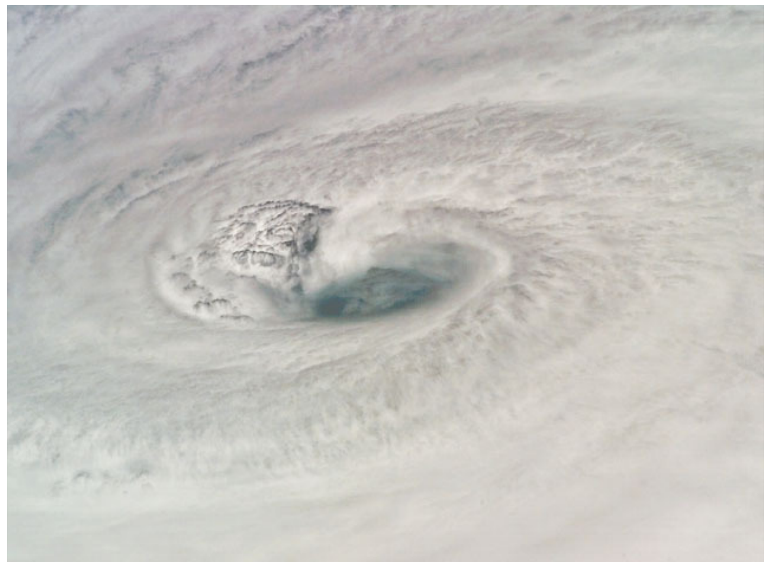
# Community Engagement and Cost Benefit Analysis for Sea Level Rise and Storm Surge Adaptation



*Samuel B. Merrill, Ph.D.*

*December 6, 2012*

# Muskie School of Public Service

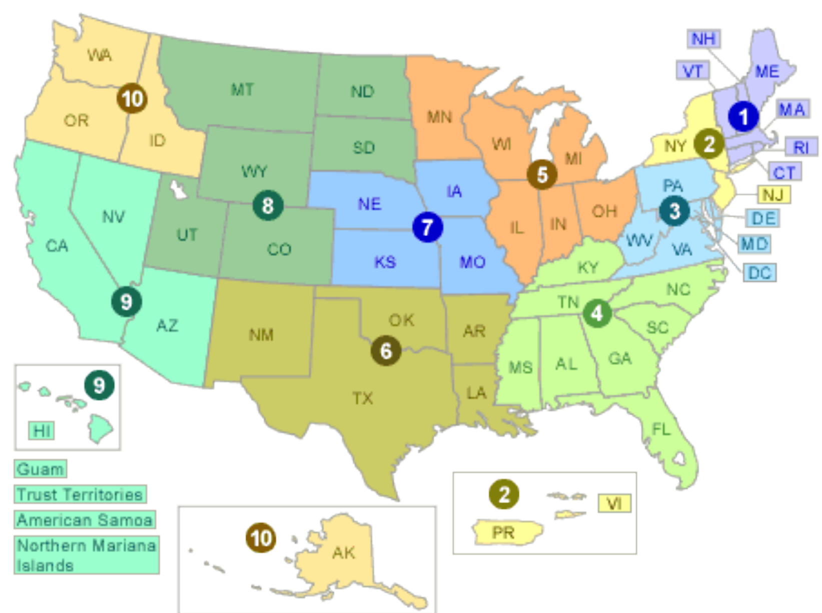
University of Southern Maine
Portland, Maine

# Environmental Finance Center Network

The EFCN is a university-based organization creating innovative solutions to managing costs of environmental protection and improvement. It consists of ten EFCs serving states in EPA's ten regions. By sharing information, tools and techniques, the EFCs <u>help address difficult how-to-pay issues of providing environmental services</u>.

[http://www.epa.gov/efinpage/efcn.htm](http://www.epa.gov/efinpage/efcn.htm).

EFCN
environmental finance center network



Catalysis Adaptation Partners, LLC

www.catalysisadaptation.com


Credit: Robin Utrecht/AFP/Getty Images


4
5
6
3
PRO-COMP
ULTRA-LITE
7
2
8
1
9
0
10
Auto Meter
RPM
THOUSANDS

# Impacts from Flooding



Mon 65 : Newark Selectable
Cam 1420 : 1420-HBKN-E and D Elevator Platform
10/29/2012
20:23:34

# 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.

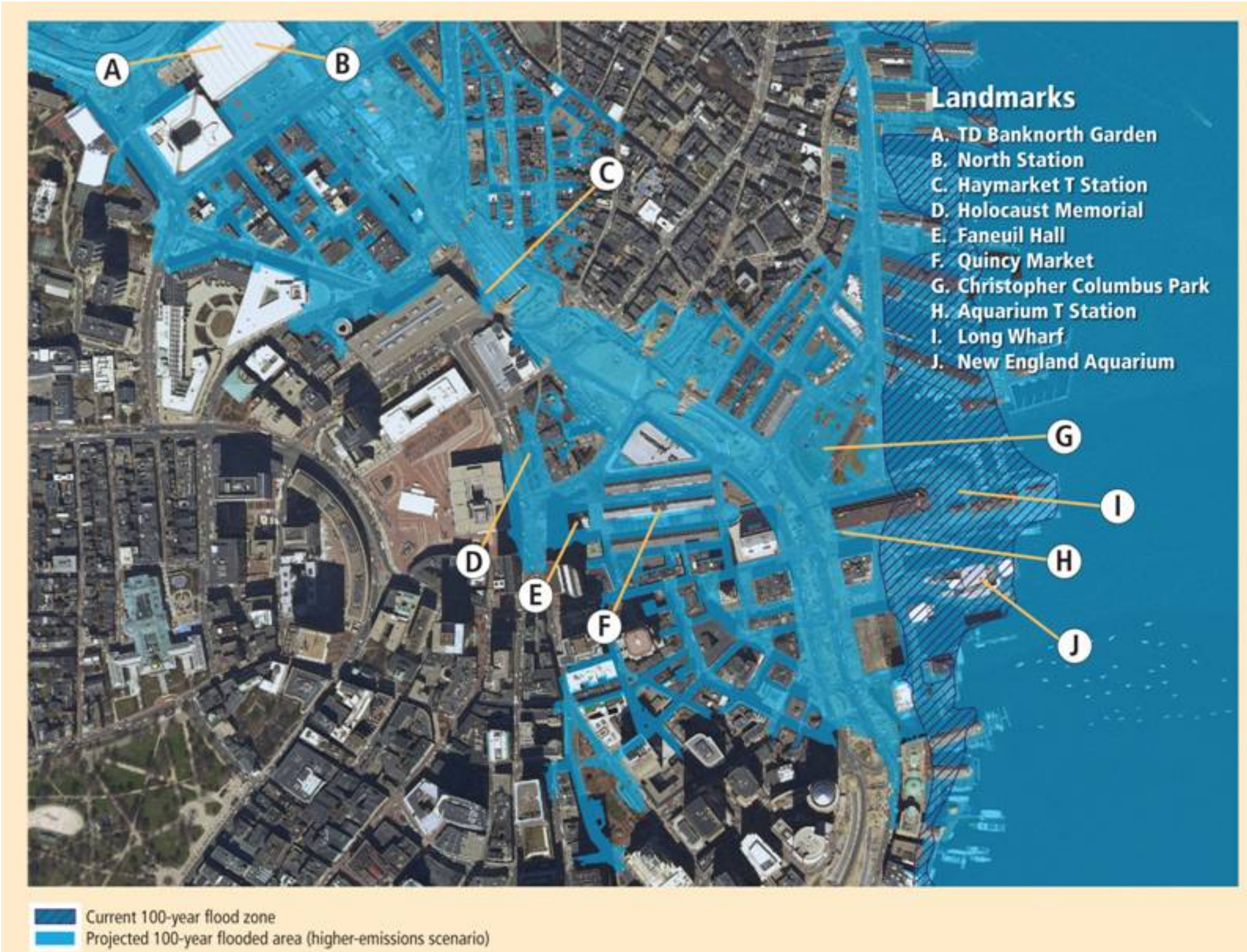
Wharton Risk Management and Decision Processes Center, University of Pennsylvania.

