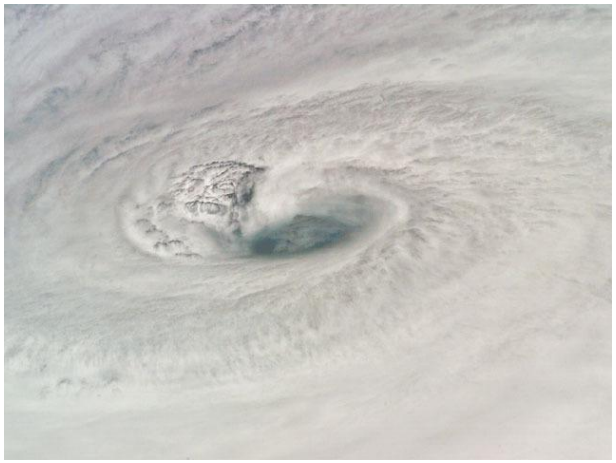
Financial Adaptation to Sea Level Rise and Storm Surge



The COAST Approach
and Issues to Consider in Coastal New Hampshire

Samuel B. Merrill, Ph.D.

June 29, 2011

New England Environmental Finance Center

Muskie School of Public Service

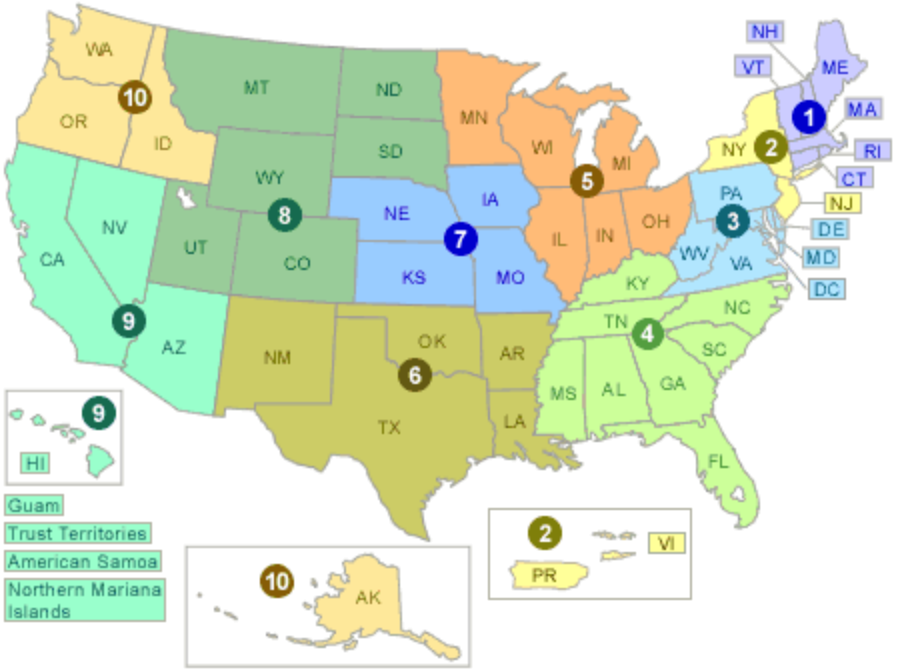
University of Southern Maine
Portland, Maine

New England Environmental Finance Center

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.

EFCN
environmental finance center network



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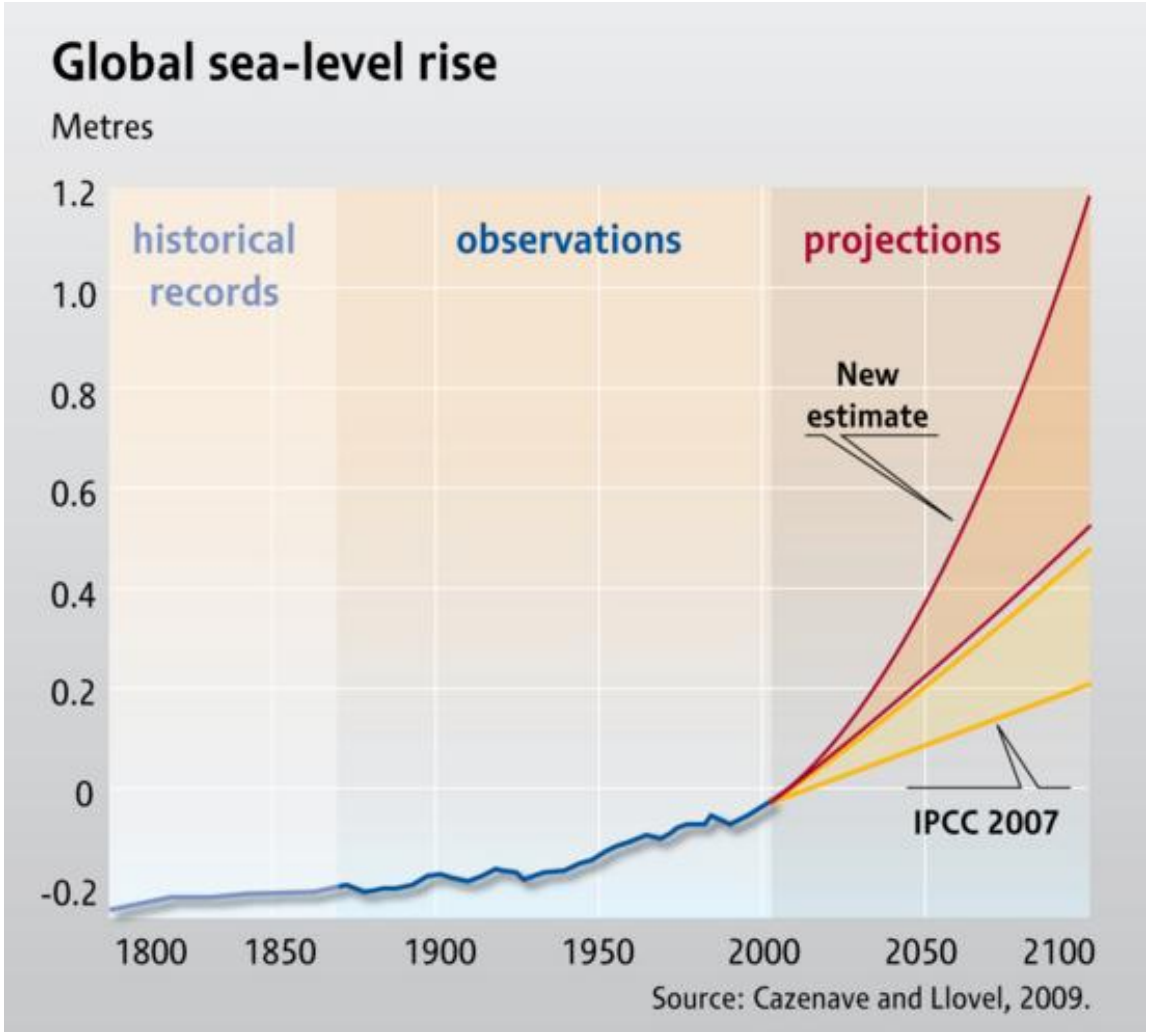
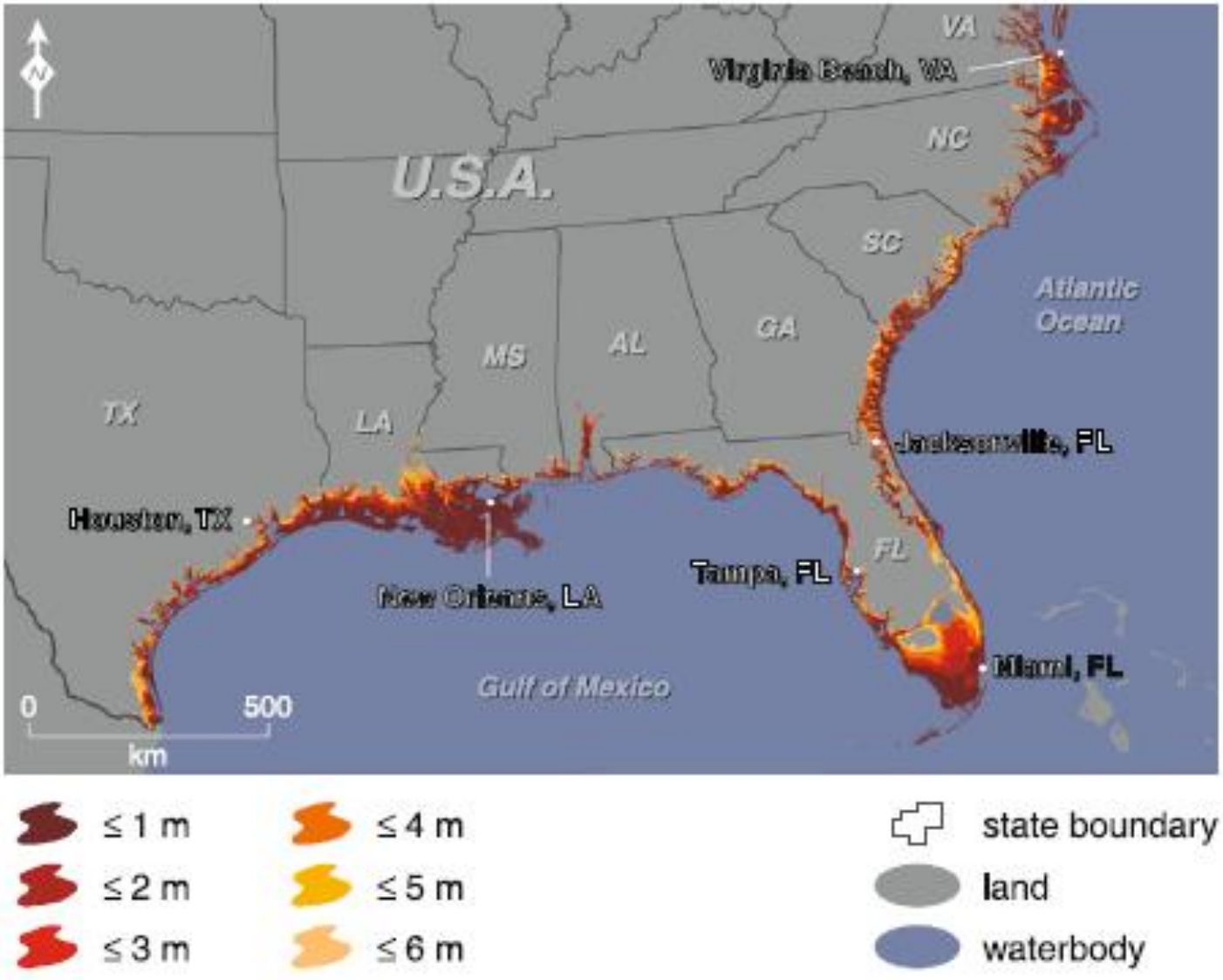
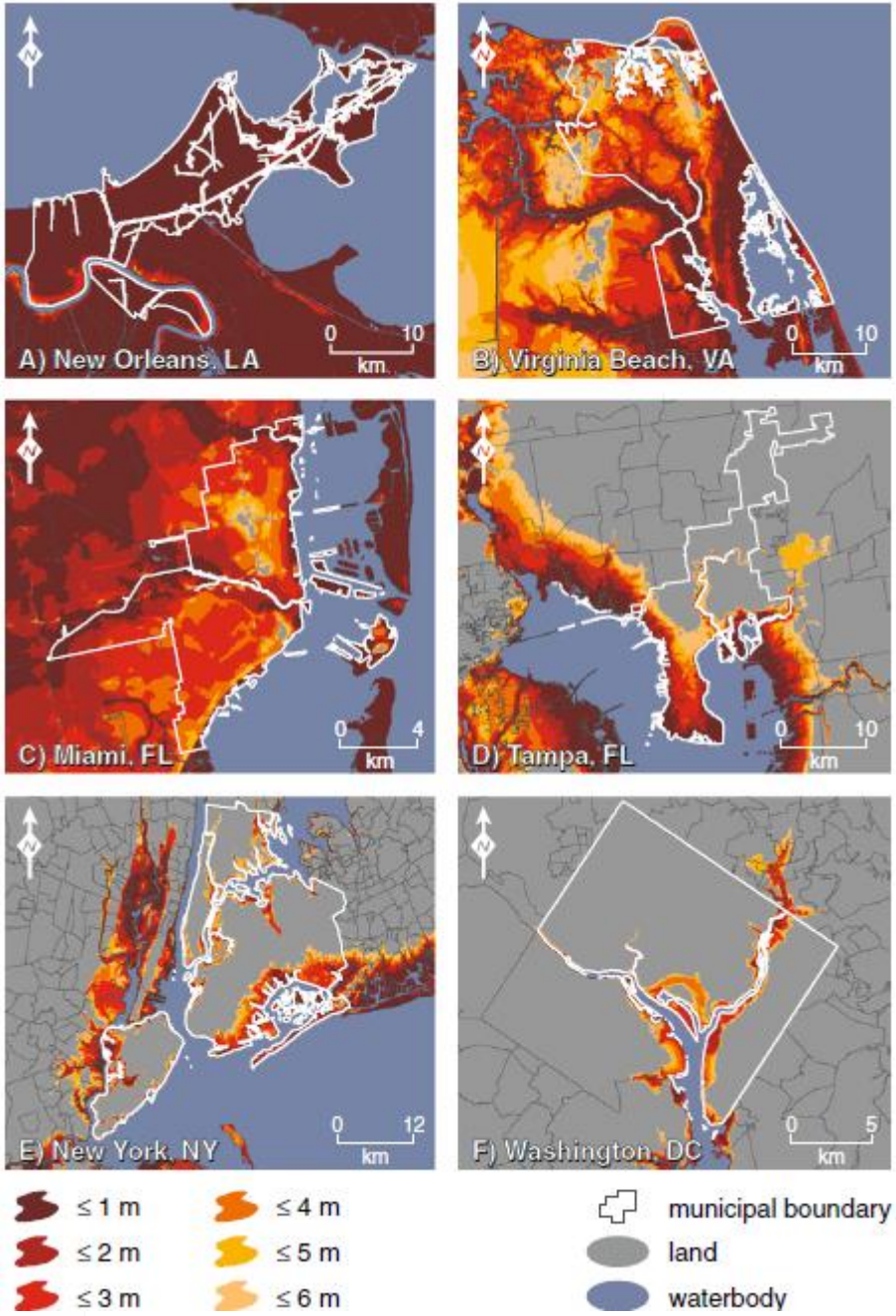
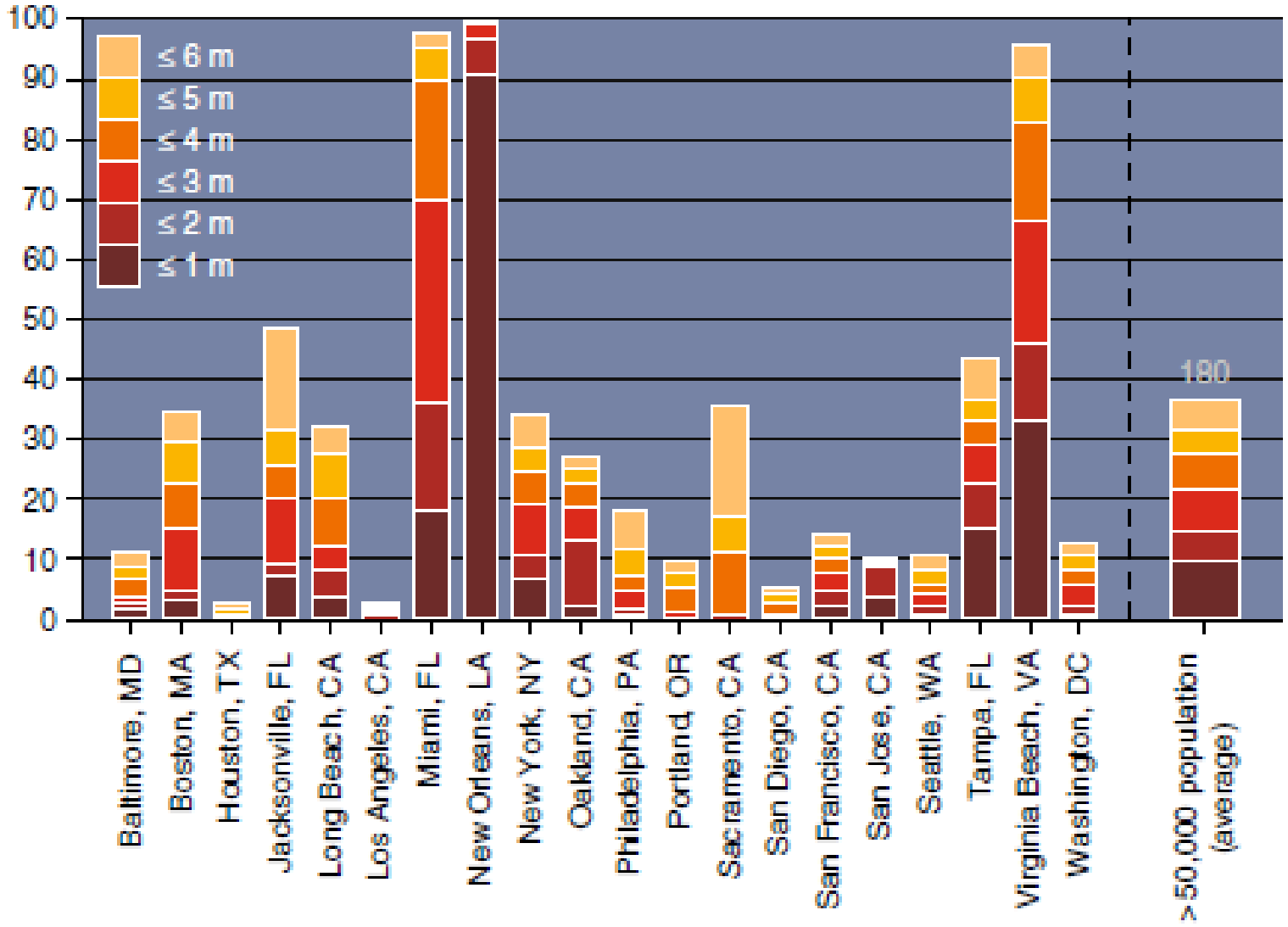

Global sea-level rise
Metres
1.2
1.0
0.8
0.6
0.4
0.2
0
-0.2
historical records
observations
projections
New estimate
IPCC 2007
1800
1850
1900
1950
2000
2050
2100
Source: Cazenave and Llovel, 2009.

