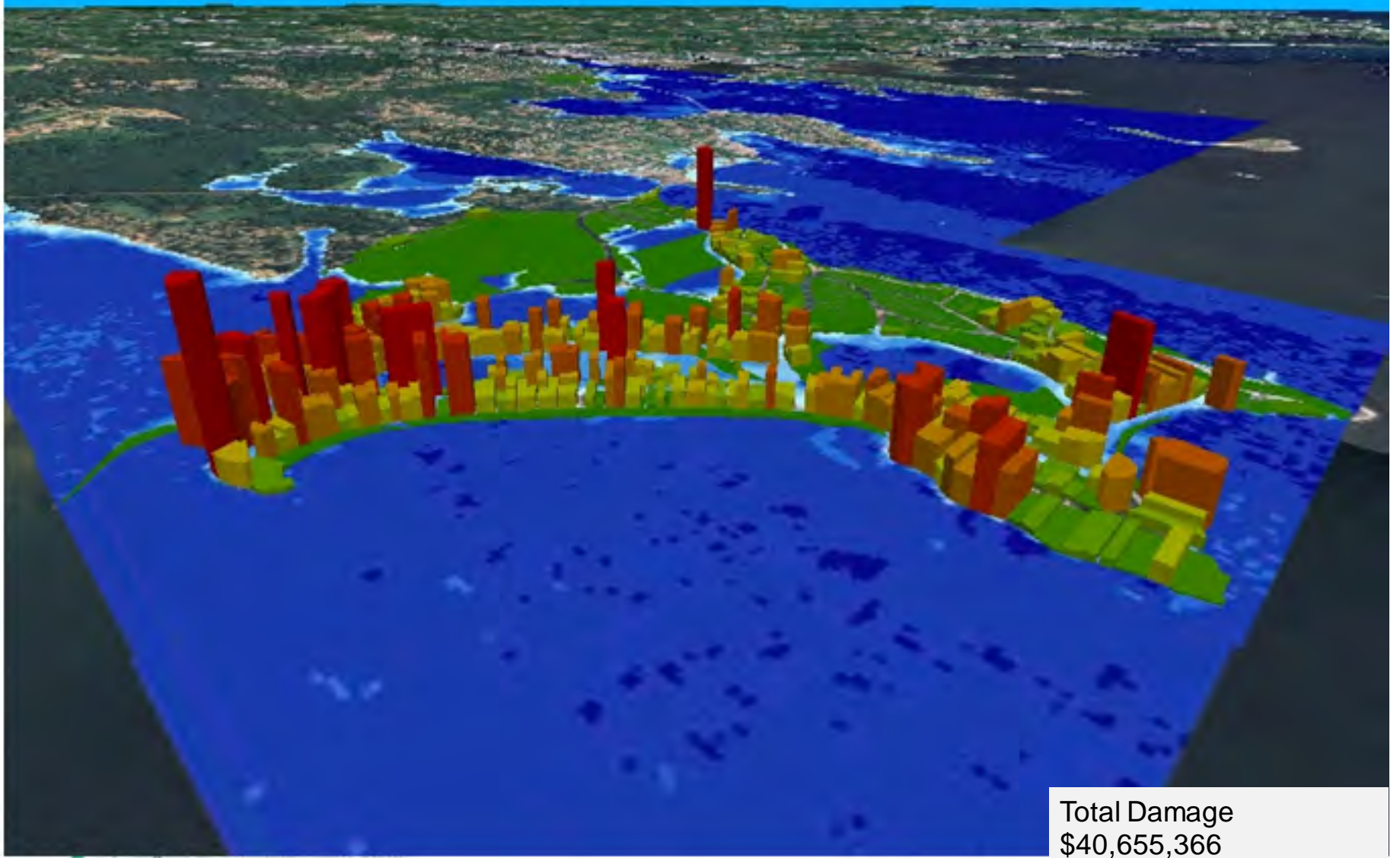
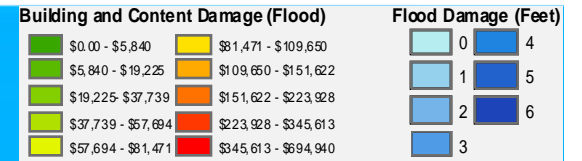
New England Environmental Finance Center





Groton Long Point

2050, Low SLR, 10 Year Flood



Total Damage
\$40,655,366



Diking and Culvert
Construction and/or
Modification

Seawall Modification
and Elevation

Barrier
Rising Gate Design
Elevation 7 ft NAVD88

Image © 2010 TerraMetrics
© 2010 Google
Image © 2010 DigitalGlobe
© 2010 Europa Technologies