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

**It is Difficult to Shift into Action Mode:**

1) Consequences appear far off in time.
2) Cost-benefit relationships are ambiguous.
3) Possible actions are complex.
4) Doing nothing is far, far easier.


# Coastal Flooding in Boston under Present and High Emission Sea Levels



**<u>There are only four options:</u>**

1) Do nothing (usually = remain in denial)
2) Fortify assets
3) Accommodate higher water levels
4) Relocate assets

**There are only four options:**

1) Do nothing (usually = remain in denial)
2) Fortify assets
3) Accommodate higher water levels
4) Relocate assets

**>> COAST is a tool and approach to help evaluate costs and benefits of these options.**

# The COAST Strategy

1) Don’t discuss climate change.

# The COAST Strategy

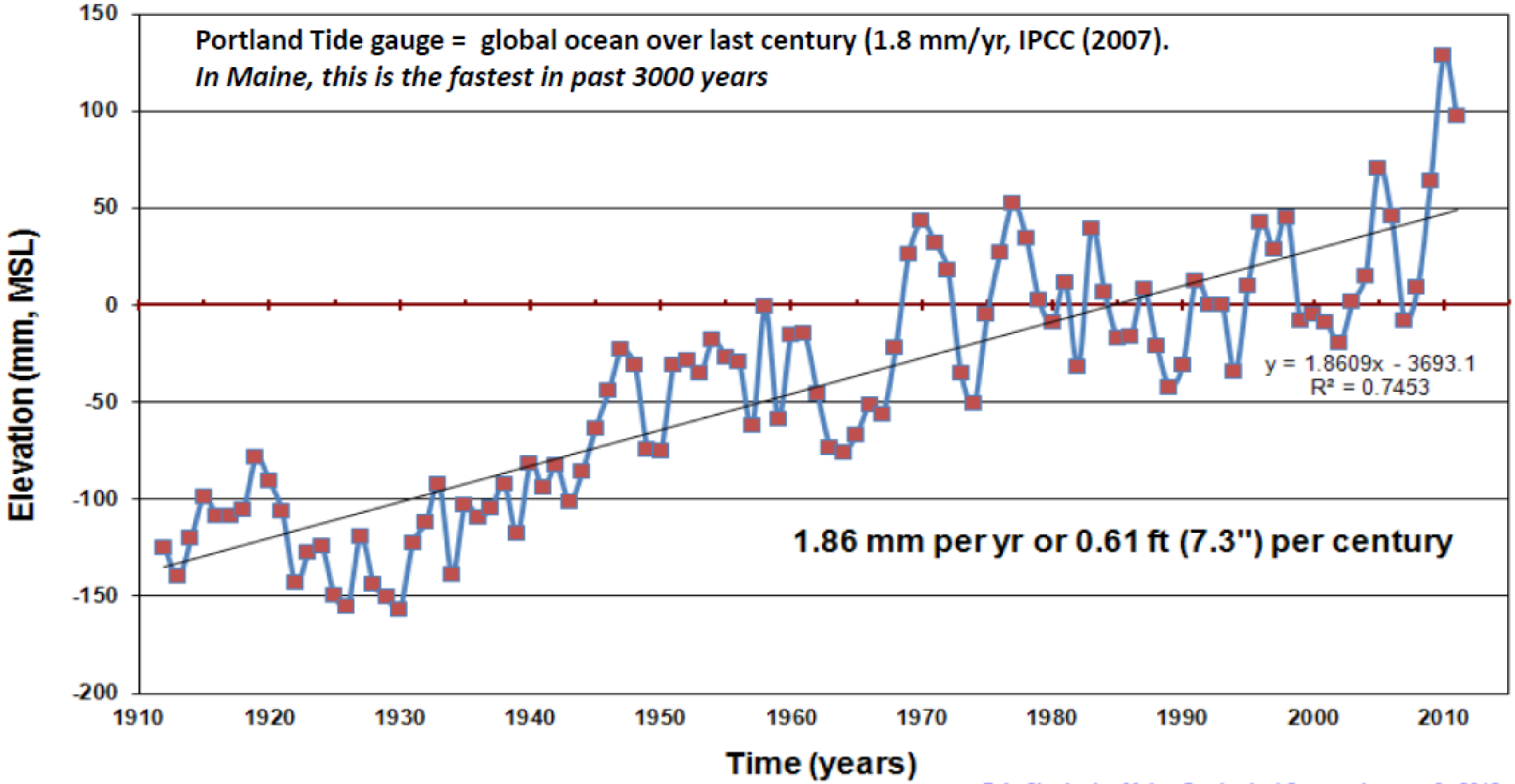
1) Don’t discuss climate change.
2) Focus on observed, local data.