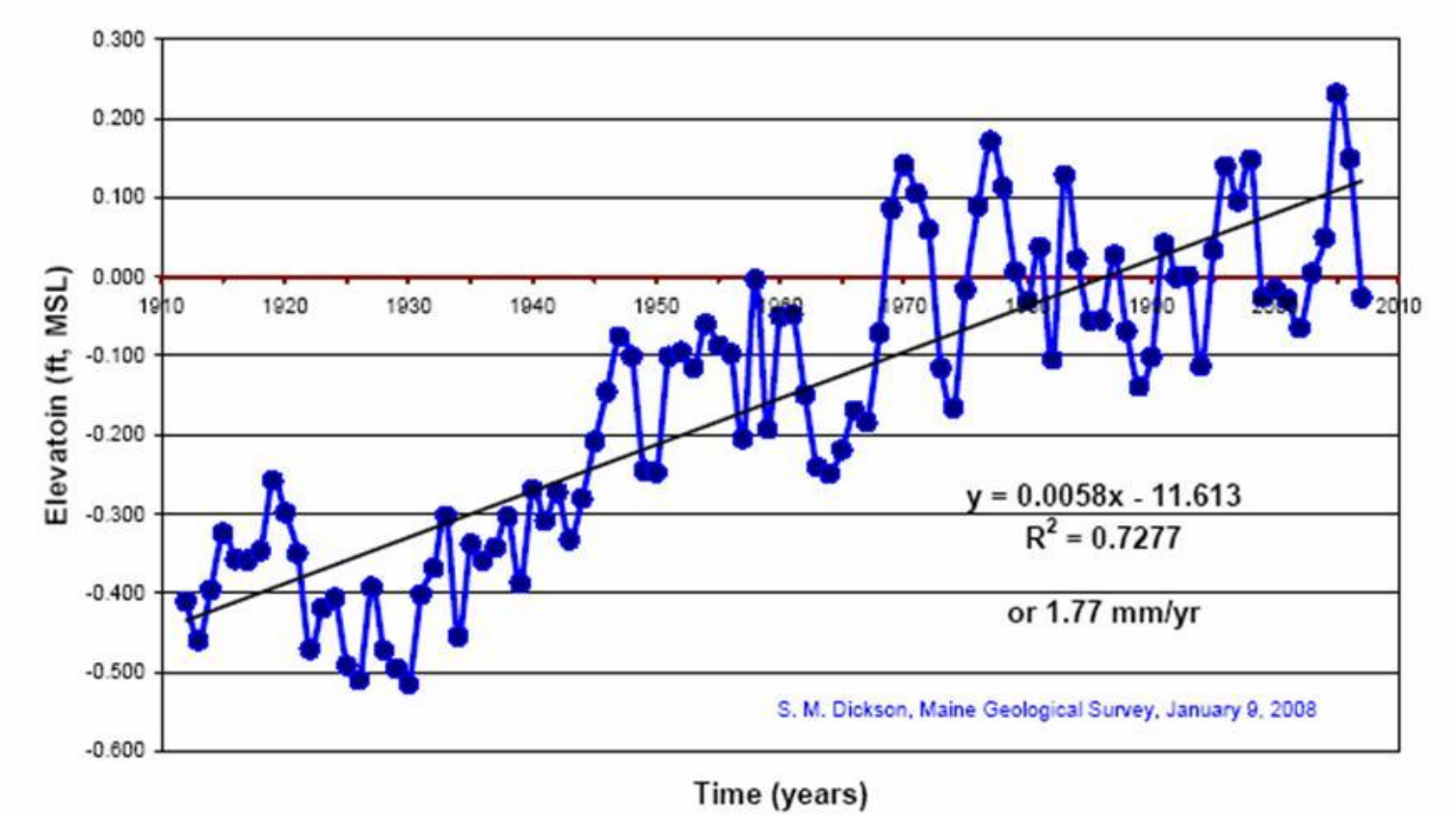


Weiss et al., *Climatic Change*, March 2011

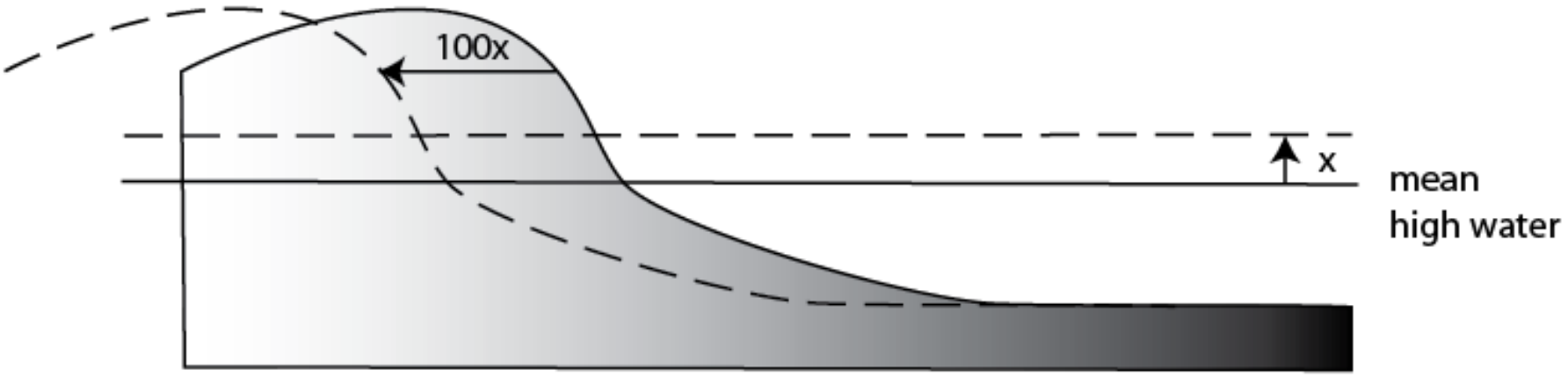

A) New Orleans, LA
0 10 km
B) Virginia Beach, VA
0 10 km
C) Miami, FL
0 4 km
D) Tampa, FL
0 10 km
E) New York, NY
0 12 km
F) Washington, DC
0 5 km
≤ 1 m
≤ 2 m
≤ 3 m
≤ 4 m
≤ 5 m
≤ 6 m
municipal boundary
land
waterbody


100
90
80
70
60
50
40
30
20
10
0
≤ 6 m
≤ 5 m
≤ 4 m
≤ 3 m
≤ 2 m
≤ 1 m
180
Baltimore, MD
Boston, MA
Houston, TX
Jacksonville, FL
Long Beach, CA
Los Angeles, CA
Miami, FL
New Orleans, LA
New York, NY
Oakland, CA
Philadelphia, PA
Portland, OR
Sacramento, CA
San Diego, CA
San Francisco, CA
San Jose, CA
Seattle, WA
Tampa, FL
Virginia Beach, VA
Washington, DC
>50,000 population (average)

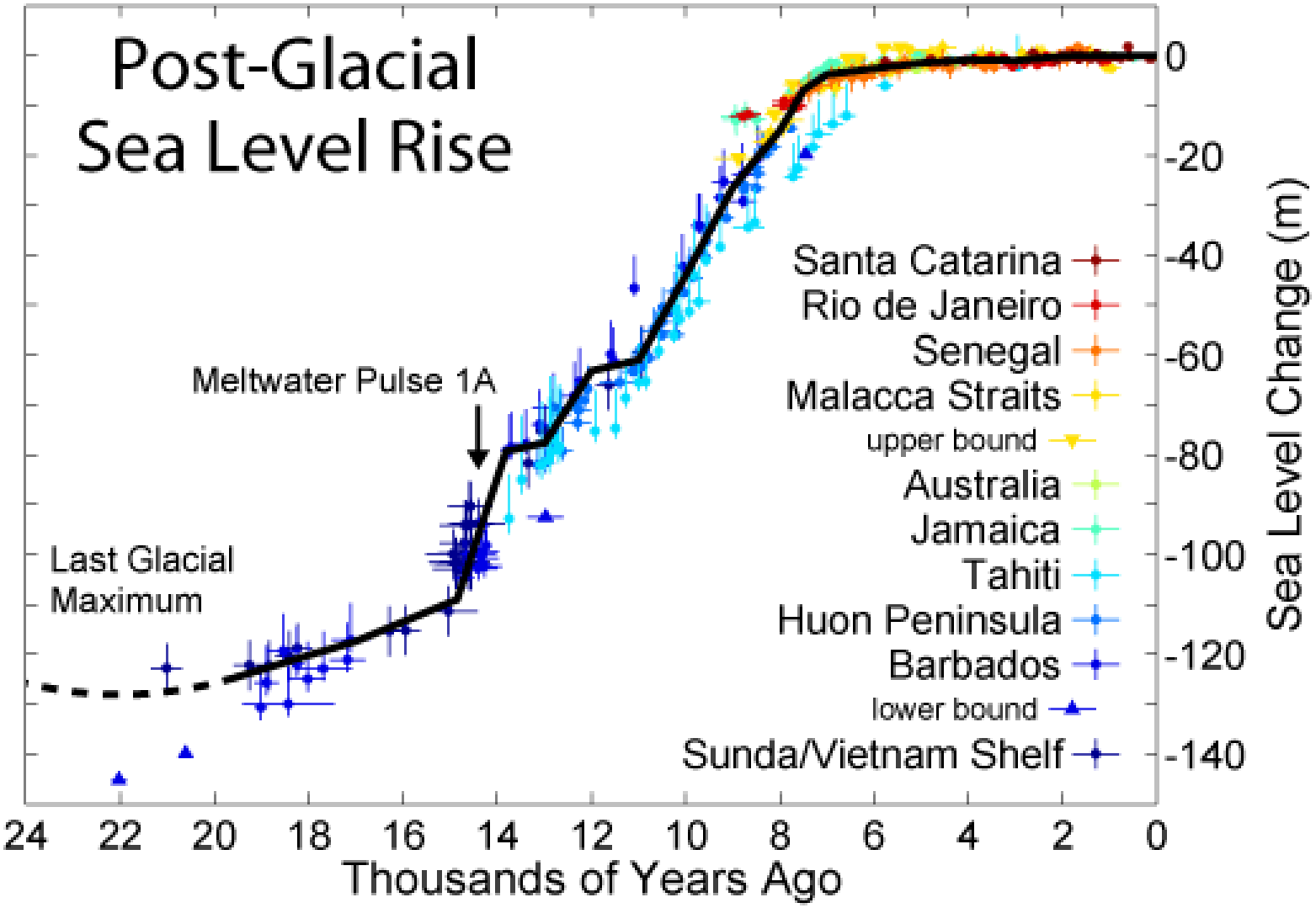
Portland Sea Level



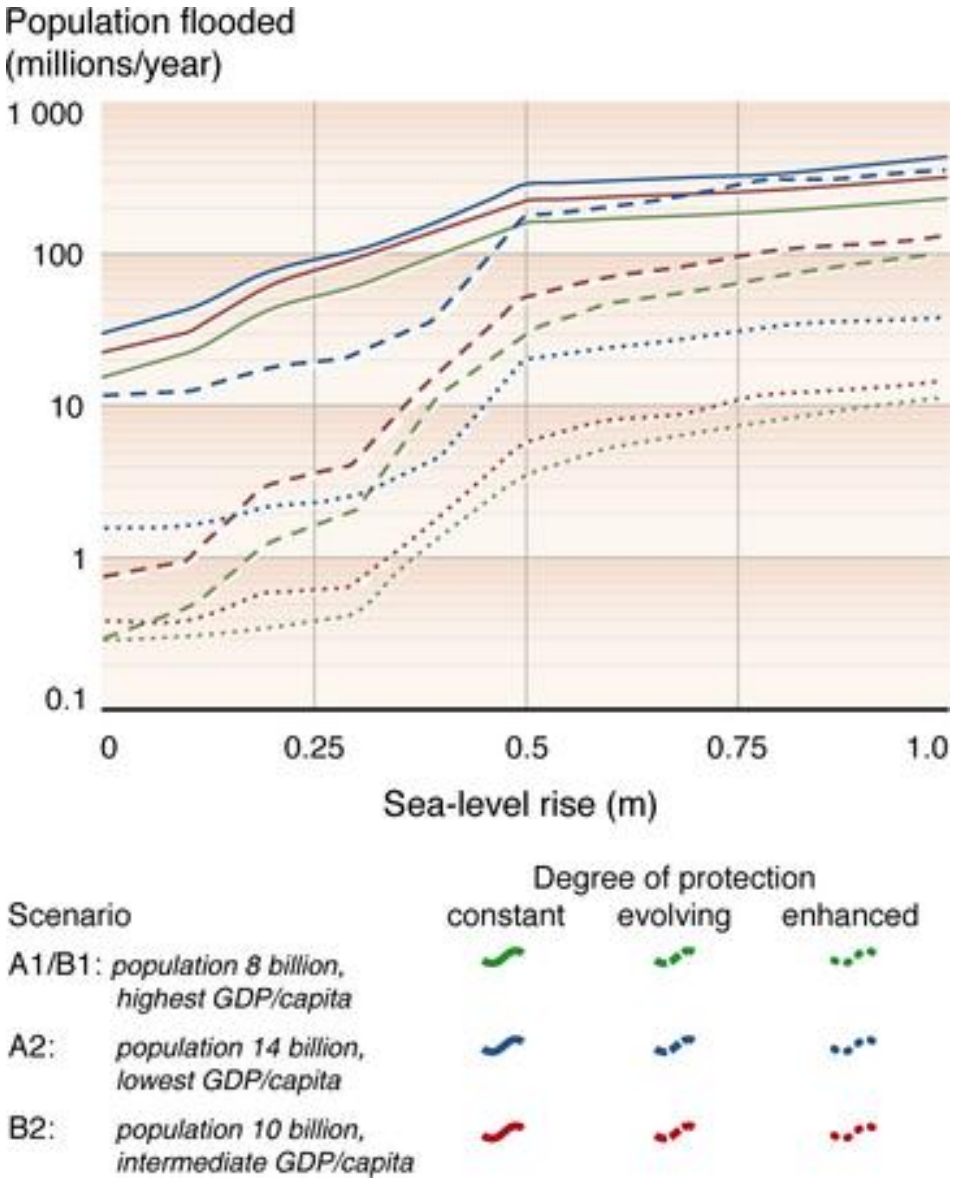
Portland Tide gauge = global ocean over last century 1.8 mm/yr (IPCC, 2007).
In Maine, this is the fastest in past 3000 years
Satellite altimetry (1993-2003) = global sea level 3.1 ± 0.7 mm/yr (IPCC, 2007)



Bruun's Rule: each increment of vertical sea level rise (x) produces a landward retreat of the beach profile at a ratio of 1:100 (100 times x). One foot of sea level rise produces a 100-foot landward retreat of the beach profile.



Graph courtesy of Dr. Robert Dolan, UVa



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

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

The Old Port, 3/10 at high tide (D. Yakovleff)

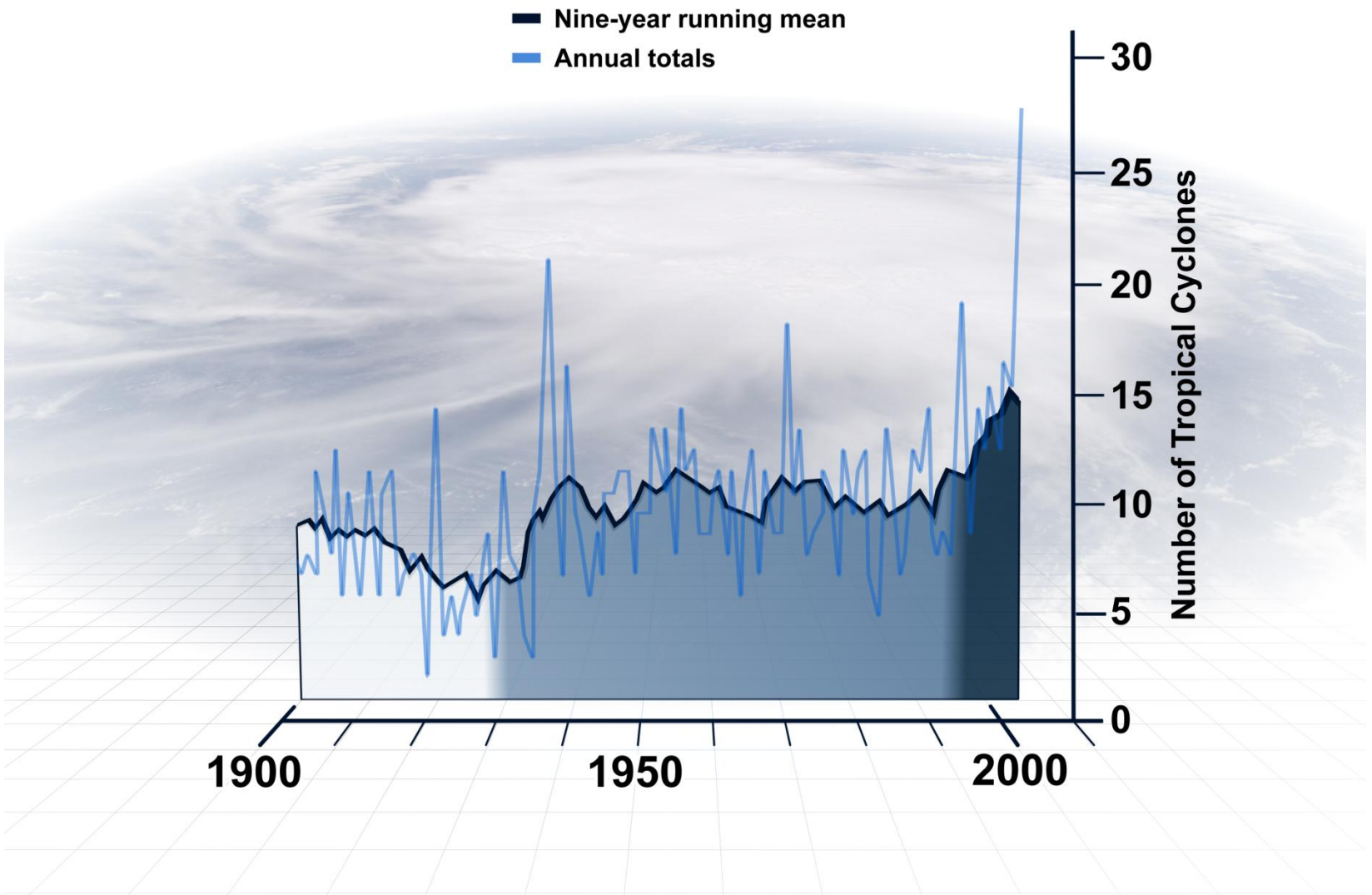
The Old Port, 3/10 at high tide (D. Yakovleff)

Whole Foods1/9/10 at high tide (R. Obrey.)