©2009 Google

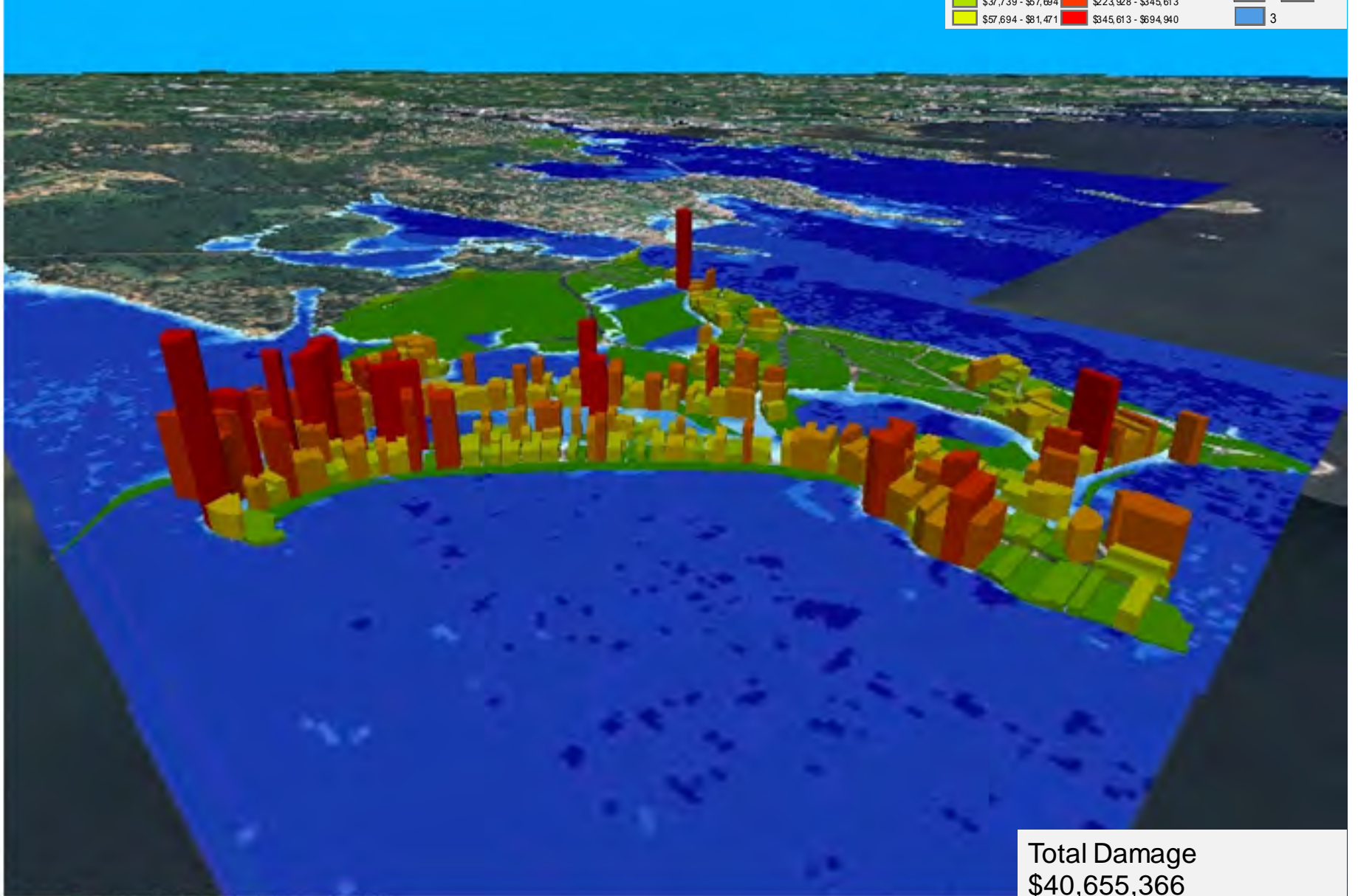
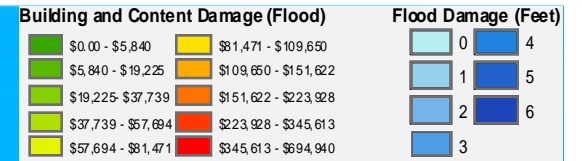
Imagery Date: Sep 30, 2008