Patriot's Day Storm 2007: York Beach

# Sea Level, Portland, Maine

**1912-2011 (through November 30, 2011)**

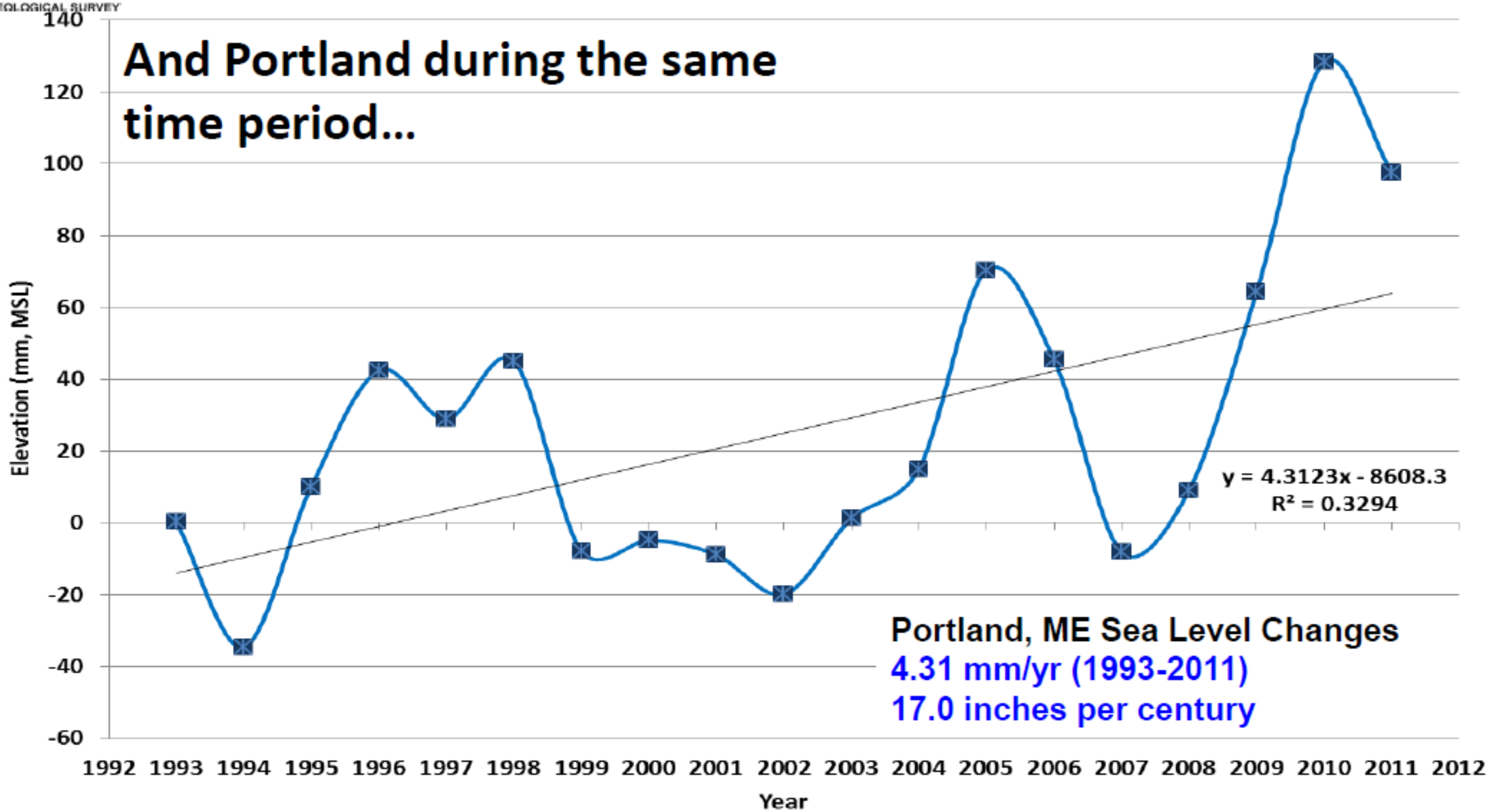
GEOLOGICAL SURVEY




*Data courtesy of NOAA CO-OPS, www.tidesandcurrents.noaa.gov*

P.A. Slovinsky, Maine Geological Survey, January 3, 2012

# Sea Level, Portland, Maine
## 1993-2011 (through November 30, 2011)




$1.00 DAILY
$1.75 SUNDAY
The Portland Press Herald
Most trips by fireboats unrelated to emergencies
DANIEL BURKE
Catch Up On YOUR LOCAL TEAMS
RED CLAWS
TO SUBSCRIBE CALL 791-6000

The Old Port, 10/11 at high tide (M. Craig)