Marginal Way and Cove St., 9/10, New Moon (J. Piribeck)

Marginal Way and Cove St., 9/10, New Moon (J. Piribeck)

Frequency of Atlantic Storms

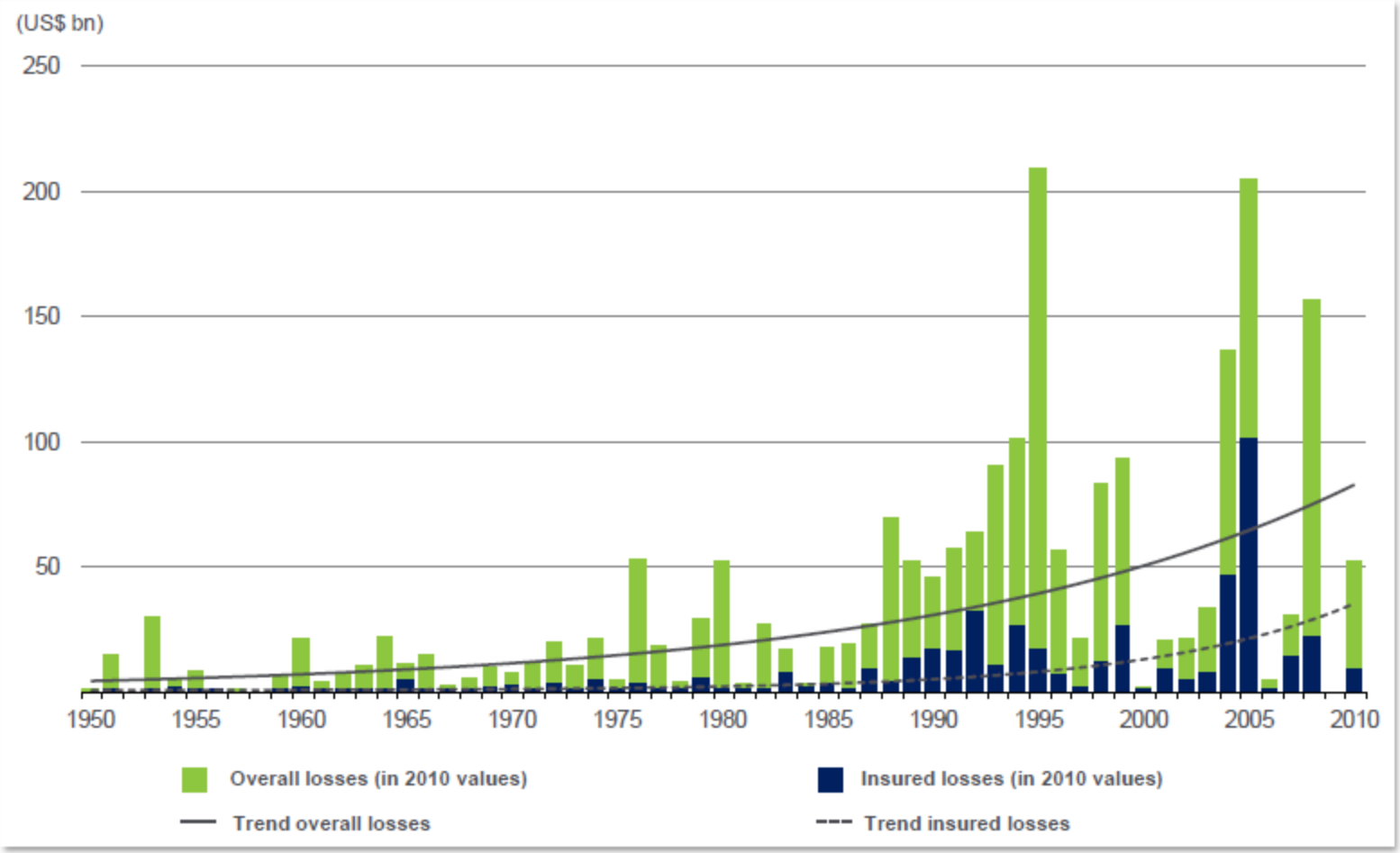


NatCatSERVICE

Great natural catastrophes worldwide 1950 – 2010

Overall and insured losses with trend

Munich RE



Adaptation Works

Homeowners in Florida could reduce losses from a severe hurricane by 61 percent, resulting in $51 billion in savings, simply by building to strong construction codes.

Wharton Risk Management and Decision Processes Center, University of Pennsylvania.

"Managing Large Scale Risks in a New Era of Catastrophe." 2007

Risk-Based Land Use Planning

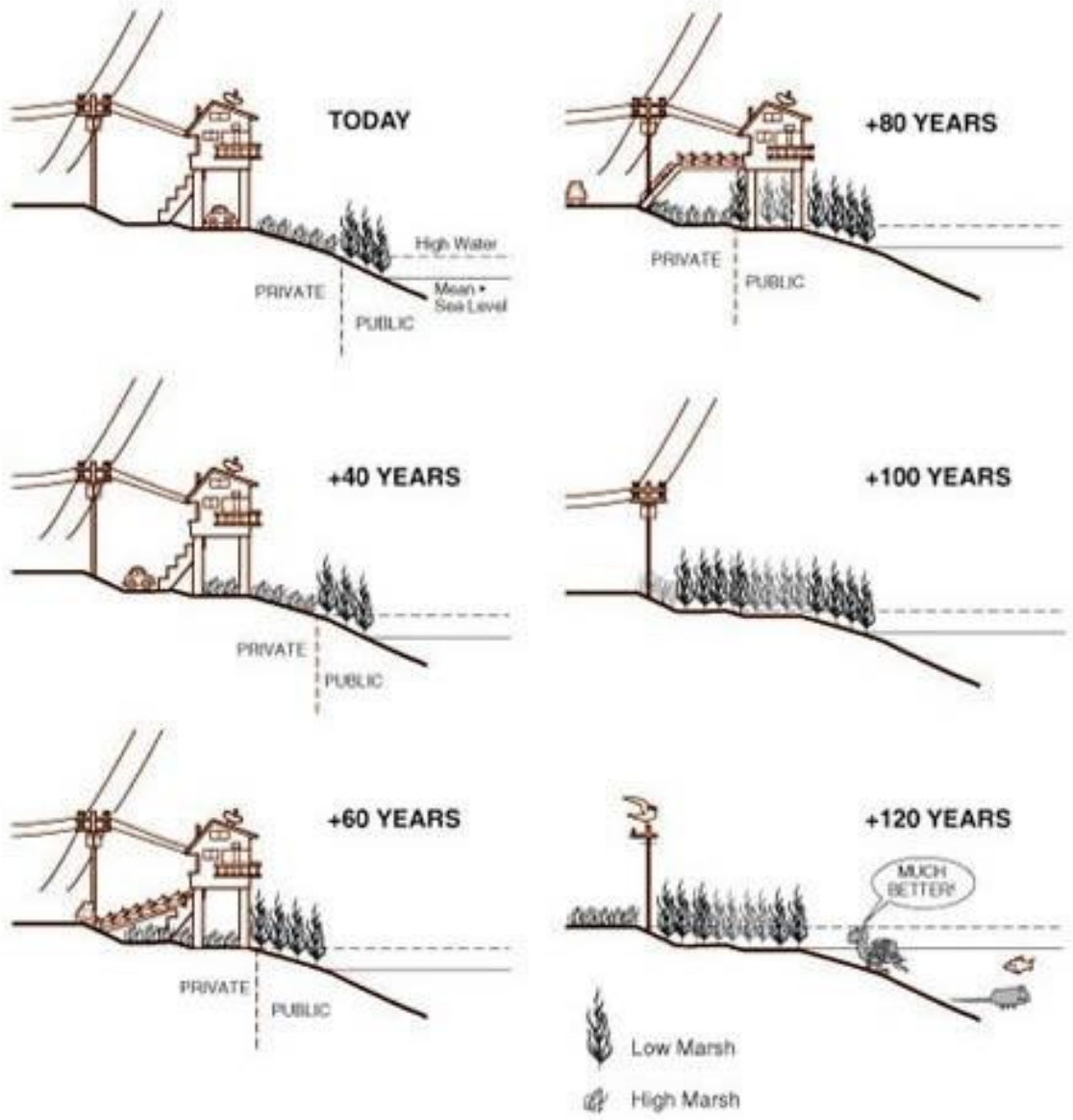
Protect development from coastal hazards

Consider climate change *in plans*

Provide no-build/no-rebuild zones

Provide incentives to relinquish property or development rights

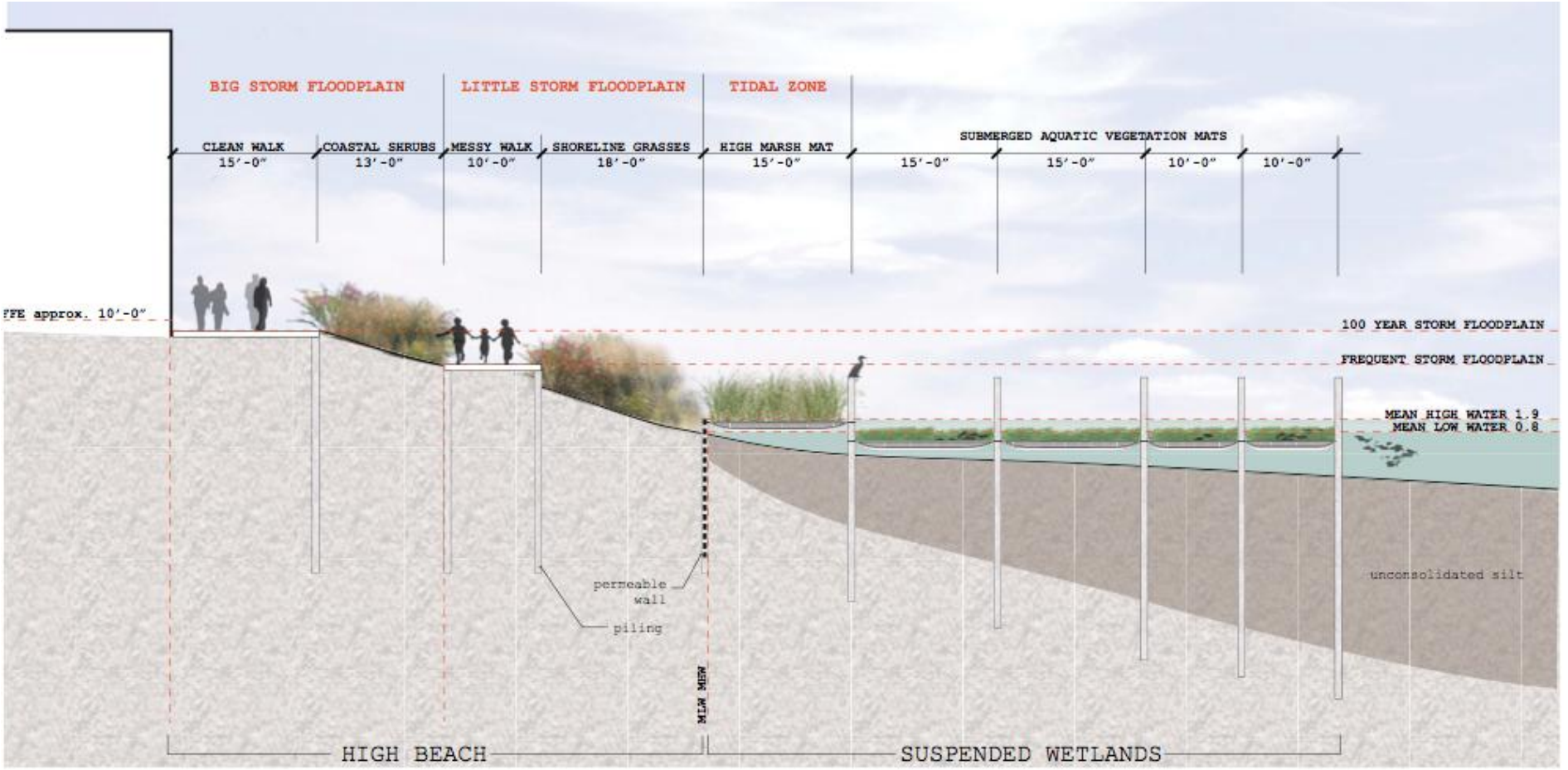
Rolling Easement



Strengthened Ecosystems

Make essential natural infrastructure part of any adaptation strategy

Protect and restore these features through adaptation funding, risk-based land use planning, and post-disaster rebuilding



SUSPENDED WETLANDS SECTION
WESTPORT DEVELOPMENT, BALTIMORE
17 January 2008

PARAMETER INC. & MSR Kristina Hill DIRT

D.I.R.T. studio
700 Harris Street #104
Charlottesville, VA 22903
dirt@dirtstudio.com

New England Environmental Finance Center

Occupation of the New Marsh Edge

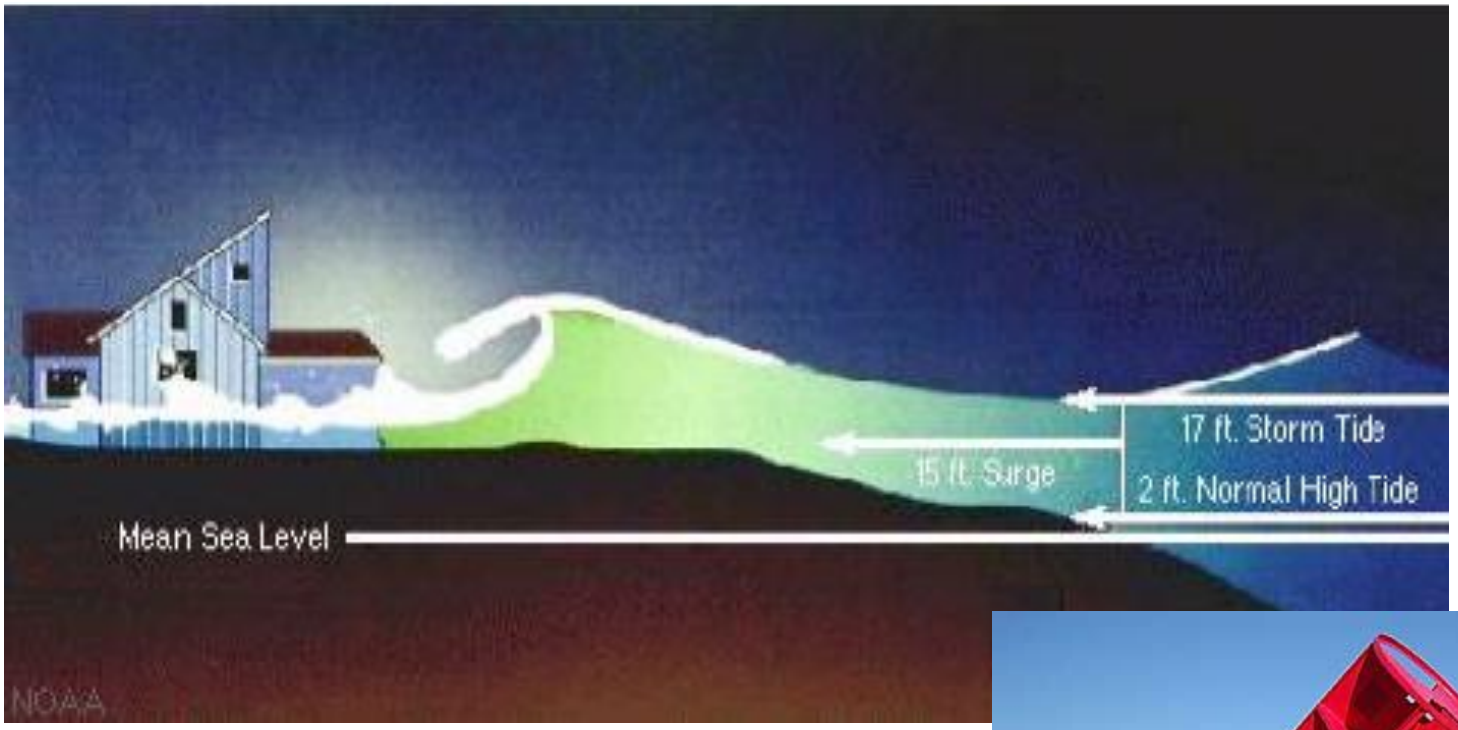
Project by Claudia Saladin

Wetland Impacts

"The impact of sea level rise on coastal wetlands will depend in large measure on whether developed areas immediately inland of the marsh are protected from rising sea level by levees and bulkheads. In a Charleston case study, protecting developed areas would increase an 80 percent wetland loss to 90 percent for a five-foot rise. In a nationwide analysis, structural protection would increase a 30-80 percent loss to 50-90 percent."

EPA's Office of Policy, Planning, and Evaluation
(http://papers.risingsea.net/Sea-level-rise-and-coastal-wetlands.html)

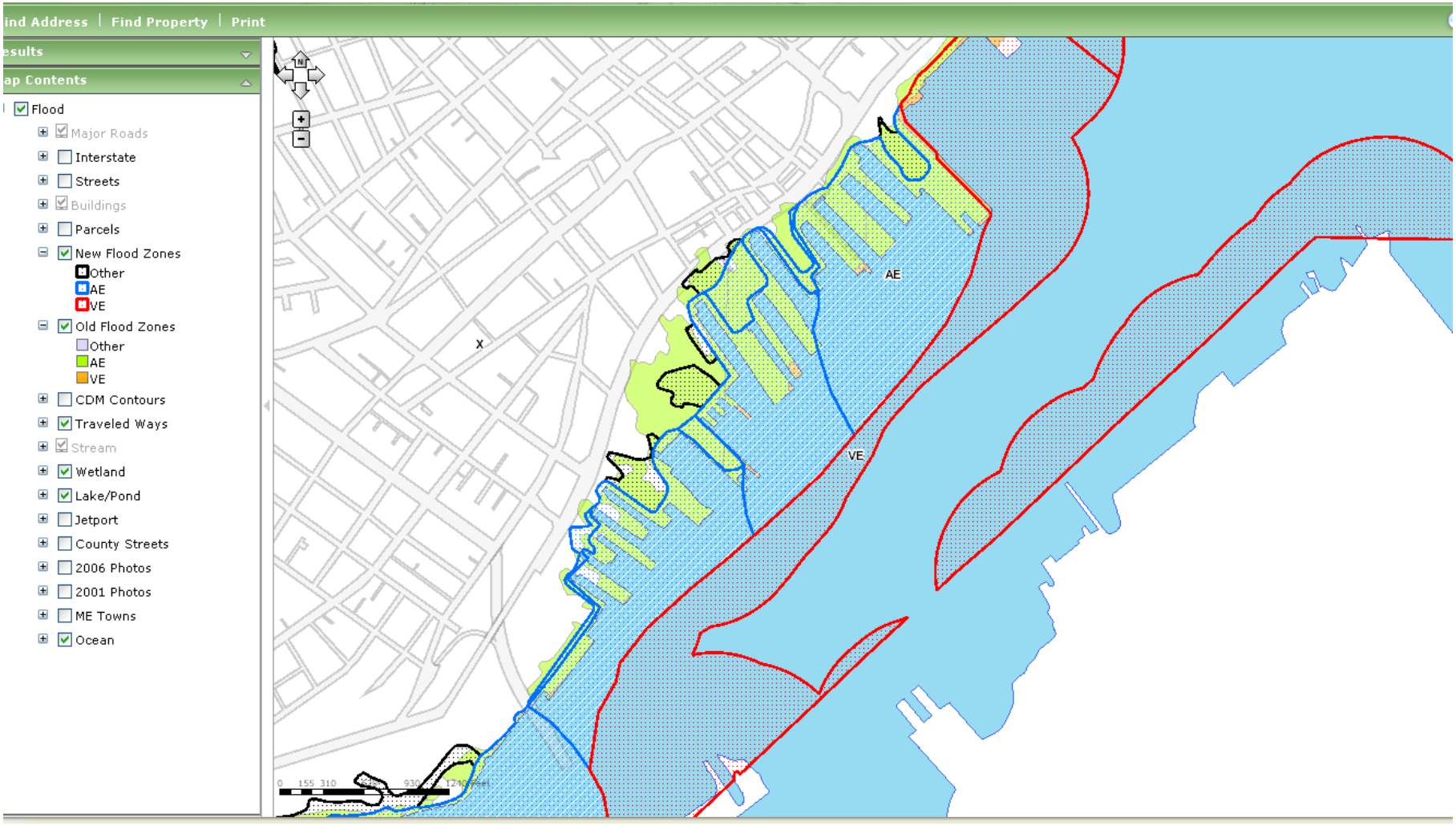
Climate Change>>Sea Level Rise>>Storm Surge



Patriot's Day Storm 2007: York Beach

New England Environmental Finance Center


MAINE BANK & TRUST
PIERCE ATWOOD
Bankworth
MEMIC


ind Address | Find Property | Print
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ap Contents
Flood
Major Roads
Interstate
Streets
Buildings
Parcels
New Flood Zones
Other
AE
VE
Old Flood Zones
Other
AE
VE
CDM Contours
Traveled Ways
Stream
Wetland
Lake/Pond
Jetport
County Streets
2006 Photos
2001 Photos
ME Towns
Ocean
X
AE
VE