41°18'49.10" N 72°00'24.43" W elev 4 m

Eye alt 2.74 km

Groton Long Point

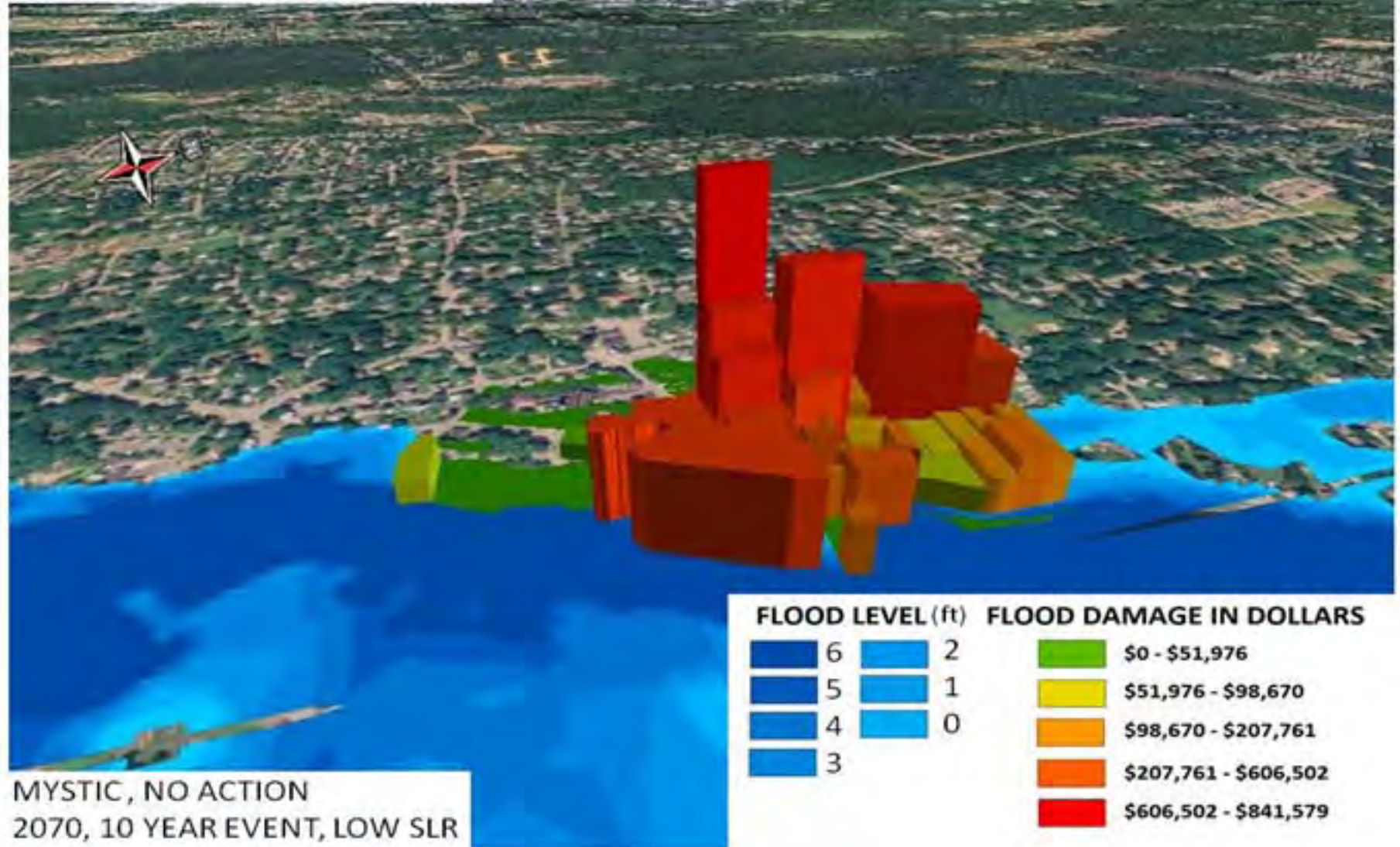
2050, Low SLR, 10 Year Flood





Cumulative Damage: \$8,768,776

1 CENTIMETER = 50 METERS

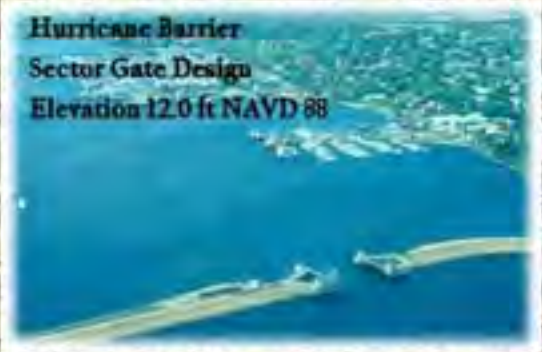




Hurricane Barrier
Sector Gate Design
Elevation 12.0 ft NAVD 88



Scenarios		Max. Water Elev. (ft., NAVD88)	Engineering Options	Construction Costs	Annual Maintenance Costs
Sea level rise, normal tides	A	3.2 – 4.0	No action up to minimal flood proofing and infrastructure elevation along river.	Insignificant	Insignificant
	B	5.5 – 6.5	Hurricane Barrier at Mystic River entrance.	\$18 Million	\$75,000
100-year storm event in 2010	C	5.4			
	D	7.4			
10-year storm in 2070, Hi SLR	E	7.0	Hurricane Barrier at Mystic River entrance. <i><u>ADDITIONAL FORTIFICATION</u> and elevating the railroad, as well as increased diking to east.</i>	\$27-30 Million	\$100,000
	F	8.9			
100-year storm in 2070, Hi SLR	G	8.6	Hurricane Barrier at Mystic River entrance. <i><u>FURTHER FORTIFICATION</u> and elevating the railroad, as well as increased diking to east.</i>	\$35 Million	\$120,000
	H	10.5			



Diking and Rail Elevation Increases

Google

Eye alt 1.77 km

41°21'13.34"N 71°58'09.17"W Alt: 10 m