NO
THRU
TRAFFIC
RESIDENT
AND
BUSINESS
TRAFFIC
ONLY
NO
LOITERING
PRIVATE
PARKING


edEx
PRIVATE PARKING
PRIVATE PARKING
RIPPLE
4A 2885

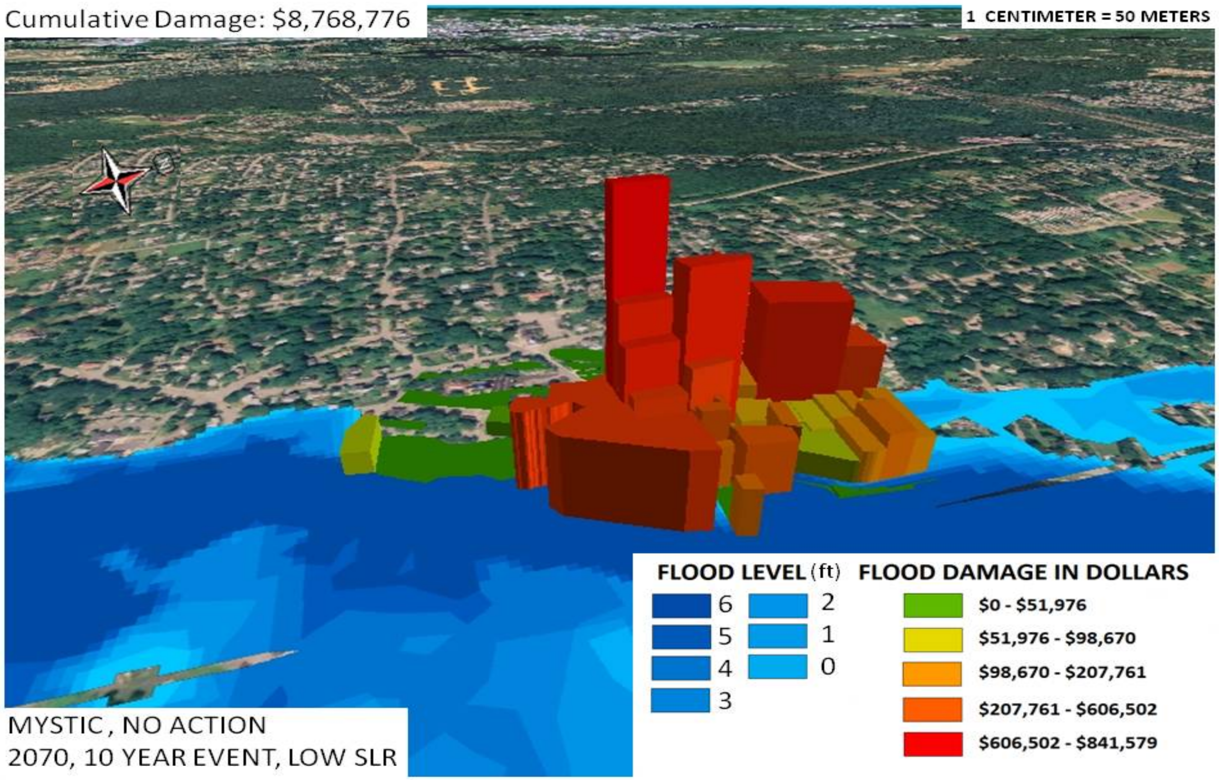
Marginal Way and Cove St., 9/10, New Moon J. Piribeck


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

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

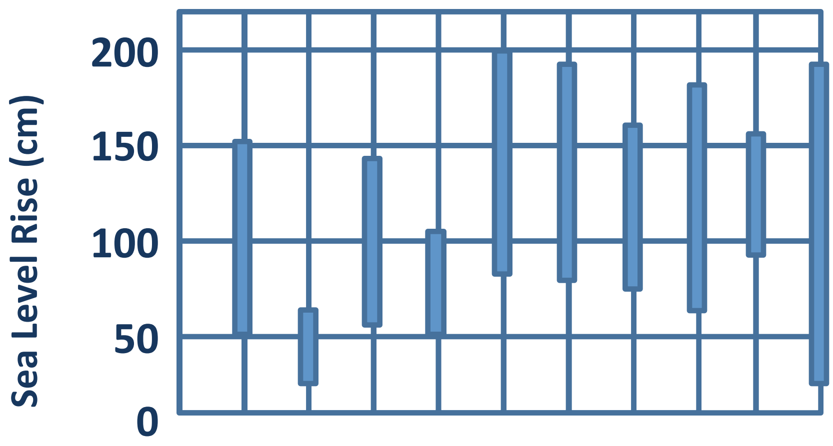
# The COAST Strategy

1) Don’t discuss climate change.
2) Focus on observed, local data.
3) Use 3D visualization.

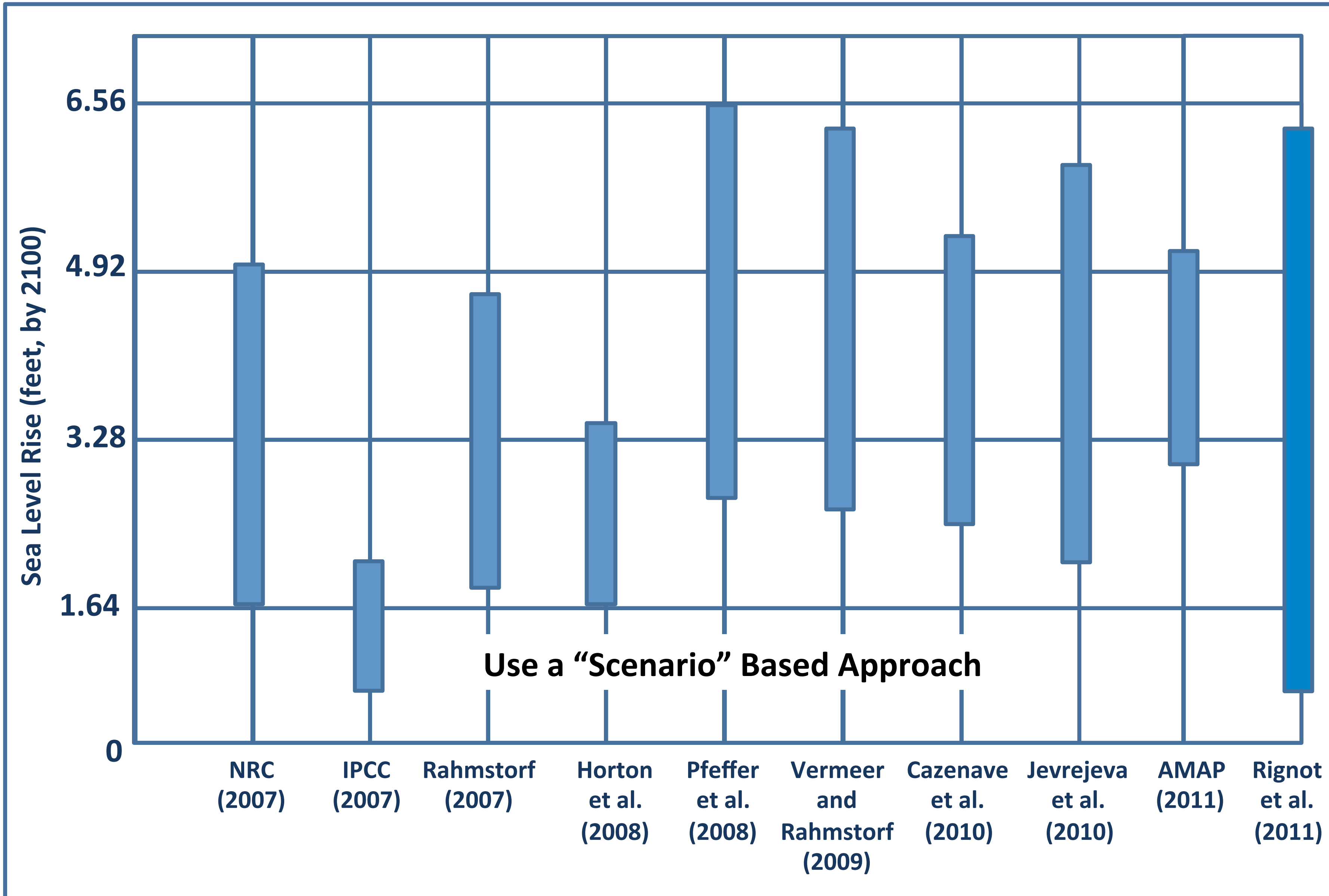


# The COAST Strategy

1) Don’t discuss climate change.
2) Focus on observed, local data.
3) Use 3D visualization.
4) Use a scenario-based approach.