CoreLogic®

2011 CoreLogic® Storm Surge Report

Residential Storm-Surge Exposure Estimates for 10 U.S. Cities

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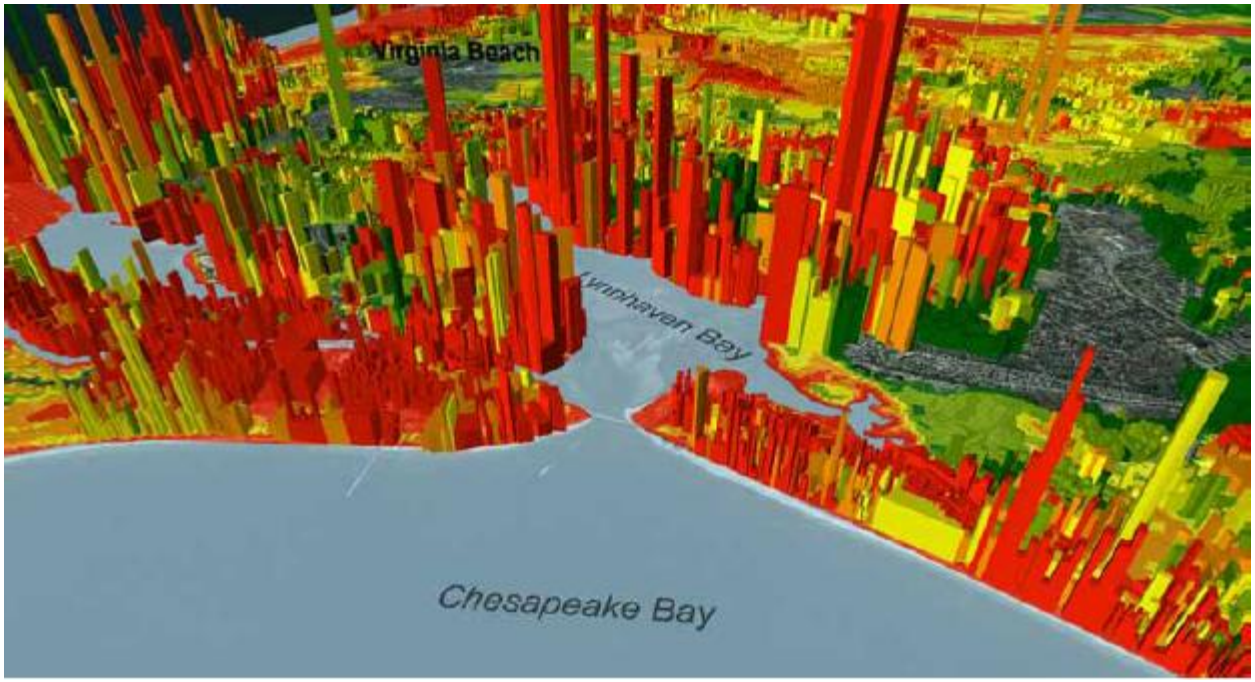
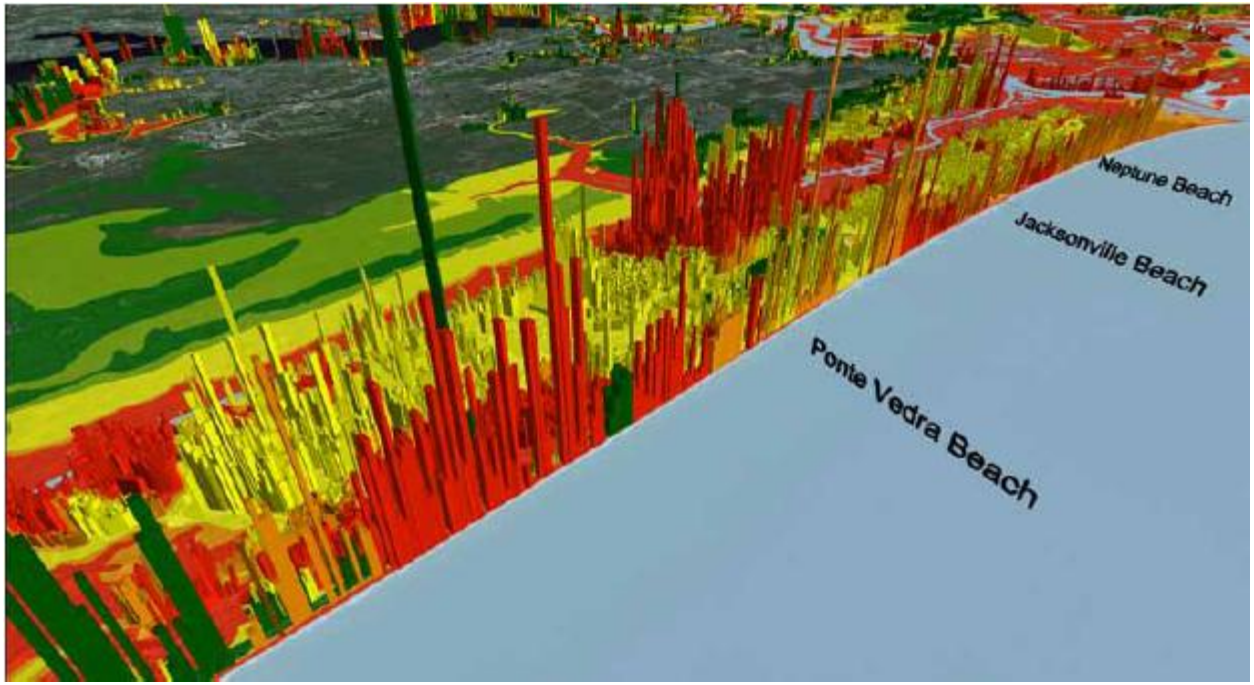
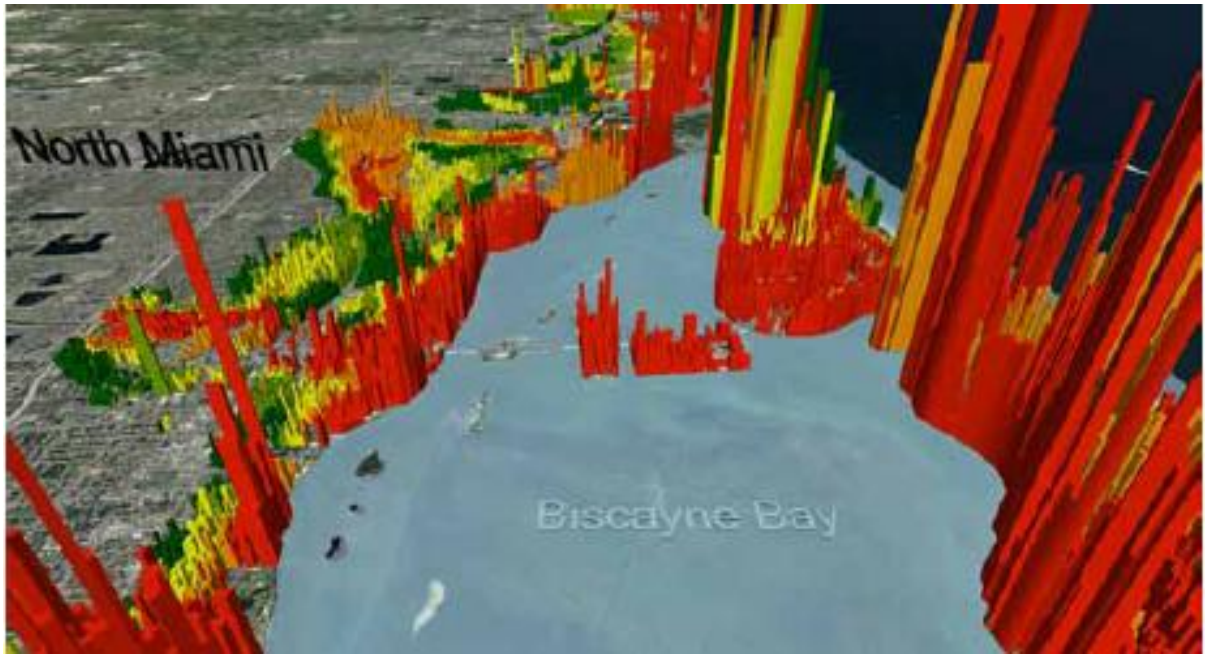
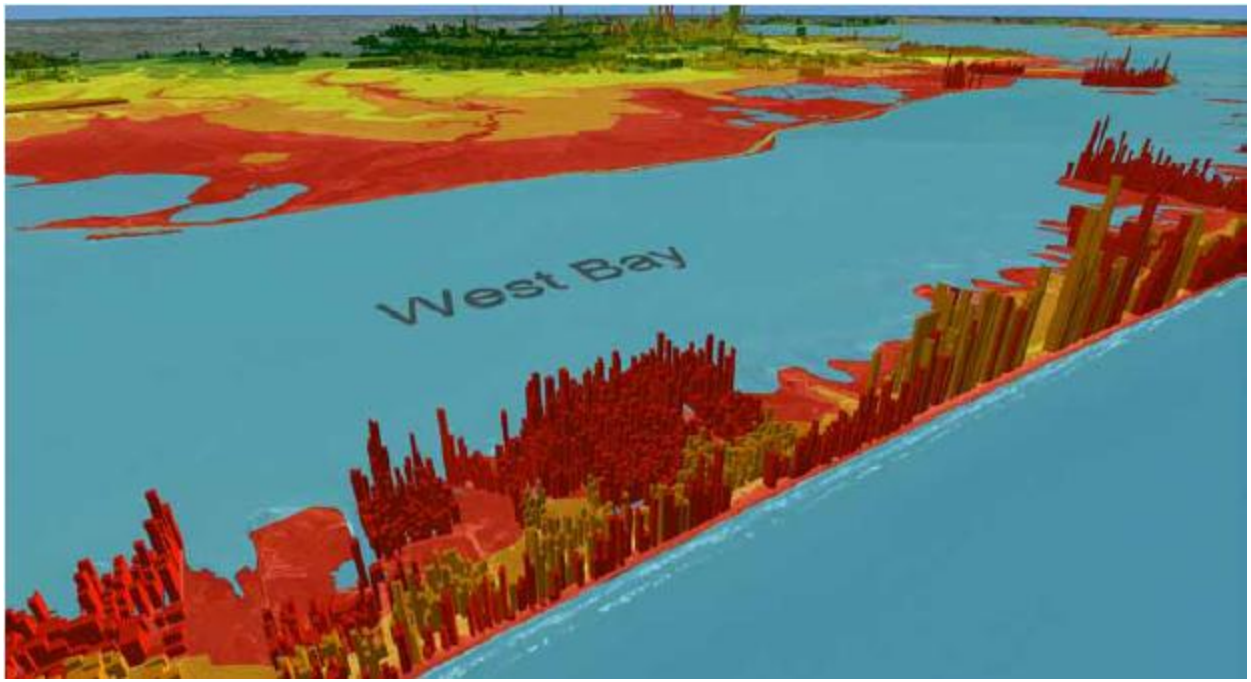
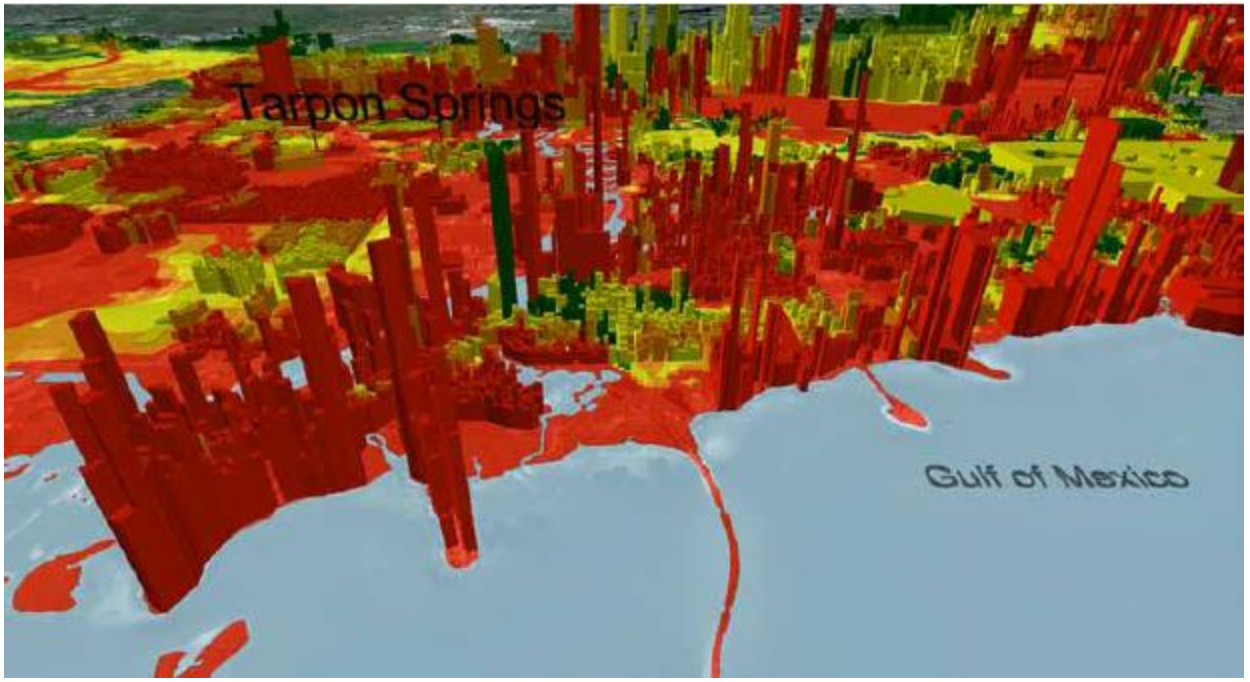

Virginia Beach
Lynnhaven Bay
Chesapeake Bay


Neptune Beach
Jacksonville Beach
Ponte Vedra Beach


North Miami
Biscayne Bay


West Bay


Tarpon Springs
Gulf of Mexico

Take home message:

- … “having a coastal property located outside a FEMA-defined flood zone doesn’t necessarily mean the property owner is free from risk since there are many areas with little correlation between flood zones and storm surge inundation zones”

The Effects of Climate Change on Economic Activity in Maine:

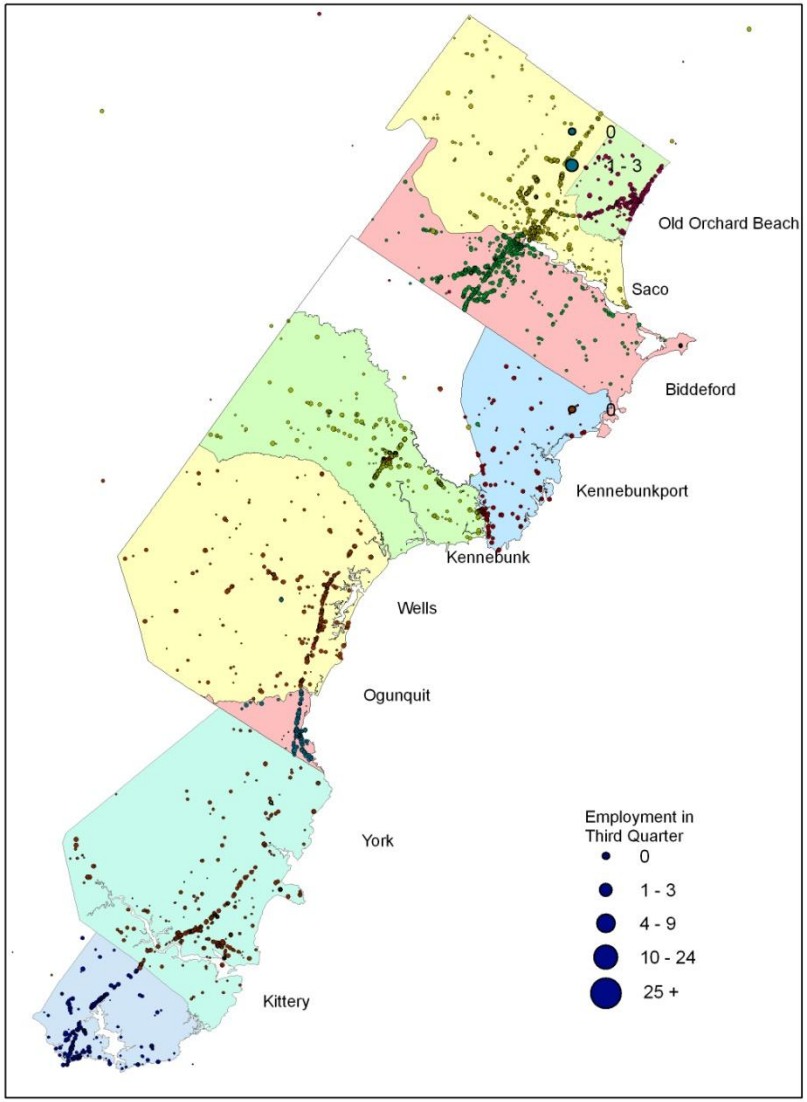
Coastal York County Case Study

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.