Scenarios		Max. Water Elev. (ft., NAVD88)	Engineering Options	Construction Costs	Annual Maintenance Costs
Sea level rise, normal tides	A	3.2 – 4.0	No action up to minimal flood proofing and infrastructure elevation along river.	Insignificant	Insignificant
	B	5.5 – 6.5	Hurricane Barrier at Mystic River entrance.	\$18 Million	\$75,000
100-year storm event in 2010	C	5.4			
	D	7.4			
10-year storm in 2070, Hi SLR	E	7.0	Hurricane Barrier at Mystic River entrance. <i><u>ADDITIONAL FORTIFICATION</u> and elevating the railroad, as well as increased diking to east.</i>	\$27-30 Million	\$100,000
	F	8.9			
100-year storm in 2070, Hi SLR	G	8.6	Hurricane Barrier at Mystic River entrance. <i><u>FURTHER FORTIFICATION</u> and elevating the railroad, as well as increased diking to east.</i>	\$35 Million	\$120,000
	H	10.5			

Ways to Frame Climate Adaptation

- **Be honest. Respect feelings and beliefs. Empower citizen involvement when possible.**
- **Make it local.**
- **Make it concrete, not abstract.**
- **Make it now, not later.**
- **Talk about trade offs between risks and benefits, and the benefits of adapting sooner rather than later.**
- **Frame adaptation within the context of local attitudes towards climate change. (There are other reasons than climate change to take many adaptive actions).**