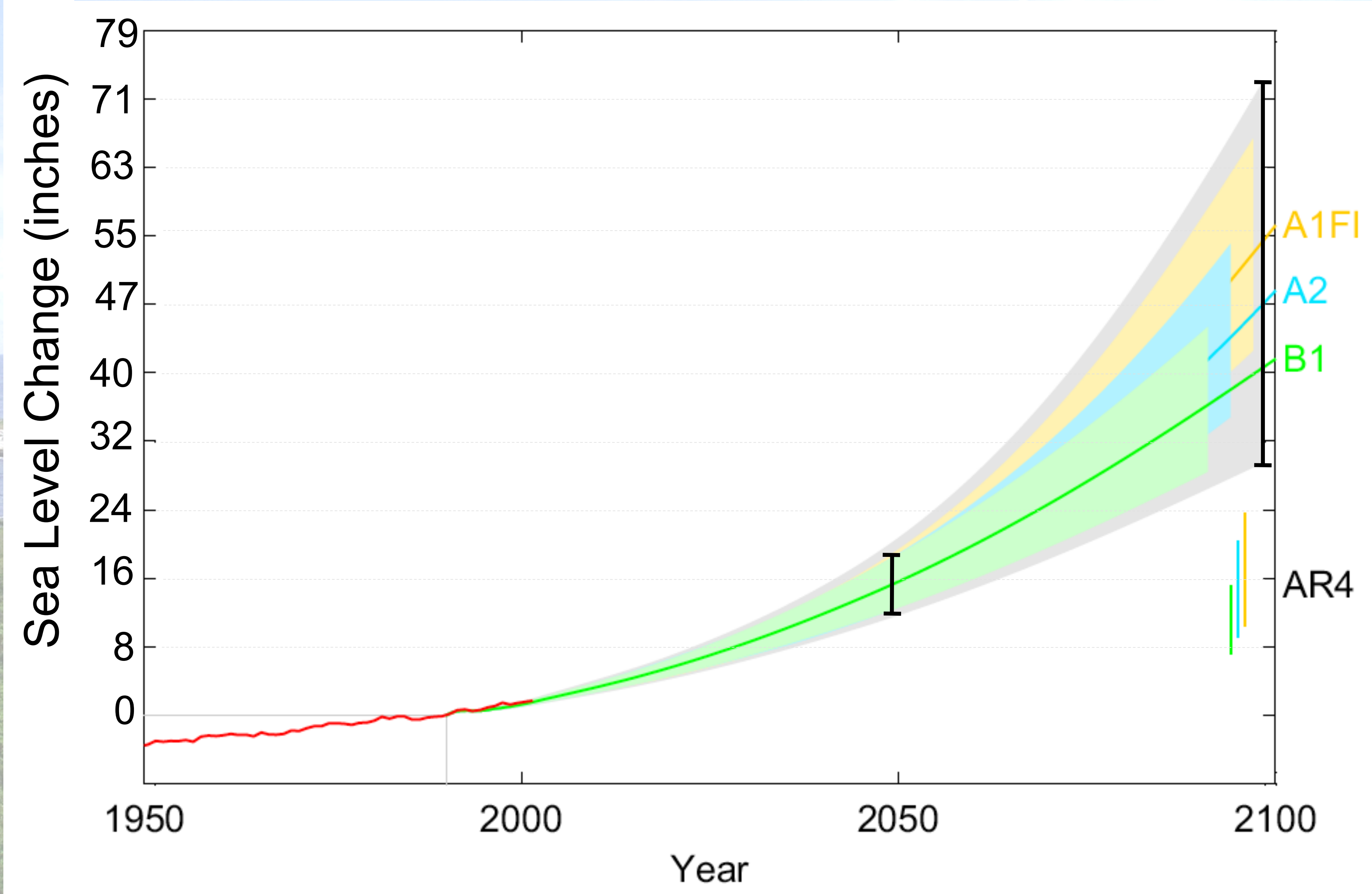


# SLR Scenario Ranges




Adapted from Rahmstorf (2010); and Williams (2012)

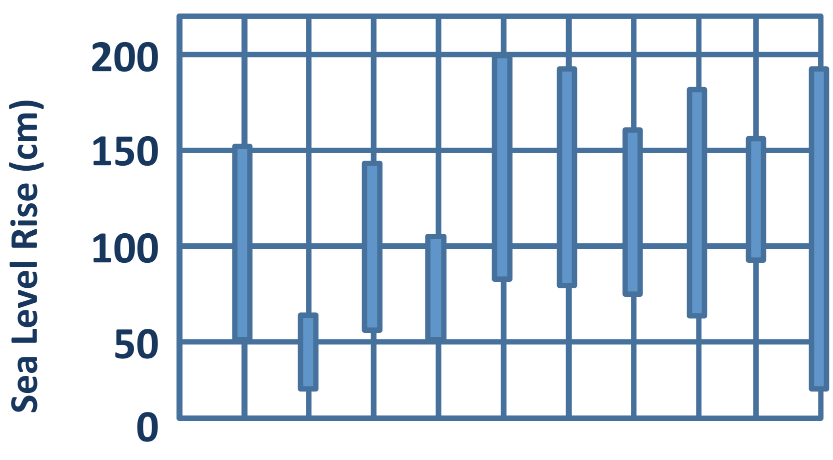
# Projection of Sea Level Rise from 1990 to 2100