Employment Locations in York County Coastal Communities 2007



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

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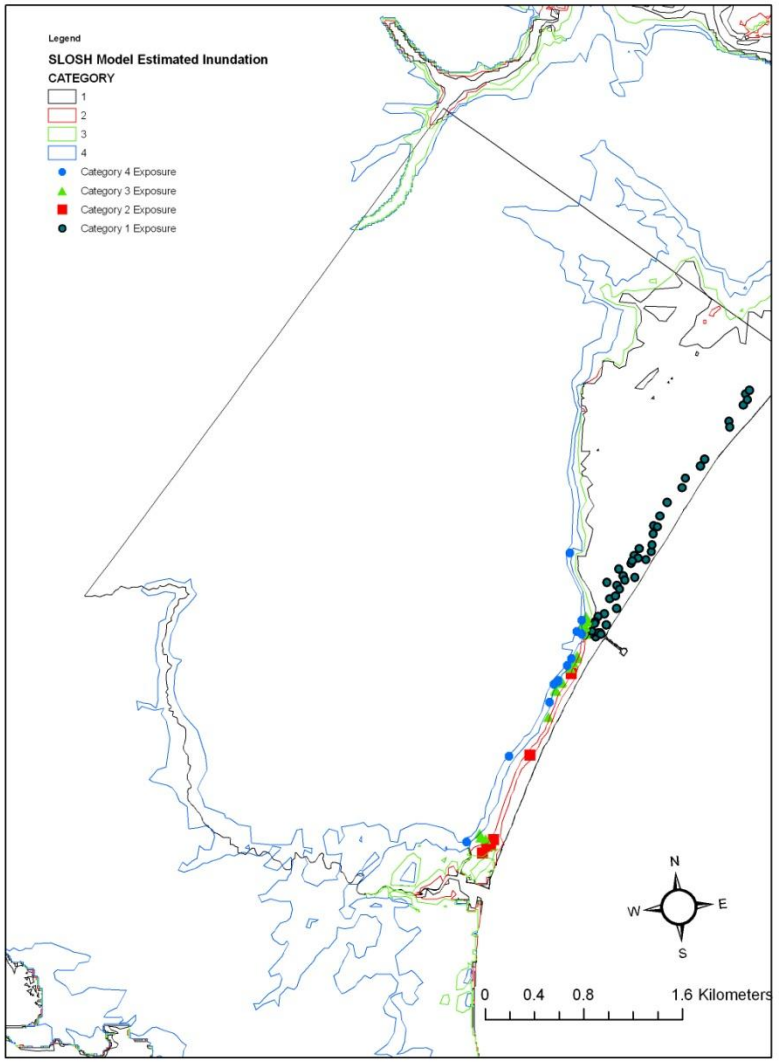
Old Orchard Beach: Employment At Risk by Different Size Storms



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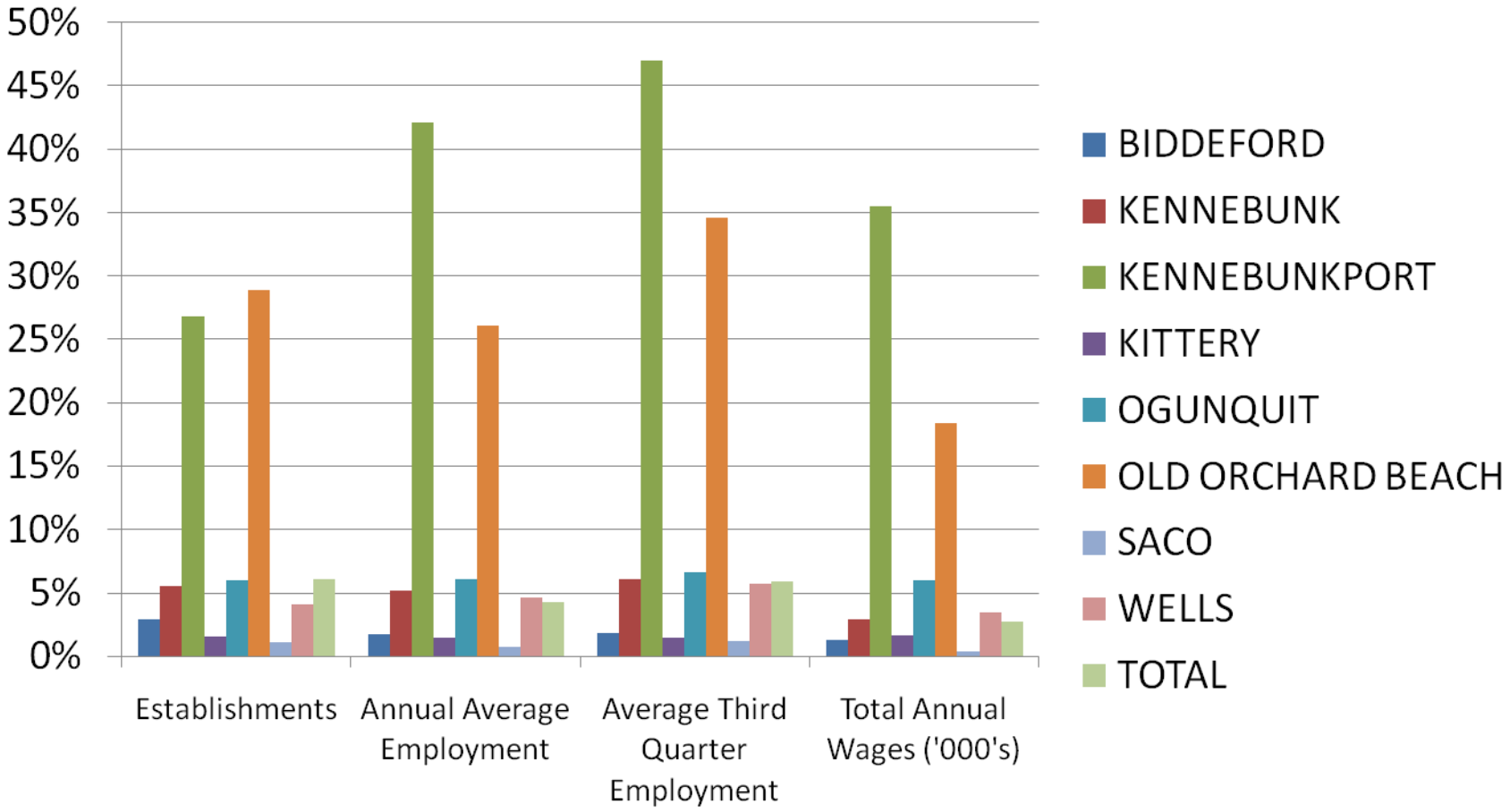
Percent of Town Economy in At Risk Employers



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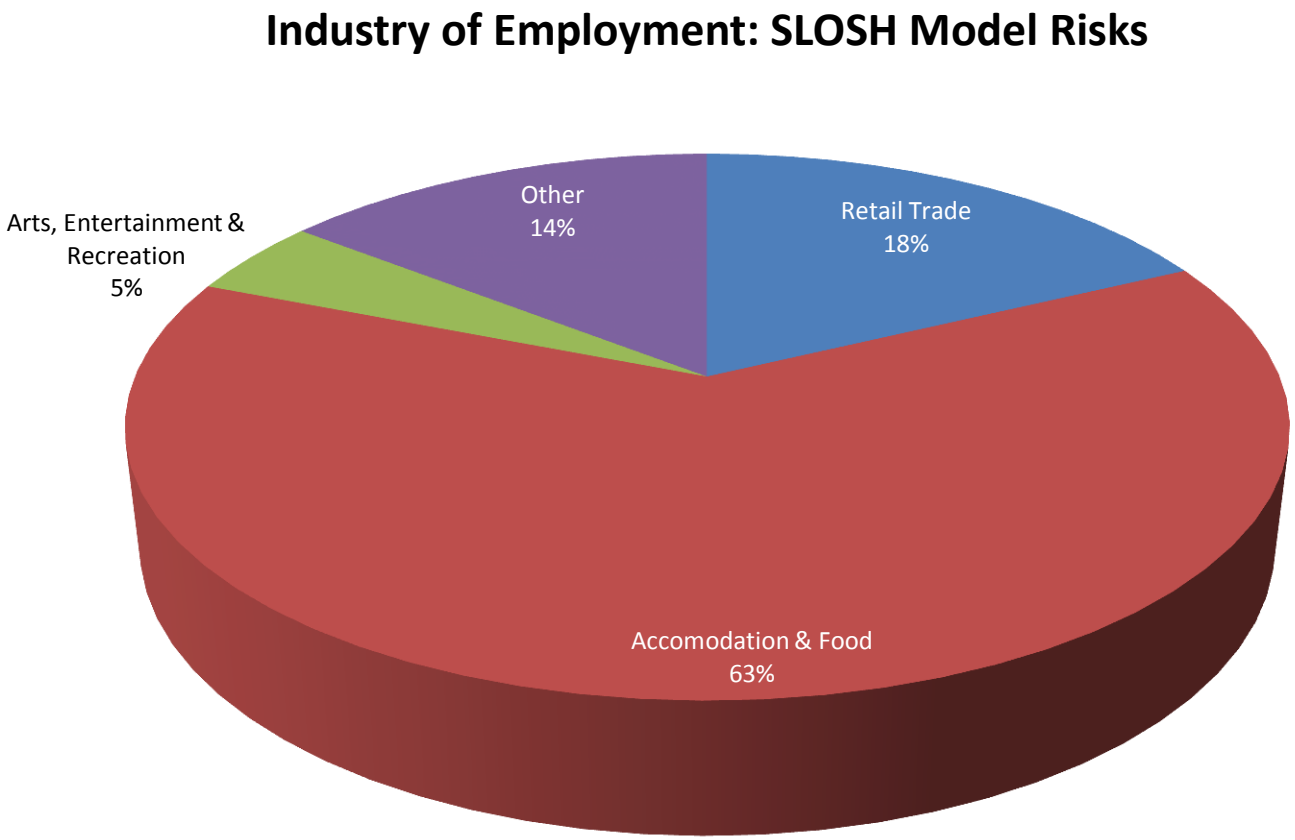
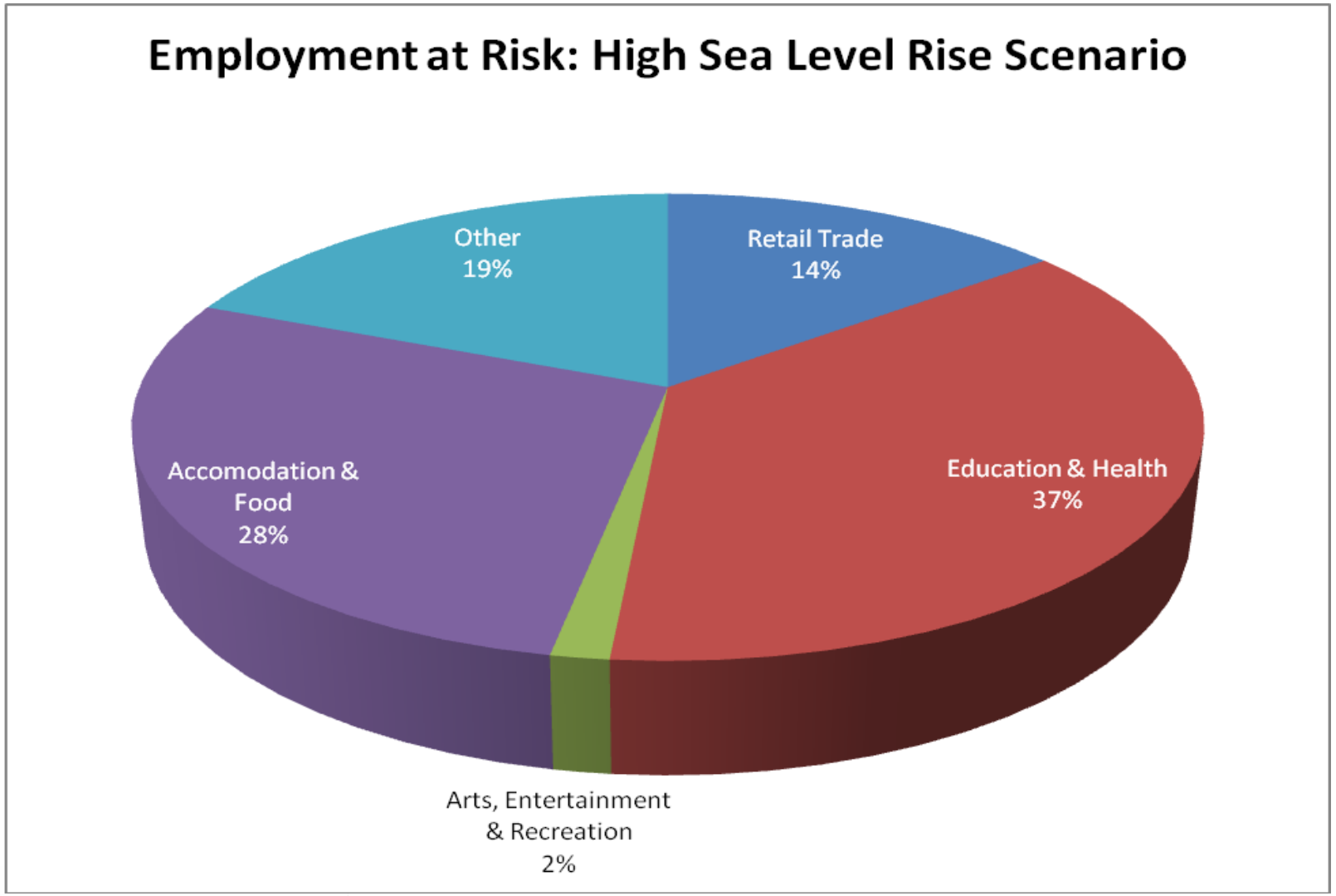
Within the SLOSH Model Zone, the biggest threat is to Establishments Related to Tourism



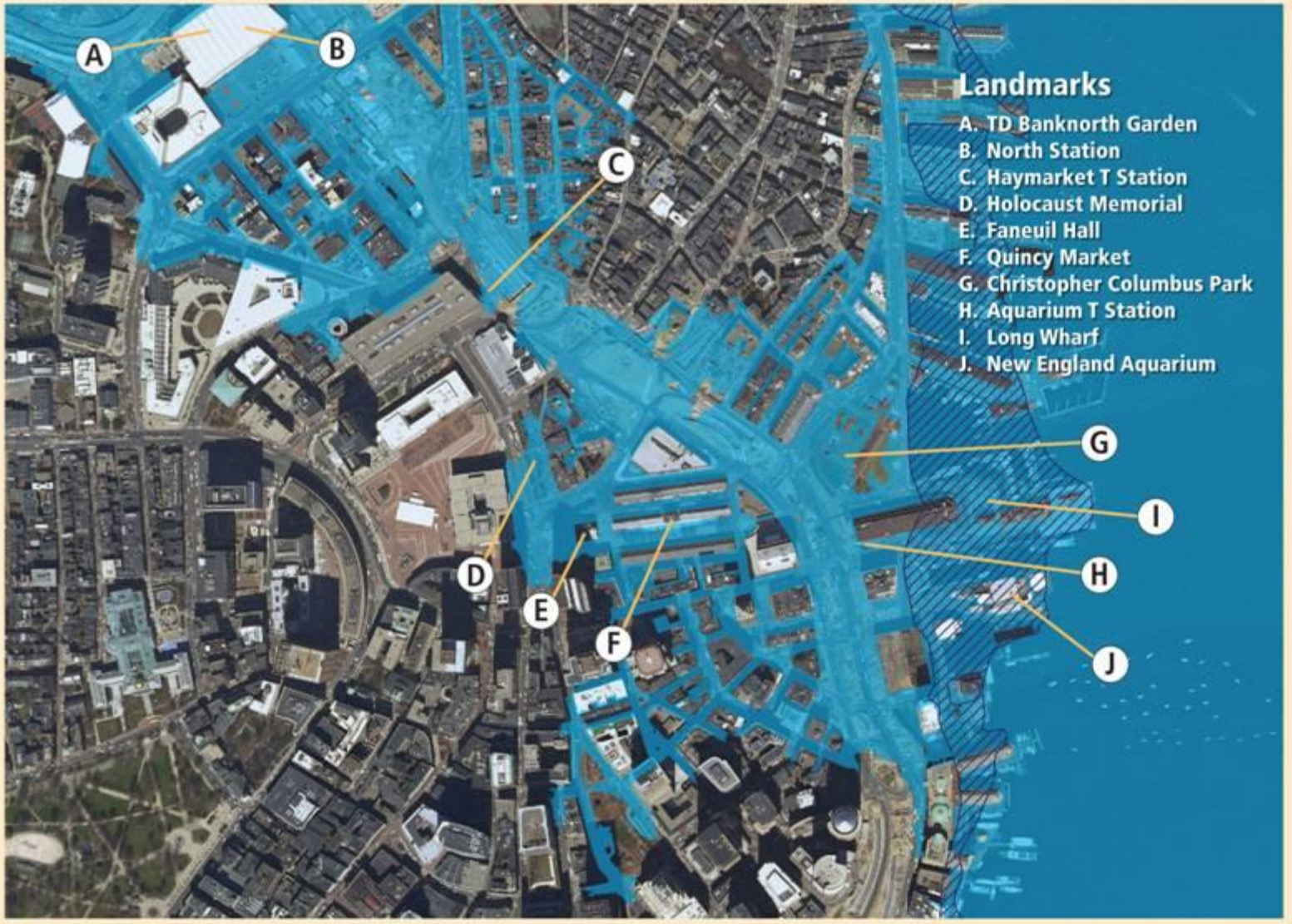
In the High Sea Level Rise Scenario, the Industries at Risk Substantially Expand



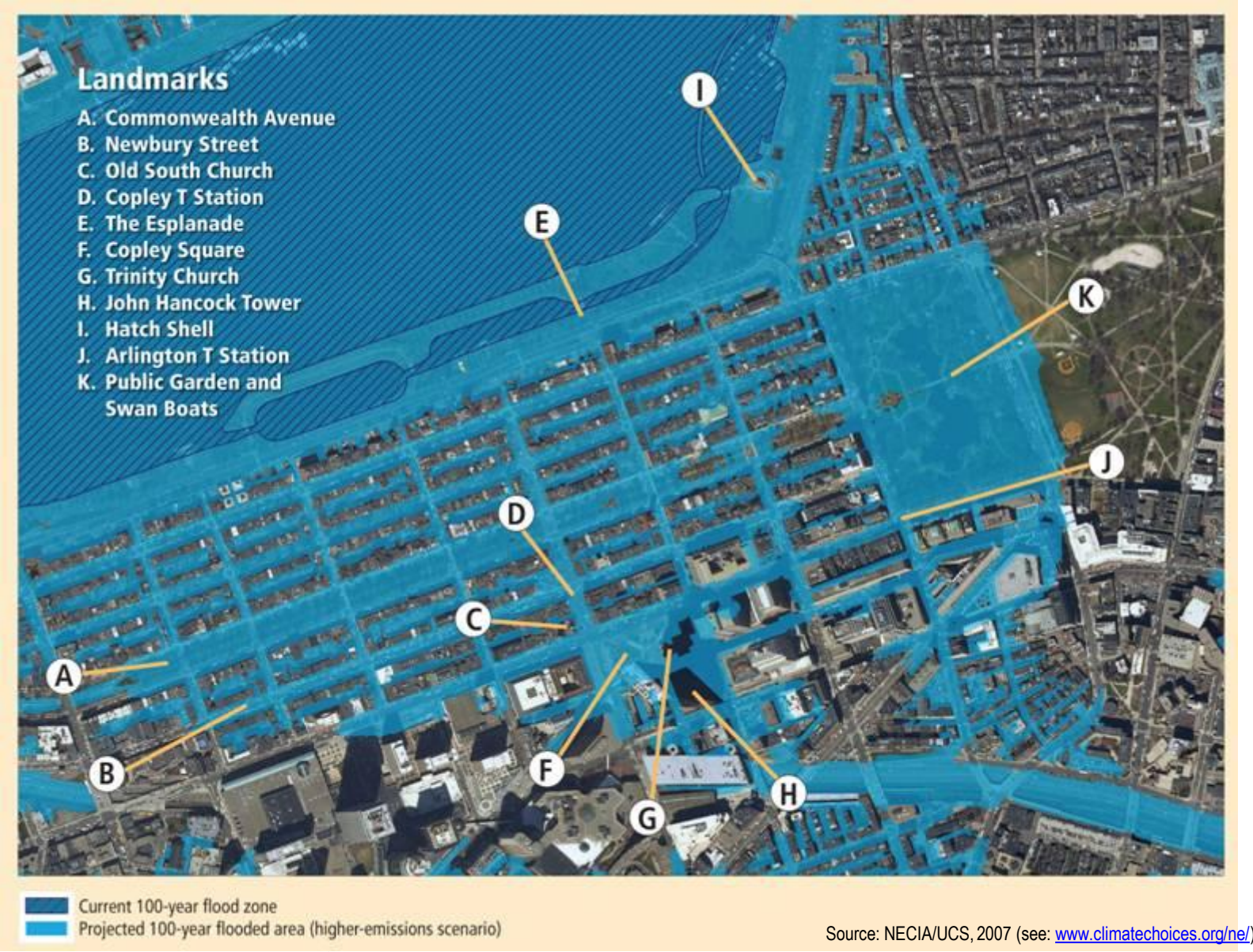
Employment at Risk Within SLOSH Model Predictions