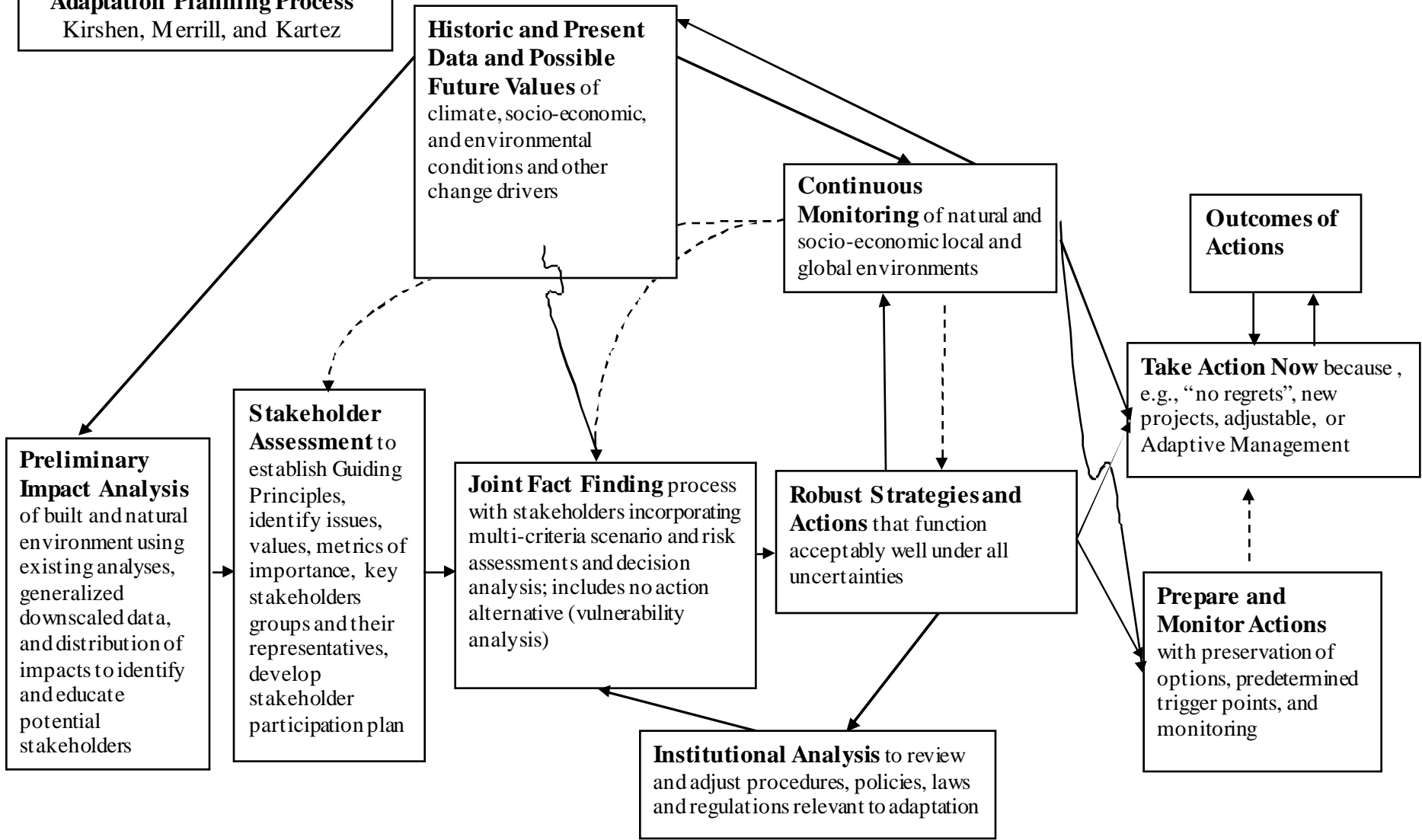
From **“Climate Skeptics Embrace Cleaner Energy.”**

<http://www.nytimes.com/2010/10/19/science/earth/19fossil.html?ref=us>

Input: a range of adaptation options

- Revetments
 - Geotextile tubes
 - Sea walls
 - Jetties
-
- Wet or dry floodproofing
 - Zoning and other regulatory changes

Adaptation Planning Process
Kirshen, Merrill, and Kartez



—————> Always part of process
 - - - - -> As needed part of process

Output: a range of “economic floodplains”

- Lost real estate values (e.g., Groton, CT)

Output: a range of “economic floodplains”

- Lost real estate values (e.g., Groton, CT)
- Lost economic output (e.g., 8-town coastal ME study)

Output: a range of “economic floodplains”

- Lost real estate values (e.g., Groton, CT)
- Lost economic output (e.g., 8-town coastal ME study)
- Infrastructure costs (e.g., 100’ bridges in Maine)

Output: a range of “economic floodplains”

- Lost real estate values (e.g., Groton, CT)
- Lost economic output (e.g., 8-town coastal ME study)
- Infrastructure costs (e.g., 100’ bridges in Maine)
- Displaced persons (getting started in Boston)

Output: a range of “economic floodplains”

- Lost real estate values (e.g., Groton, CT)
- Lost economic output (e.g., 8-town coastal ME study)
- Infrastructure costs (e.g., 100’ bridges in Maine)
- Displaced persons (getting started in Boston)
- **Lost natural resources values (collaborators wanted)**

Output: a range of “economic floodplains”

- Lost real estate values (e.g., Groton, CT)
- Lost economic output (e.g., 8-town coastal ME study)
- Infrastructure costs (e.g., 100’ bridges in Maine)
- Displaced persons (getting started in Boston)
- Lost natural resources values (collaborators wanted)
- Lost cultural resources values (e.g., NPS gravesites)

Output: a range of “economic floodplains”

- Lost real estate values (e.g., Groton, CT)
- Lost economic output (e.g., 8-town coastal ME study)
- Infrastructure costs (e.g., 100’ bridges in Maine)
- Displaced persons (getting started in Boston)
- Lost natural resources values (collaborators wanted)
- Lost cultural resources values (e.g., NPS gravesites)

>> Software development is underway. Core shell is customizable for CBA on a range of vulnerable asset types.

Learn the alchemy
True human beings know.
The moment you accept
 what troubles you've been given,
The door will open.

- Jalallabad Rumi, 13th Century Persia