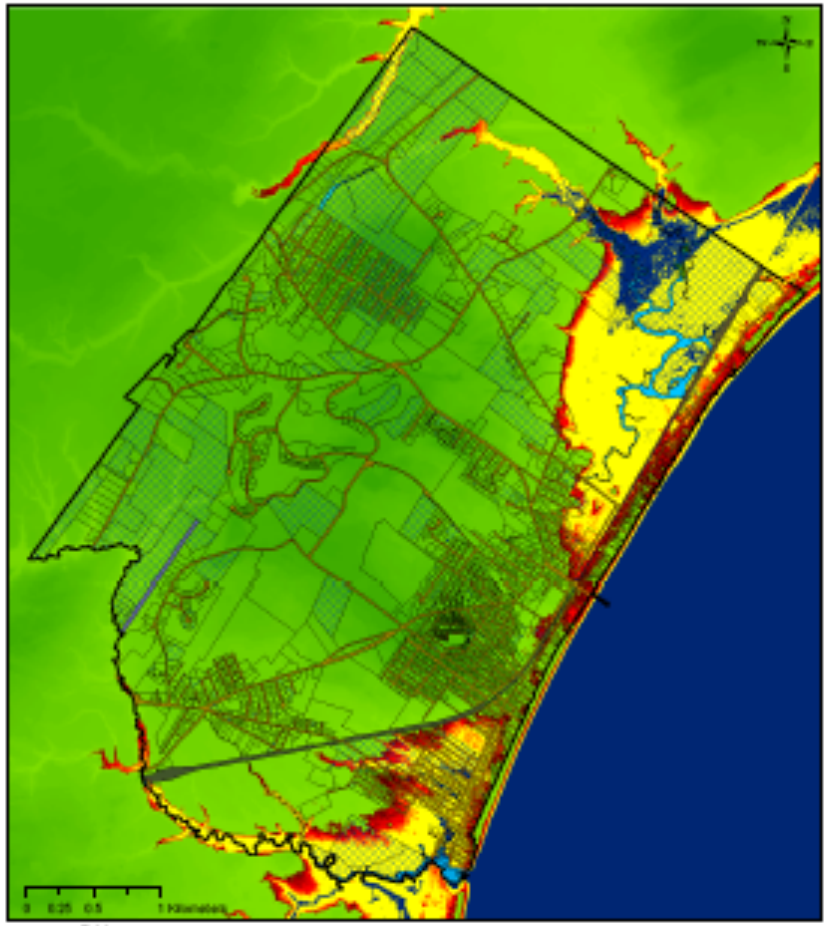


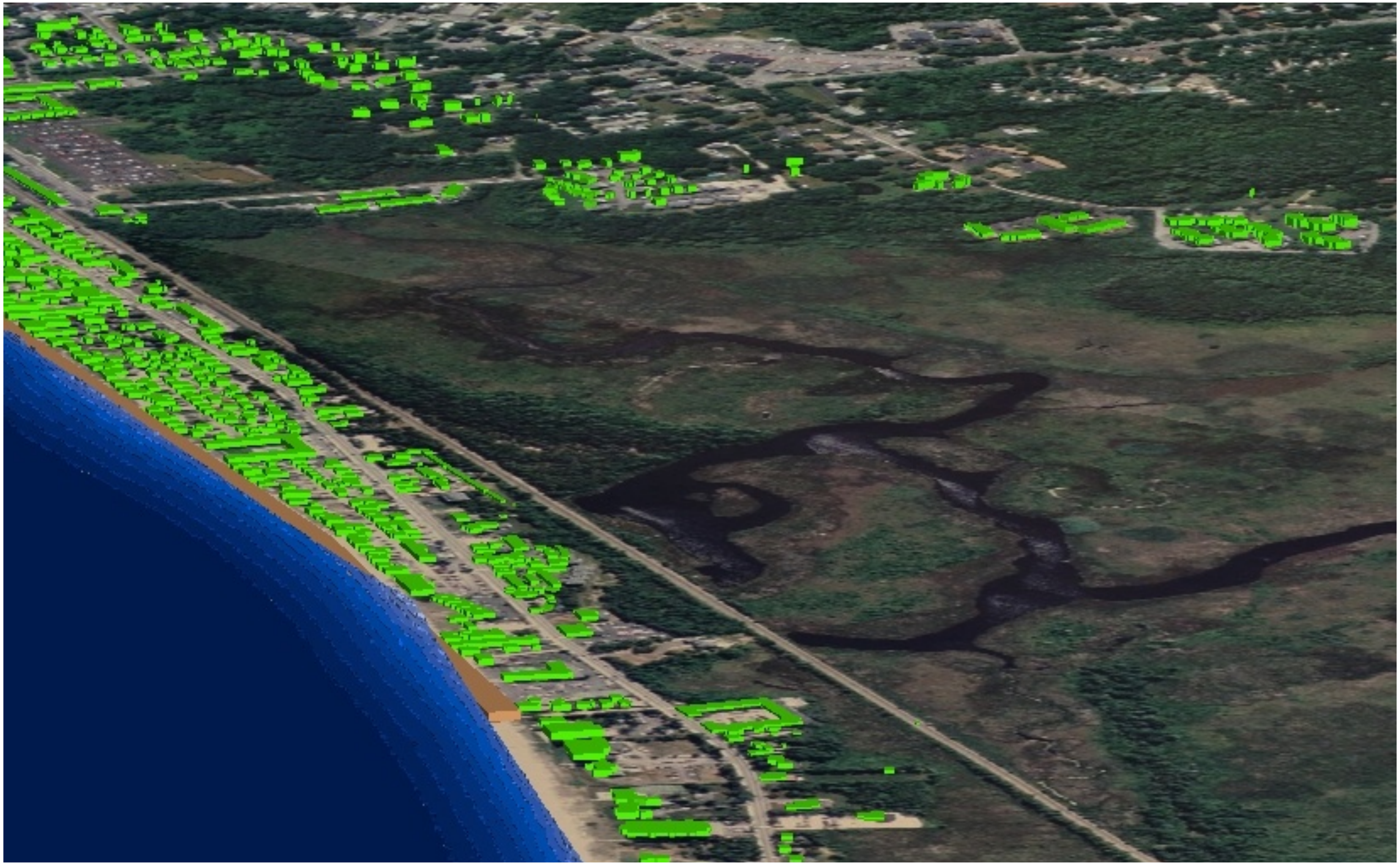

Vermeer and Rahmstorf (2009) Global sea level linked to global temperature. PNAS 106, 21527–21532.