	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



Coastal Flooding in Boston under Present and High Emission Sea Levels

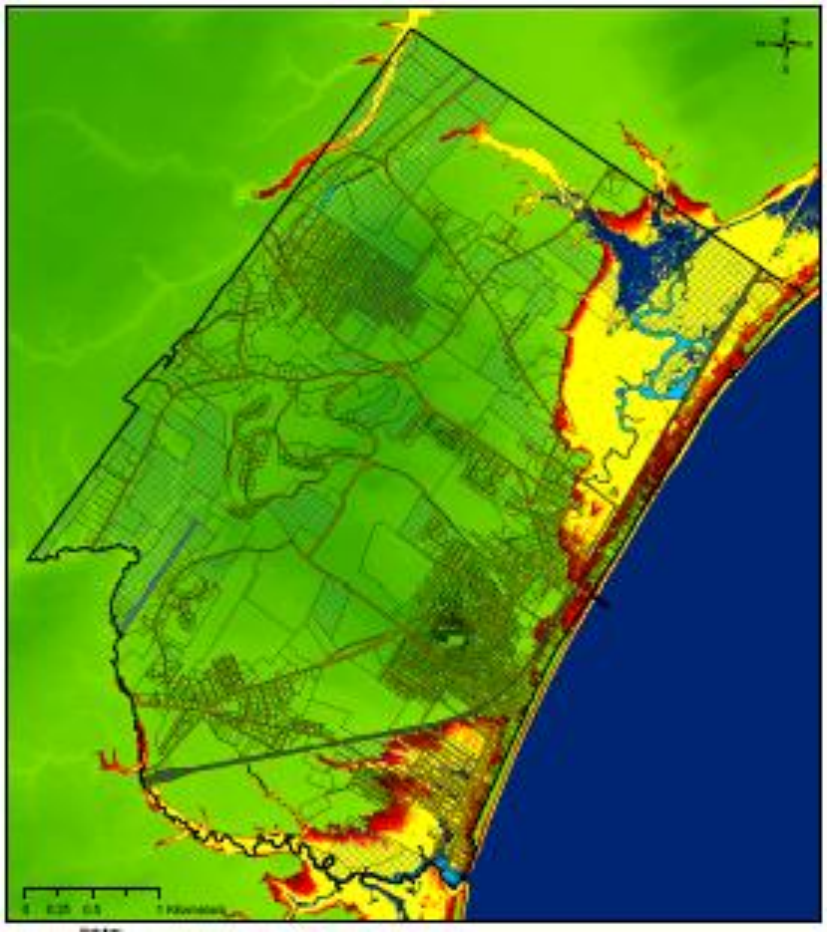


Source: NECIA/UCS, 2007 (see: www.climatechoices.org/ne/)

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).**

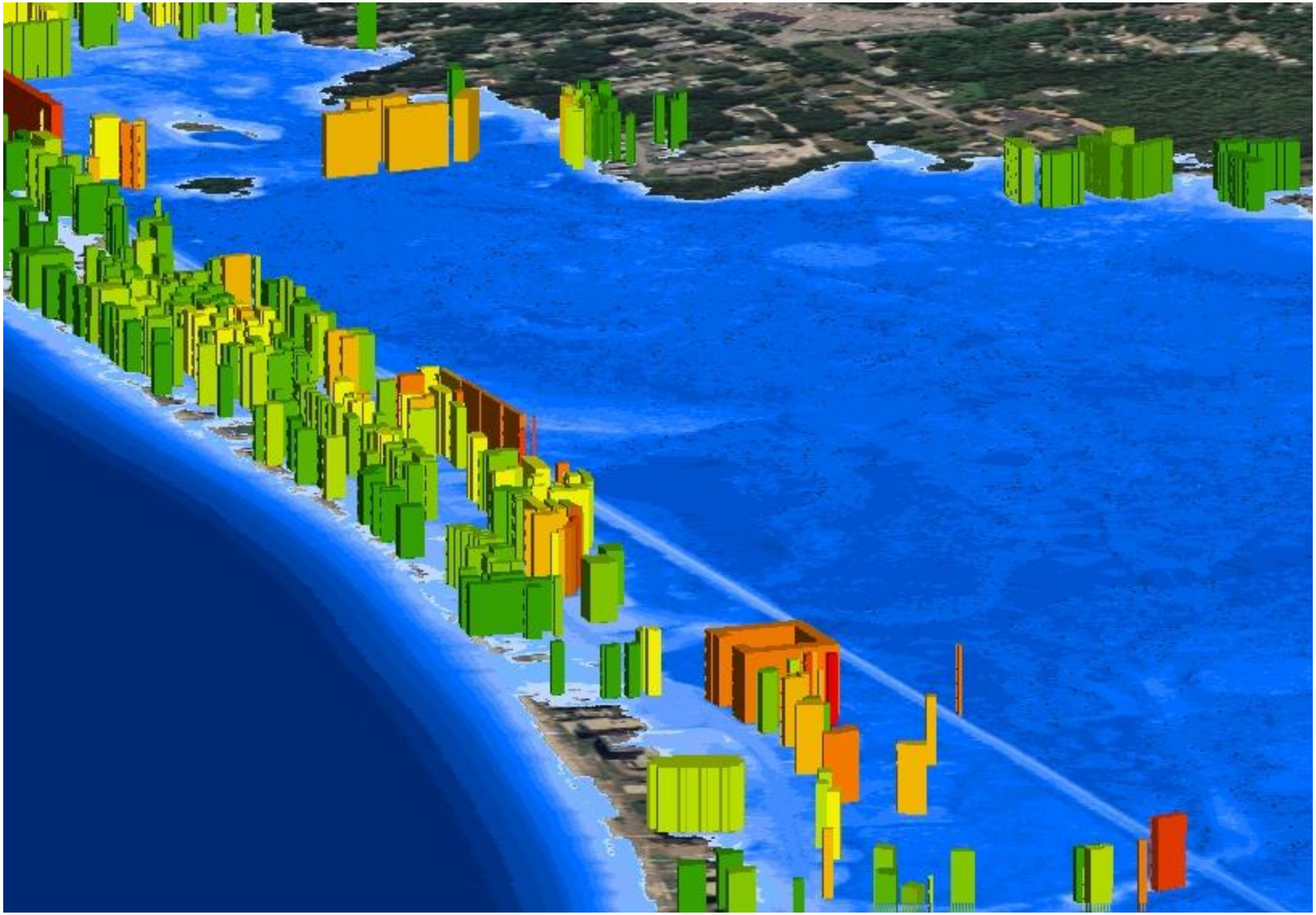
From "Climate Skeptics Embrace Cleaner Energy."
http://www.nytimes.com/2010/10/19/science/earth/19fossil.html?ref=us



DAMAGE FUNCTIONS FOR SINGLE FAMILY RESIDENTIAL STRUCTURES WITH BASEMENTS

Structure Depth-Damage

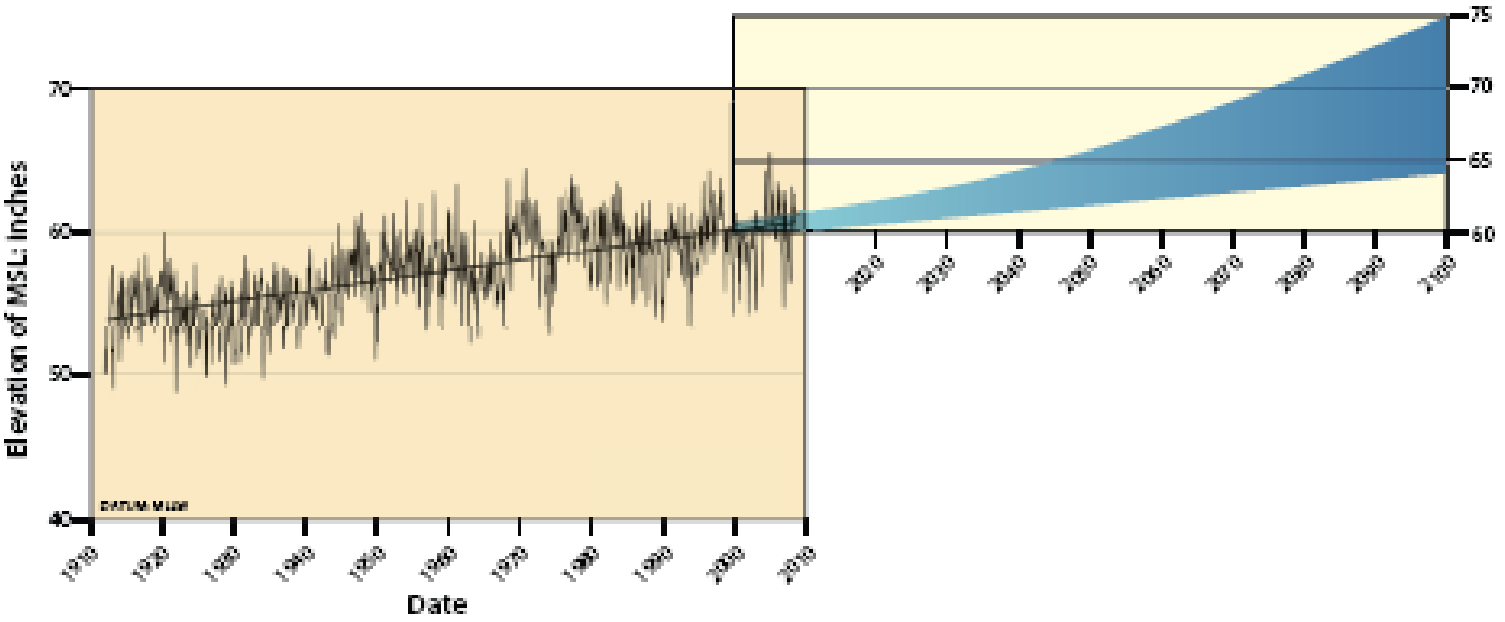
Table 1 Structure One Story, With Basement		
Depth	Mean of Damage	Standard Deviation of Damage
-8	0%	0
-7	0.7%	1.34
-6	0.8%	1.06
-5	2.4%	0.94
-4	5.2%	0.91
-3	9.0%	0.88
-2	13.8%	0.85
-1	19.4%	0.83
0	25.5%	0.85
1	32.0%	0.96
2	38.7%	1.14
3	45.5%	1.37
4	52.2%	1.63
5	58.6%	1.89
6	64.5%	2.14
7	69.8%	2.35
8	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



Expected costs and damages, 2010 - 2050

SLR Scenario	Adaptation	Residual Damages ($ million)	Adaptation Cost ($ million)	Total Damages and Costs ($ 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

Maine Sea Level, 1912-2100



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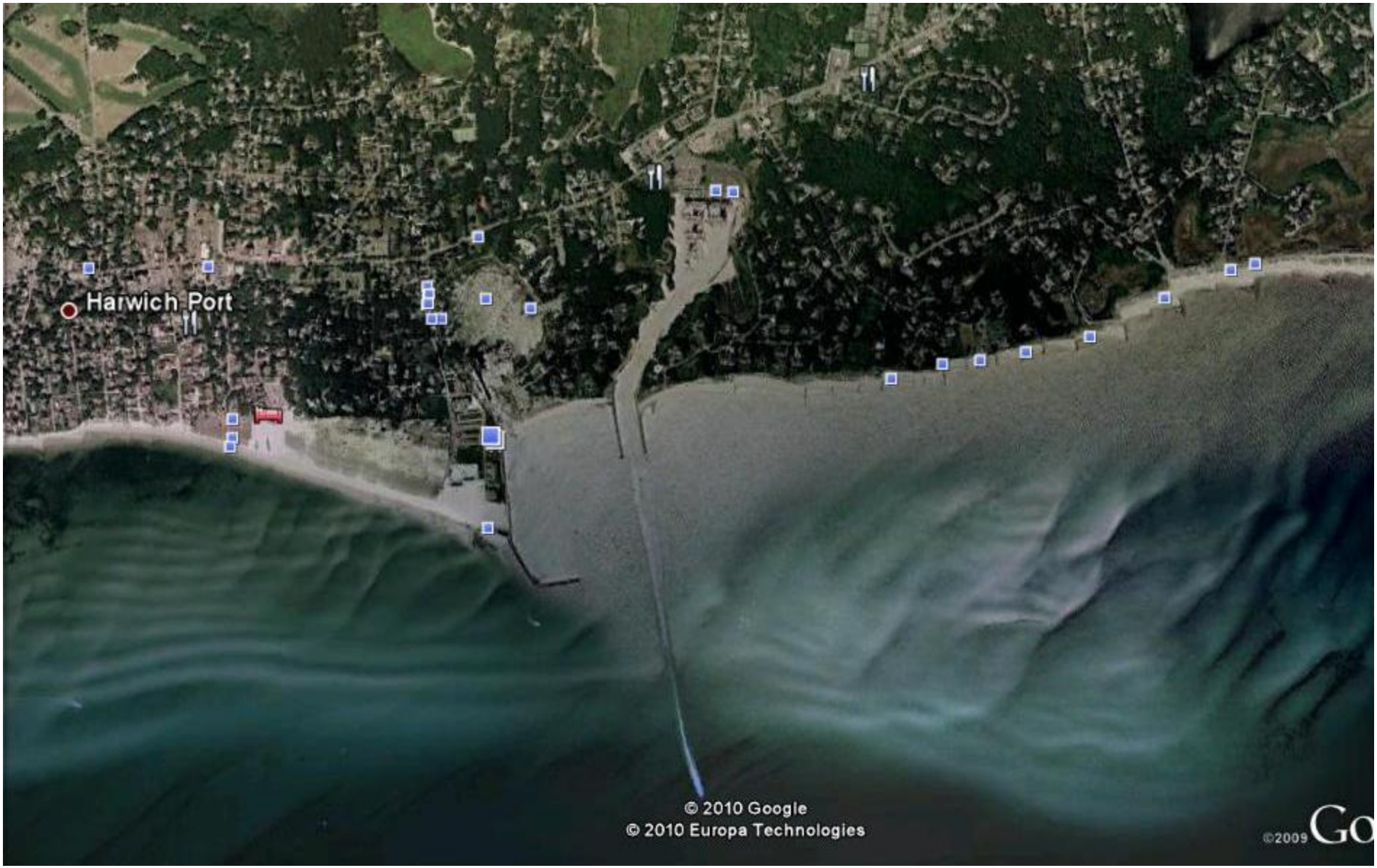
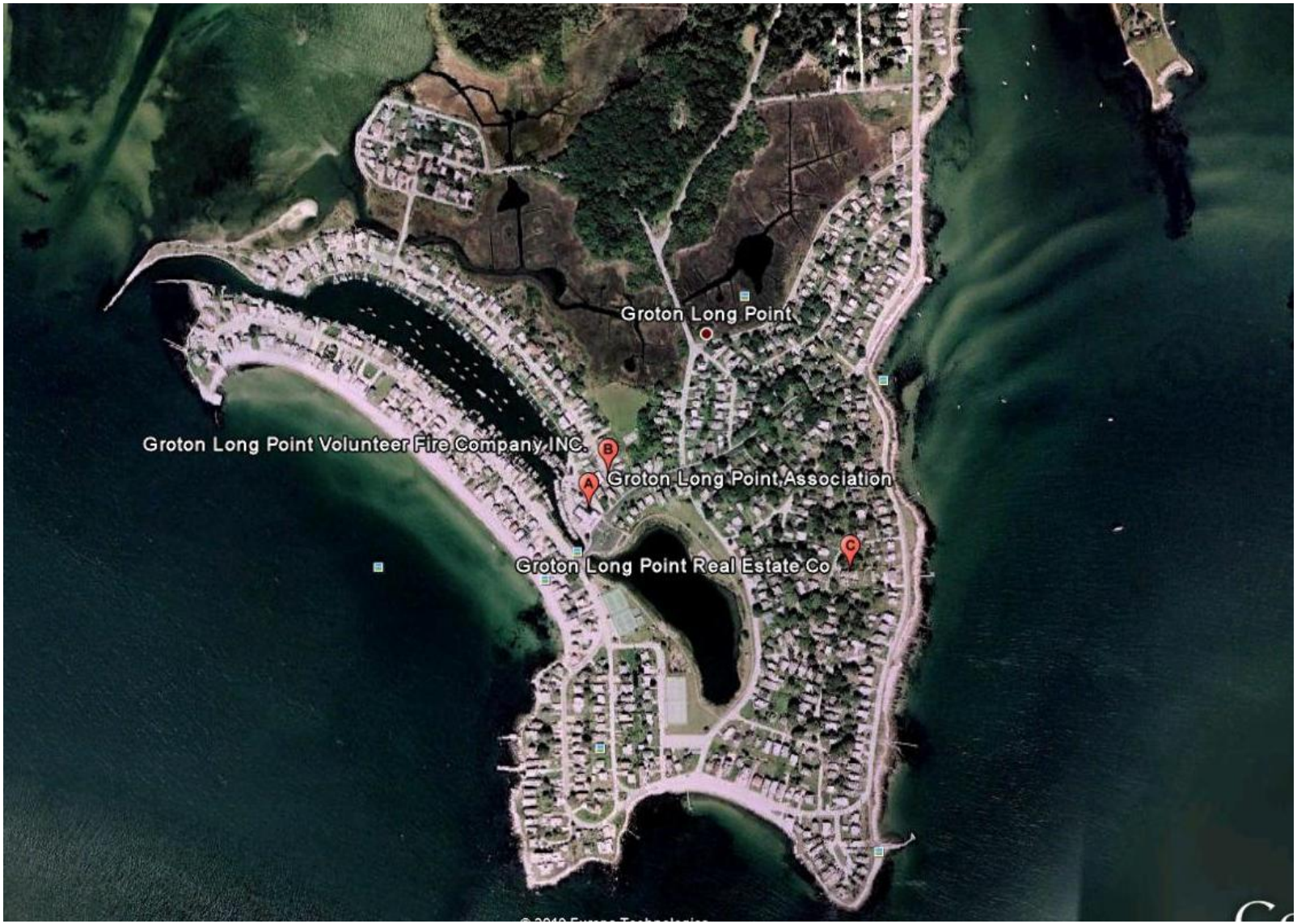
Input: a range of adaptation options

- Revetments
- Geotextile tubes
- Sea walls
- Jetties

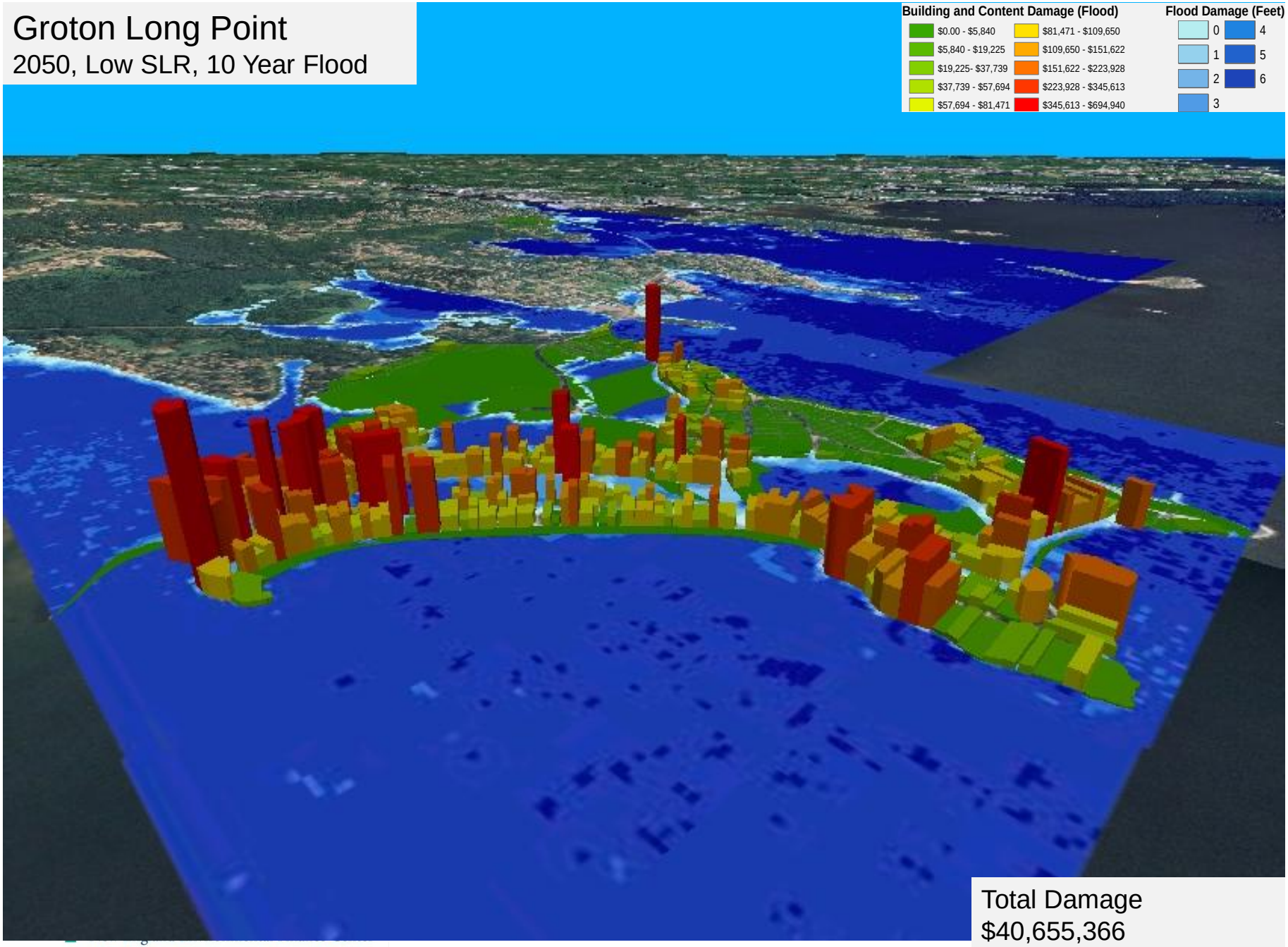
- Wet or dry floodproofing
- Zoning and other regulatory changes


Harwich Port
© 2010 Google
© 2010 Europa Technologies
©2009


Groton Long Point
Groton Long Point Volunteer Fire Company INC.
B
Groton Long Point Association
A
C
Groton Long Point Real Estate Co

Groton Long Point

2050, Low SLR, 10 Year Flood

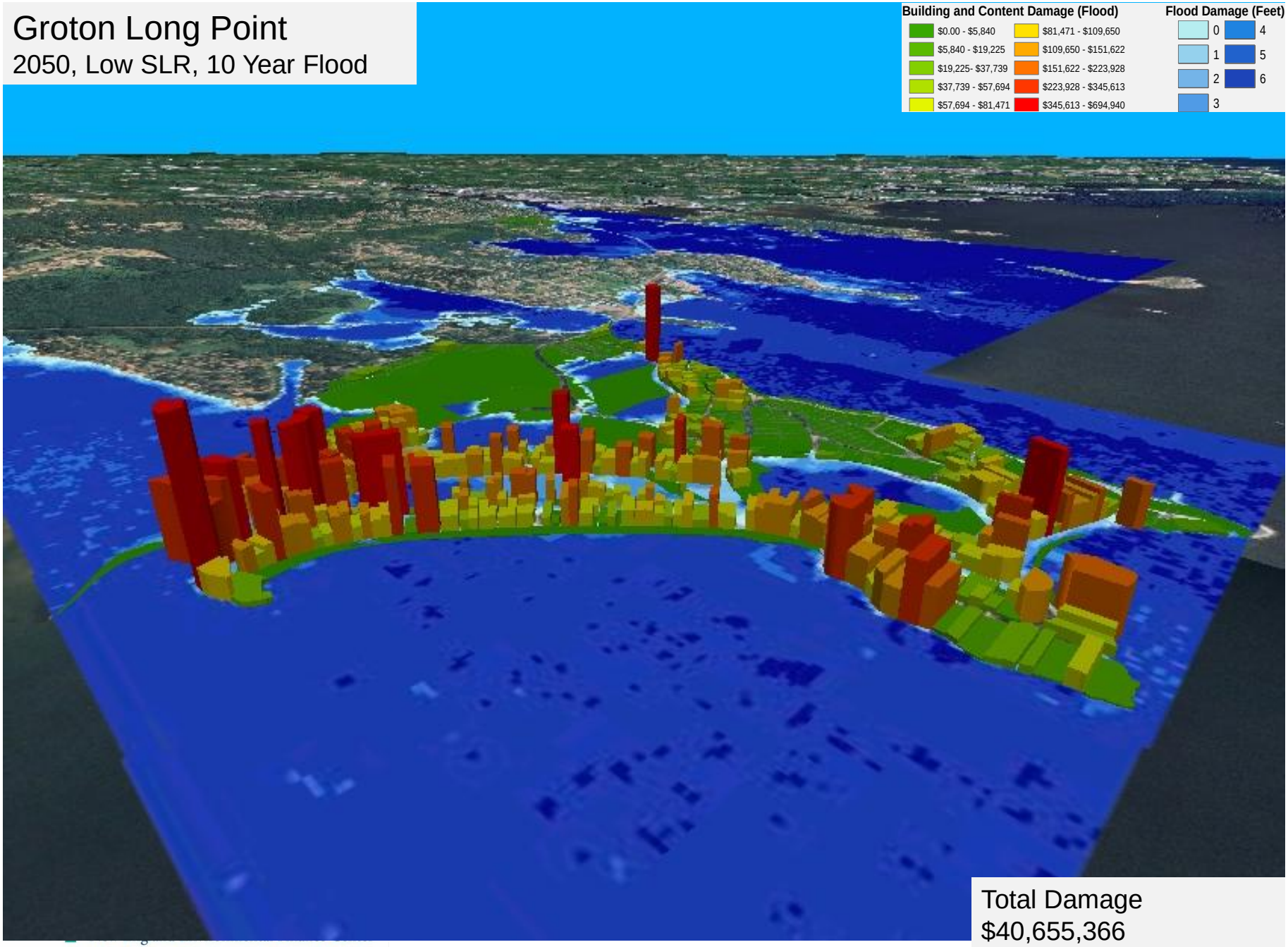


Total Damage
$40,655,366

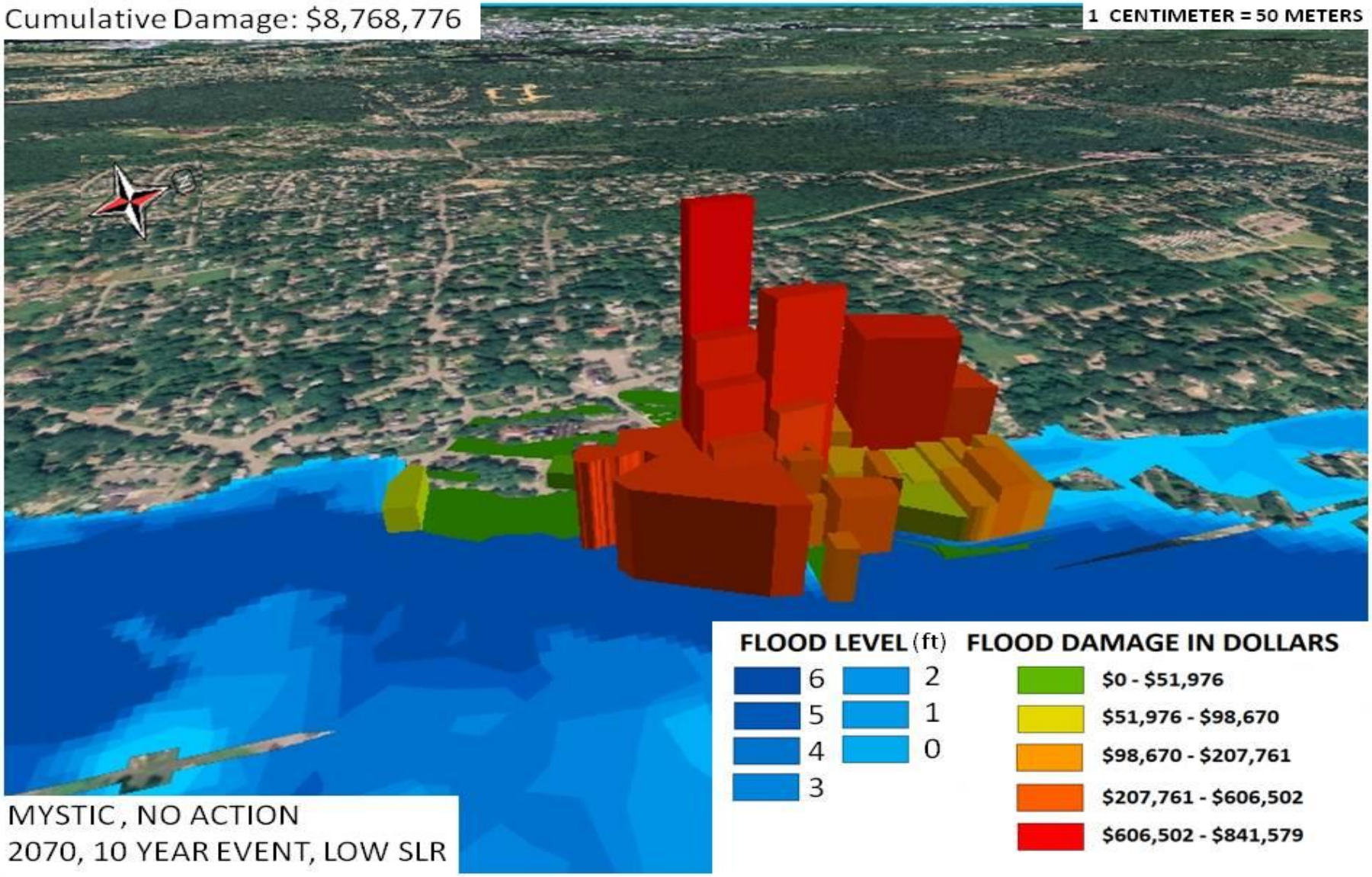

Diking and Culvert Construction and/or Modification
Seawall Modification and Elevation
Barrier
Rising Gate Design
Elevation 7 ft NAVD88
Image © 2010 TerraMetrics
© 2010 Google
Image © 2010 DigitalGlobe
© 2010 Europa Technologies
©2009 Google
Imagery Date: Sep 30, 2006
41°18'49.10" N 72°00'24.43" W elev 4 m
Eye alt 2.74 km

Groton Long Point

2050, Low SLR, 10 Year Flood



Total Damage
$40,655,366



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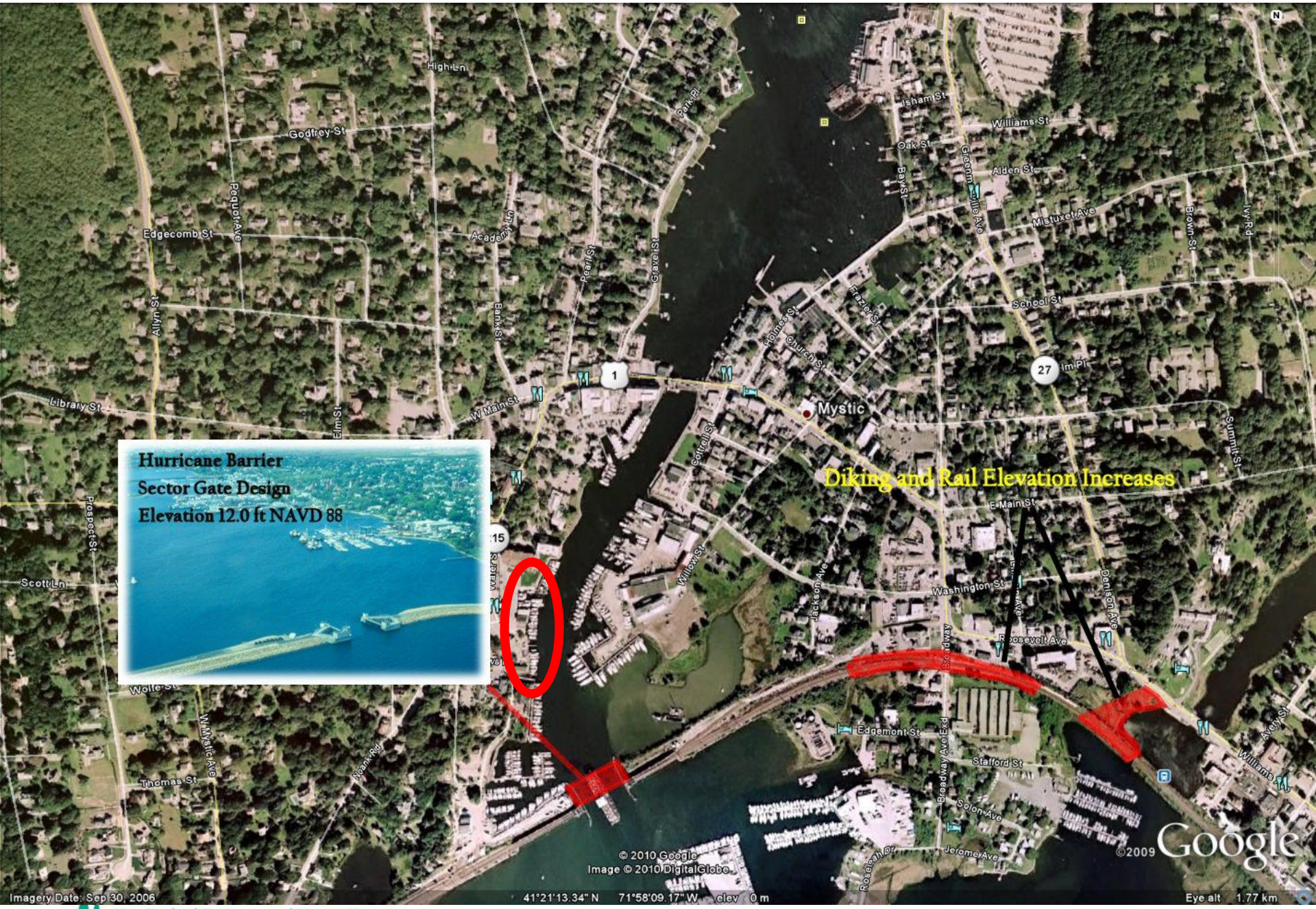
Scenarios		Max. Water Elev. (ft., NAVD88)	Engineering Options	Construction Costs	Annual Maintenance Costs
Sea level rise, normal tides	A	3.2 – 4.0	No action up to minimal flood proofing and infrastructure elevation along river.	Insignificant	Insignificant
	B	5.5 – 6.5	Hurricane Barrier at Mystic River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


Hurricane Barrier
Sector Gate Design
Elevation 12.0 ft NAVD 88
Diking and Rail Elevation Increases
Mystic
High Ln
Godfrey St
Edgecomb St
Pequot Ave
Allyn St
Library St
Elm St
W Main St
Academy Ln
Bank St
Pearl St
Gravel St
Park Pl
Isham St
Oak St
Bay St
Williams St
Alden St
Greenmanville Ave
Mistuxet Ave
Brown St
Ivy Rd
School St
Holmes St
Church St
Fraser St
Elm Pl
Summit St
E Main St
Cortell St
Willow St
Jackson Ave
Washington St
Roosevelt Ave
Broadway
Broadway Ave Ext
Edgemont St
Stafford St
Solon Ave
Jerome Ave
Rosebank Dr
Avery St
Williams St
Prospect St
Scott Ln
Wolfe St
W Mystic Ave
Thomas St
Noank Rd
1
27
15
© 2010 Google
Image © 2010 DigitalGlobe
©2009 Google
Imagery Date: Sep 30, 2006
41°21'13.34" N 71°58'09.17" W elev 0 m
Eye alt 1.77 km

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			
	F	8.9	Hurricane Barrier at Mystic River entrance. ***<u>ADDITIONAL FORTIFICATION</u> and elevating the railroad, as well as increased diking to east.***	$27-30 Million	$100,000
100-year storm in 2070, Hi SLR	G	8.6			
	H	10.5	Hurricane Barrier at Mystic River entrance. ***<u>FURTHER FORTIFICATION</u> and elevating the railroad, as well as increased diking to east.***	$35 Million	$120,000

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

Output: a range of “economic floodplains”

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

Output: a range of “economic floodplains”

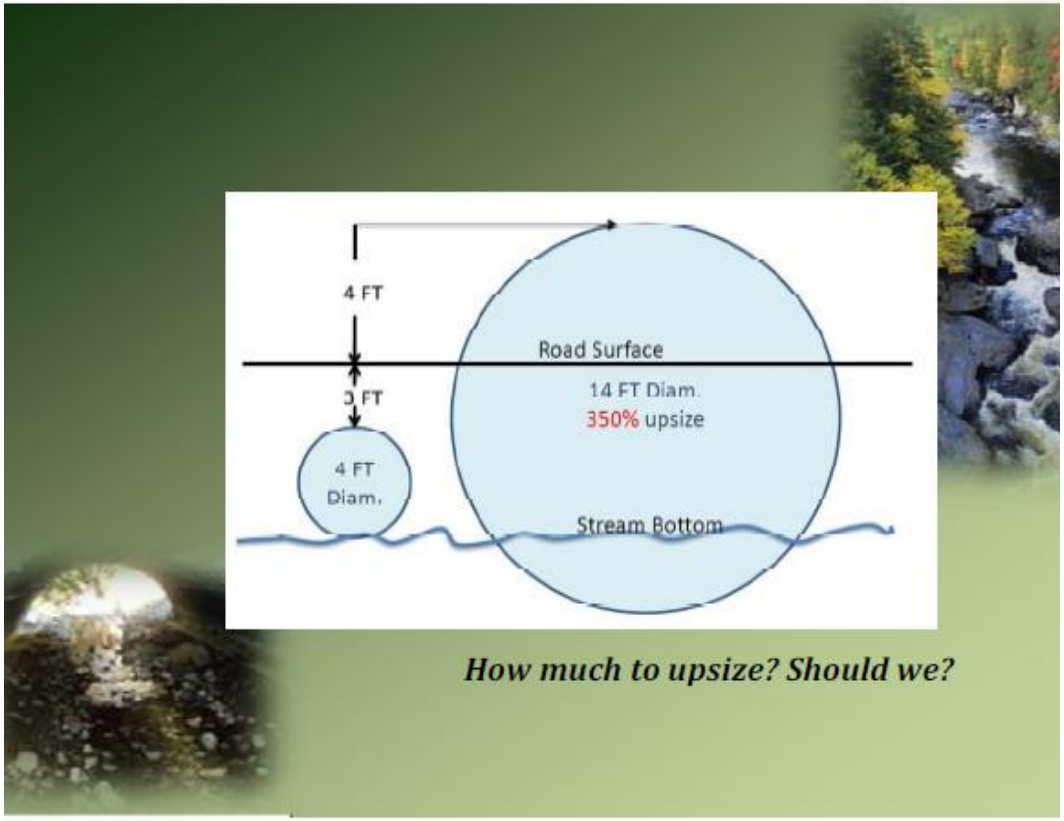
- Lost real estate values (e.g., Groton, CT)
- Lost economic output (e.g., 8-town coastal ME study)

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)

New England Environmental Finance Center

A Financial Impact Assessment of LD 1725: Stream Crossings



Prepared by: The New England Environmental Finance Center
For the Maine Department of Transportation Office of Environmental Planning

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”

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- Lost cultural resources values (e.g., NPS gravesites)

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- 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.


Sea Isle City, NJ
Geotextile Tubes

Possible Activities in Coastal New Hampshire

- Stakeholders identify vulnerable assets to model.
- Stakeholders identify adaptation actions to consider.
- EFC runs calculations, produces maps and tables, and communicates results to group.
- Stakeholders use products in planning process as appropriate.