# The COAST Strategy

1) Don't discuss climate change.
2) Focus on observed, local data.
3) Use 3D visualization.
4) Use a scenario-based approach.
5) Empower with a sense of possibility
   … then get out of the way.



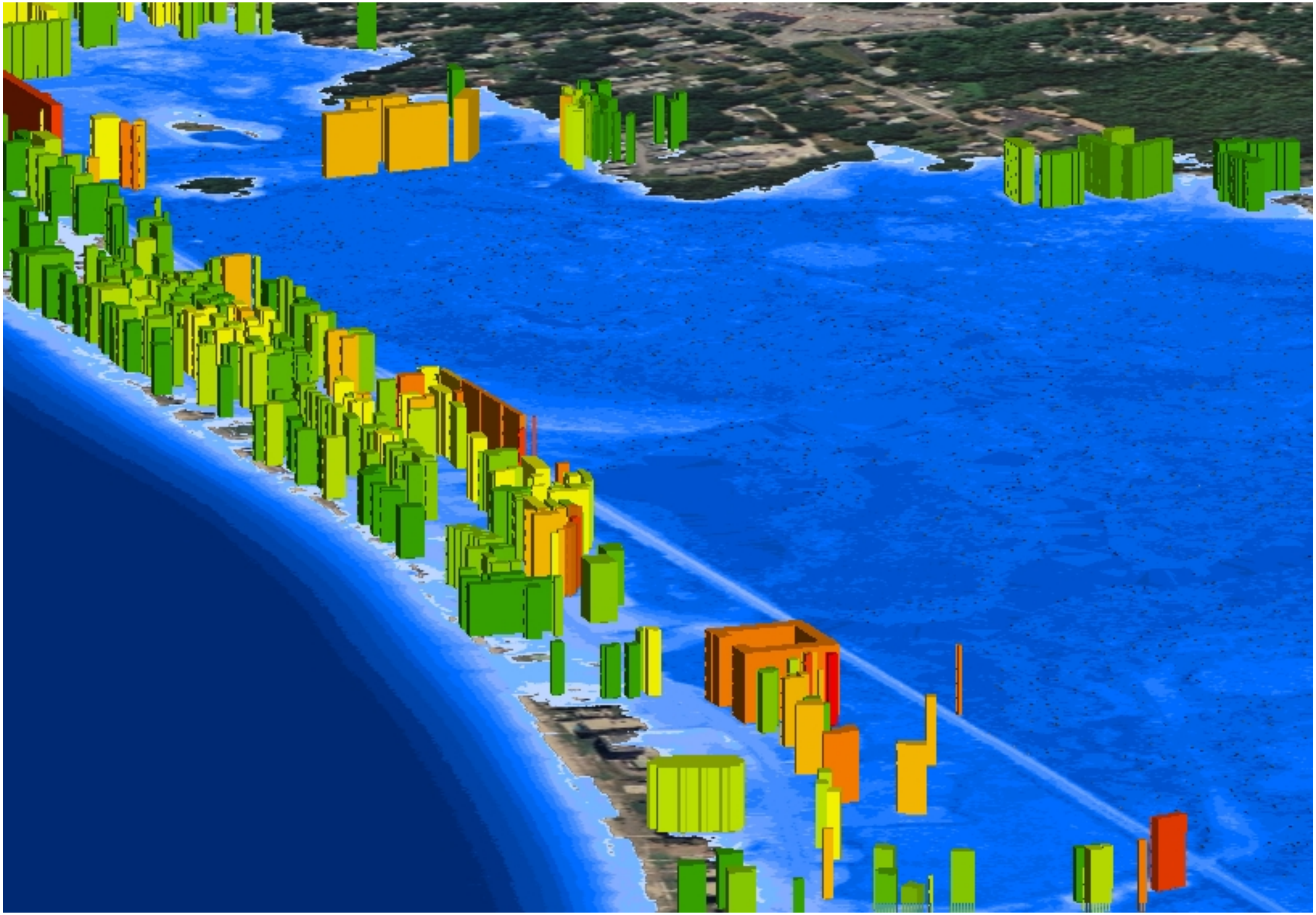


0
0.25
0.5
1 Kilometers



# Data for Decision-Making

Damage Functions for Single Family
Residential Structures with Basement

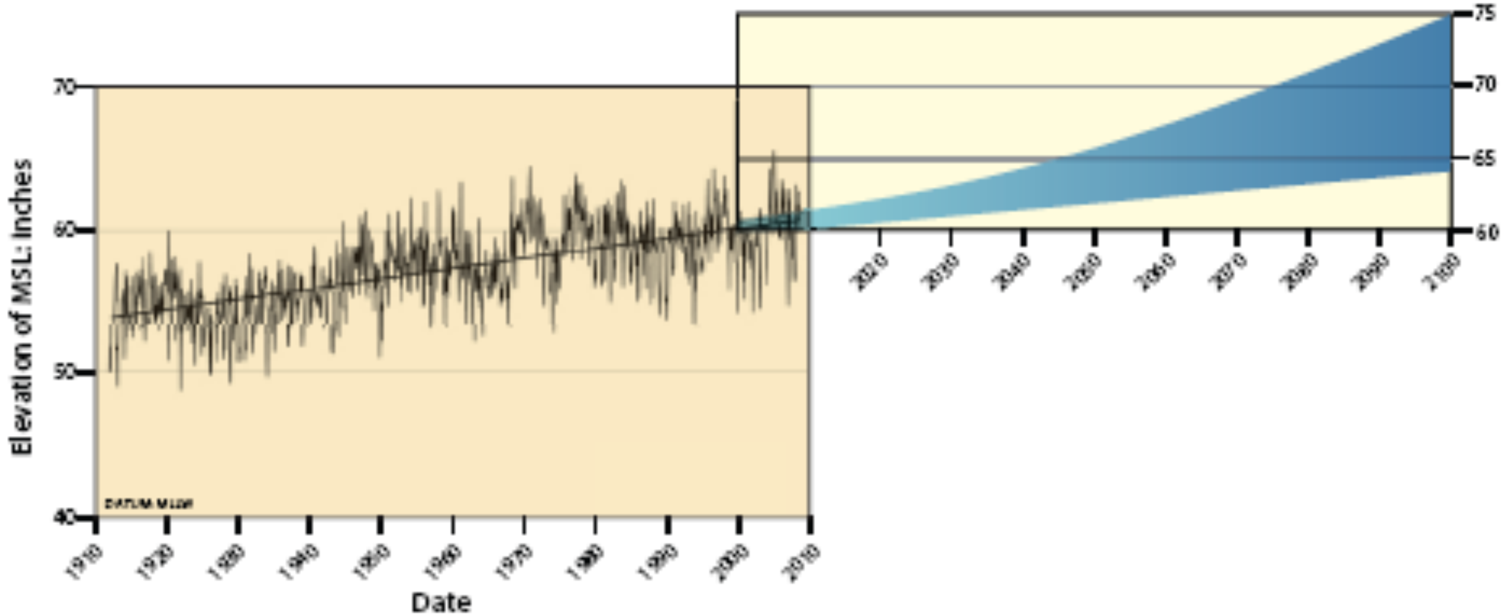
| Depth (feet) | Mean of Damage |
|---|---|
| | |
| 0 | 25.5% |
| 1 | 32.0% |
| 2 | 38.7% |
| 3 | 45.5% |
| 4 | 52.2% |
| 5 | 58.6% |
| 6 | 64.5% |
| | |