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207-228-8596

New England Environmental Finance Center:

http://efc.muskie.usm.maine.edu

Thank you!

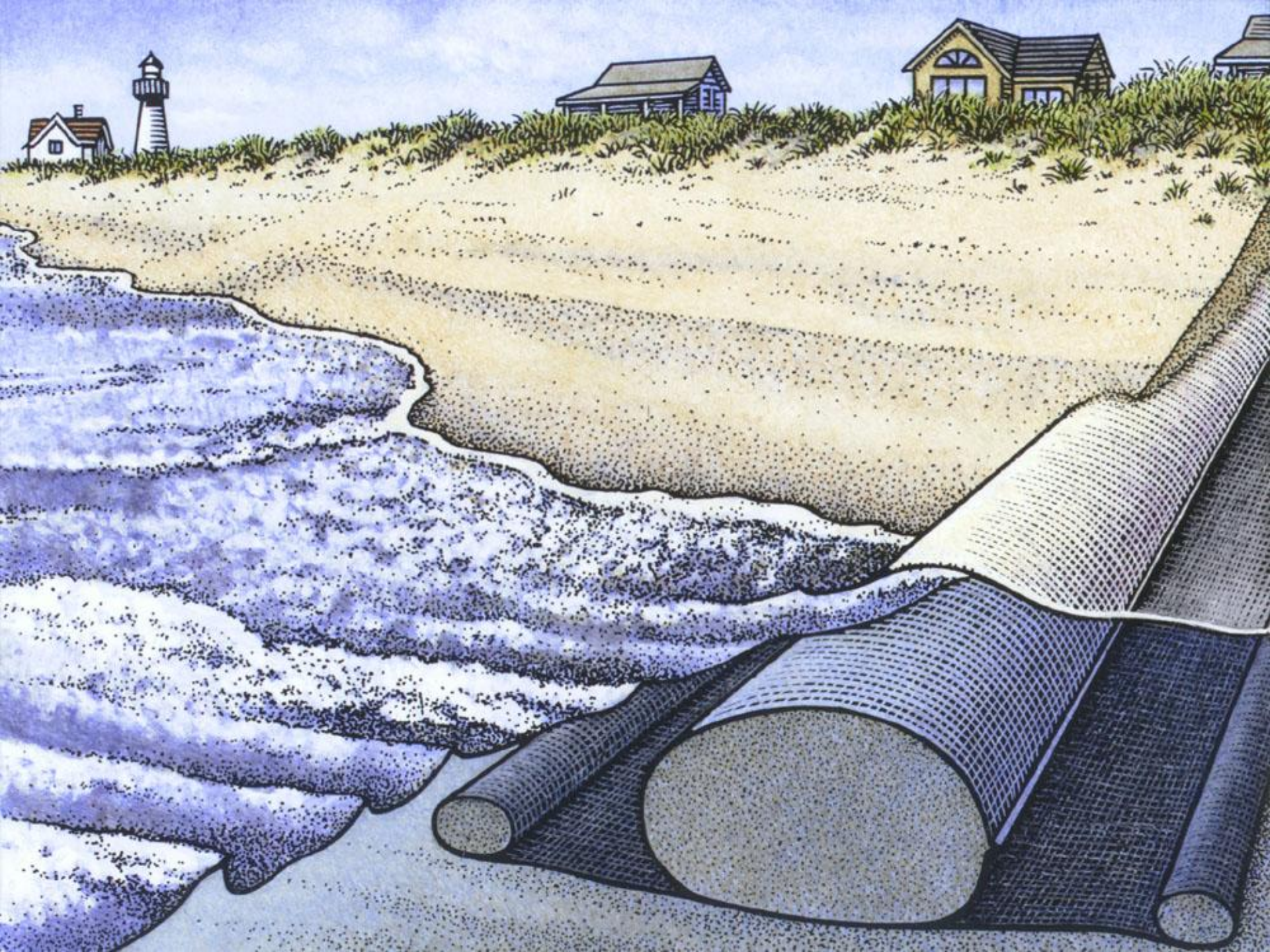
Input: a range of adaptation options

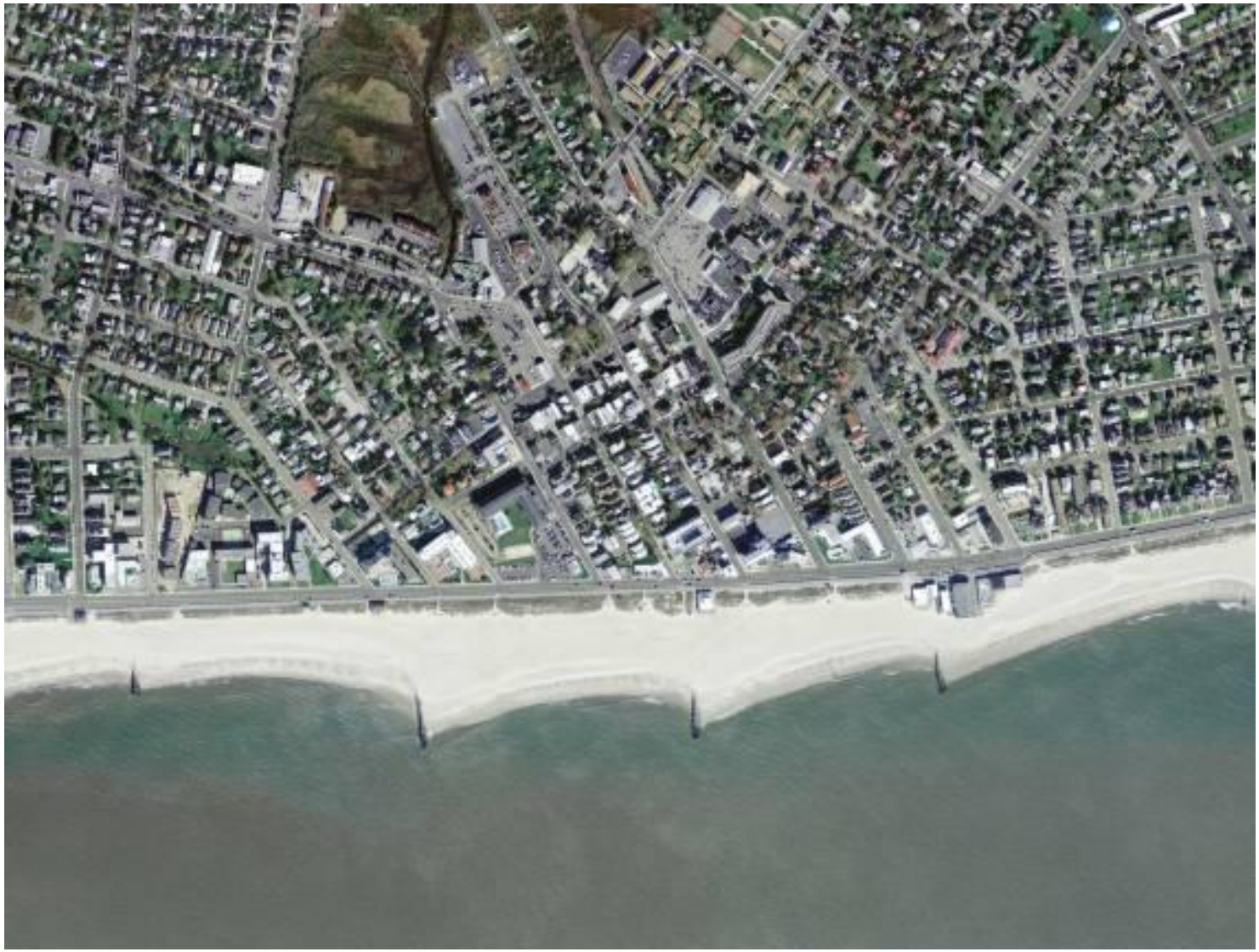
- Revetments

Pea Patch Island, DE (Delaware River)

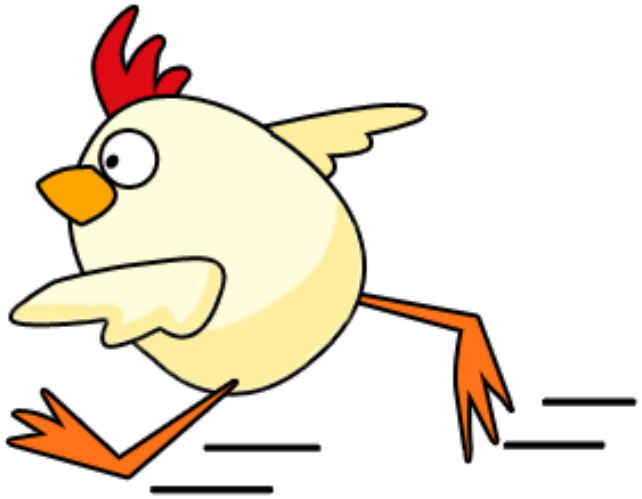
Input: a range of adaptation options

- Revetments
- Geotextile tubes






Sea Isle City, NJ
Geotextile Tubes

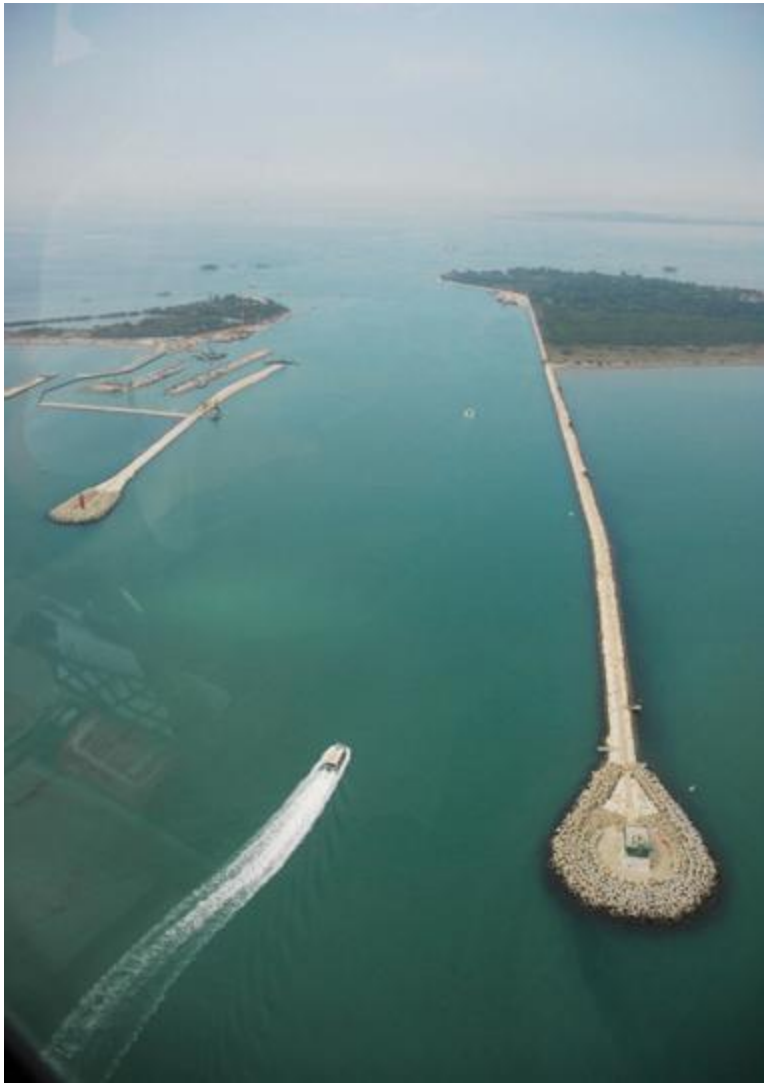


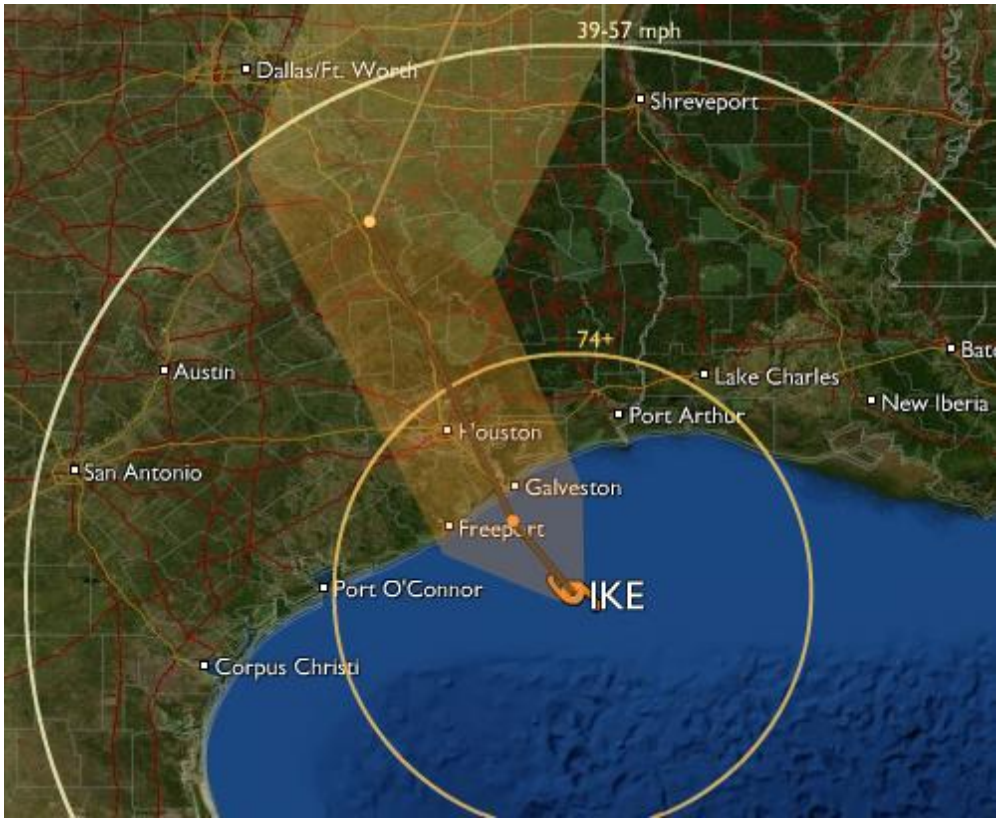
“Facing the bluntness of reality is the highest form of sanity and enlightened vision.”

- Chogyam Trungpa Rinpoche

Input: a range of adaptation options

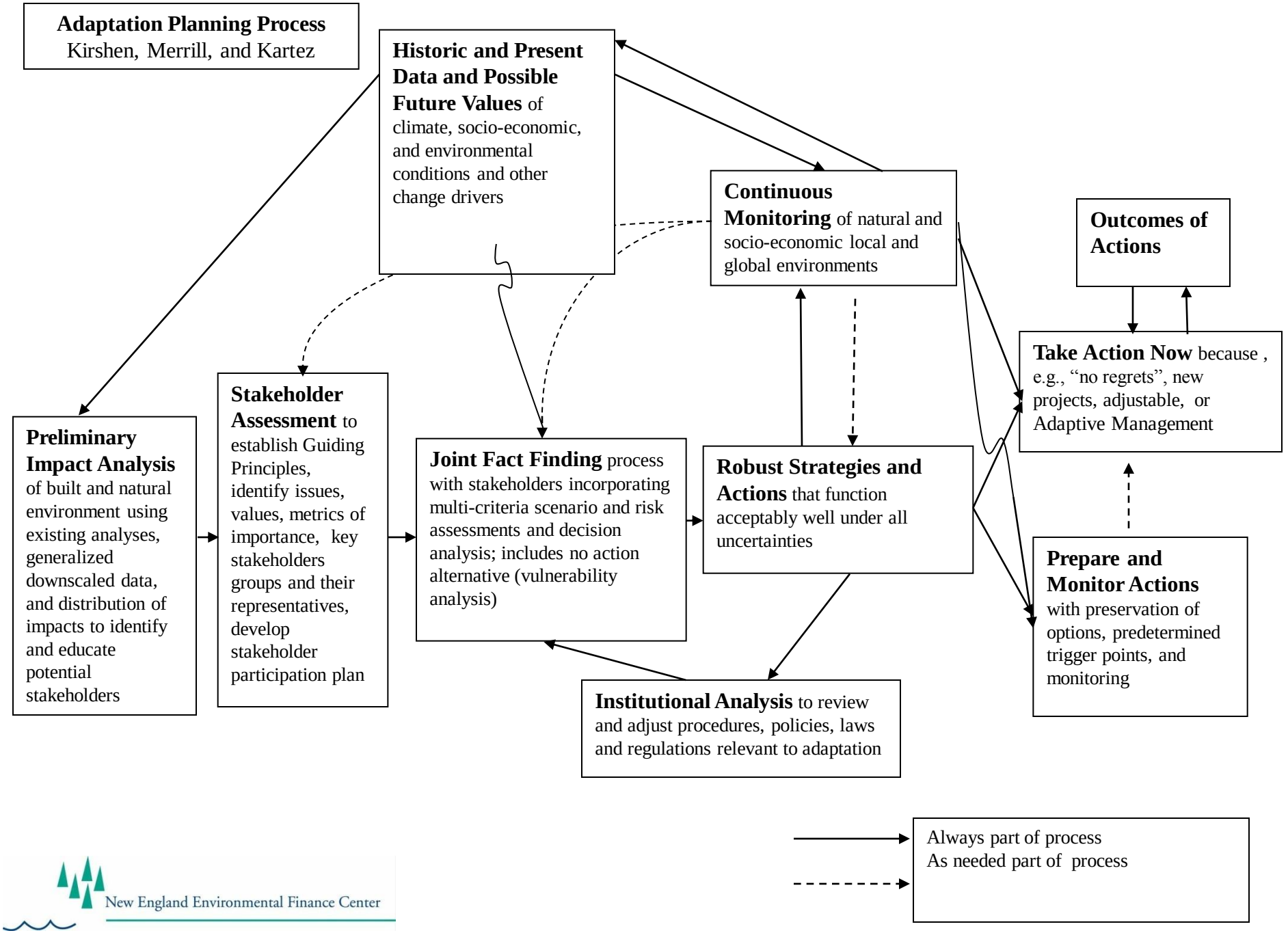
- Revetments
- Geotextile tubes
- Sea walls




39-57 mph
Dallas/Ft. Worth
Shreveport
74+
Austin
Lake Charles
New Iberia
Port Arthur
Houston
San Antonio
Galveston
Freeport
Port O'Connor
IKE
Corpus Christi

Input: a range of adaptation options

- Revetments
- Geotextile tubes
- Sea walls
- Jetties


Adaptation Planning Process
Kirshen, Merrill, and Kartez
Historic and Present Data and Possible Future Values of climate, socio-economic, and environmental conditions and other change drivers
Continuous Monitoring of natural and socio-economic local and global environments
Outcomes of Actions
Take Action Now because , e.g., "no regrets", new projects, adjustable, or Adaptive Management
Preliminary Impact Analysis of built and natural environment using existing analyses, generalized downscaled data, and distribution of impacts to identify and educate potential stakeholders
Stakeholder Assessment to establish Guiding Principles, identify issues, values, metrics of importance, key stakeholders groups and their representatives, develop stakeholder participation plan
Joint Fact Finding process with stakeholders incorporating multi-criteria scenario and risk assessments and decision analysis; includes no action alternative (vulnerability analysis)
Robust Strategies and Actions that function acceptably well under all uncertainties
Prepare and Monitor Actions with preservation of options, predetermined trigger points, and monitoring
Institutional Analysis to review and adjust procedures, policies, laws and regulations relevant to adaptation
Always part of process
As needed part of process
New England Environmental Finance Center

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