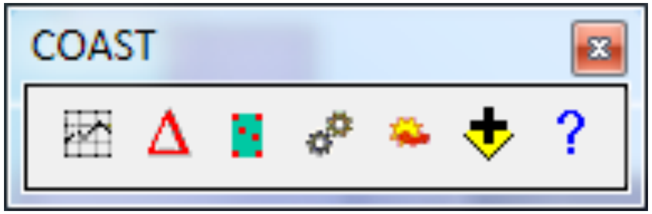


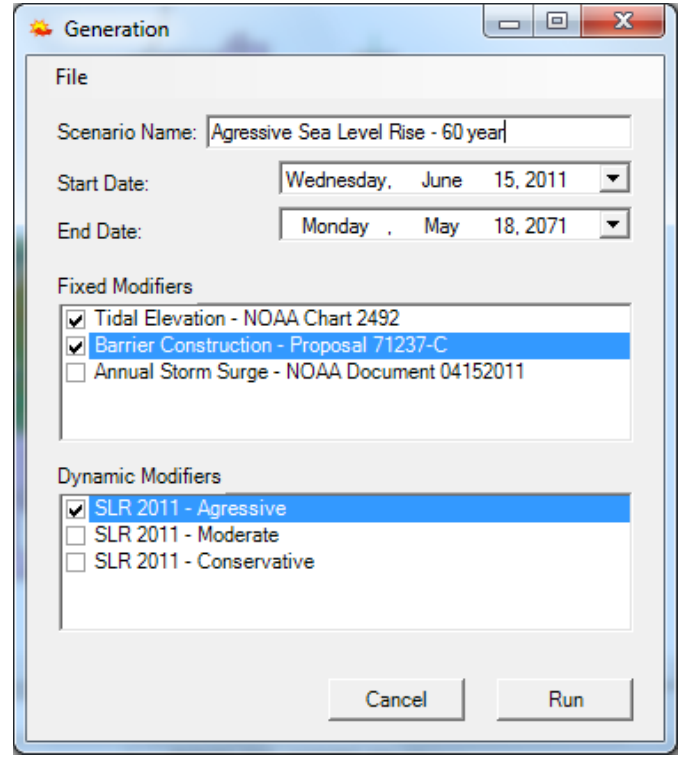
# Expected costs and damages, 2010 - 2050

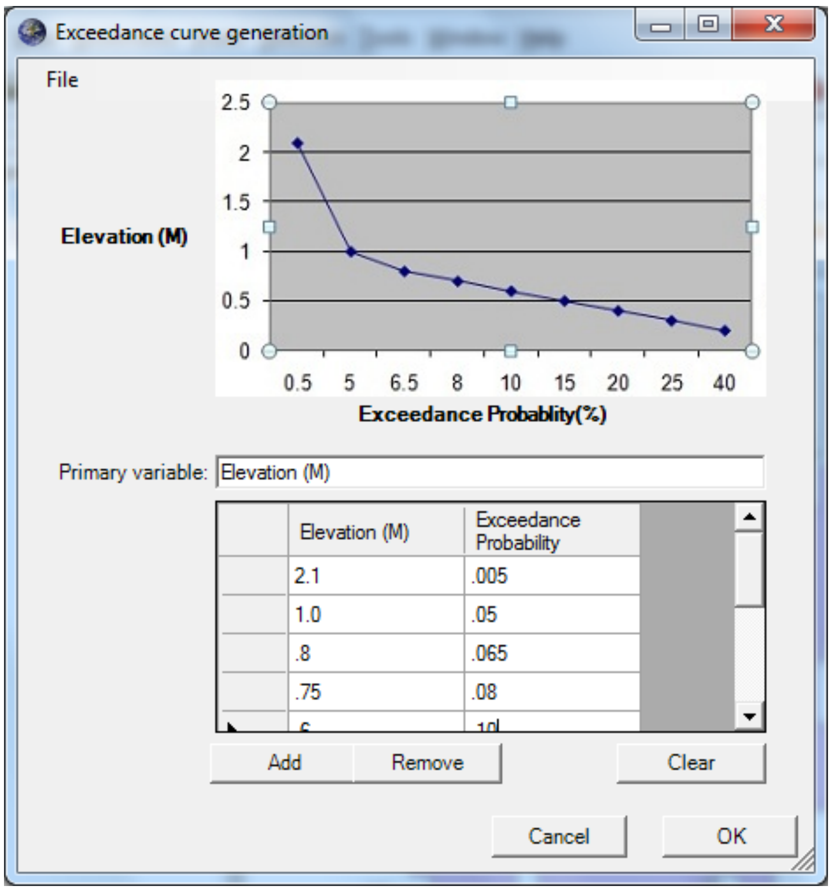
| SLR Scenario | Adaptation | Residual Damages ($ million) | Adaptation Cost ($ million) | Total Damages and Costs ($ million) |
|---|---|---|---|---|
| No SLR | No Action | 680 | 0 | 680 |
| | 50 yr flood | 3.4 | 52.4 | 55.8 |
| | 100 yr flood | 0 | 60 | 60 |
| Low | No Action | 899.3 | 0 | 899.3 |
| | 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 |

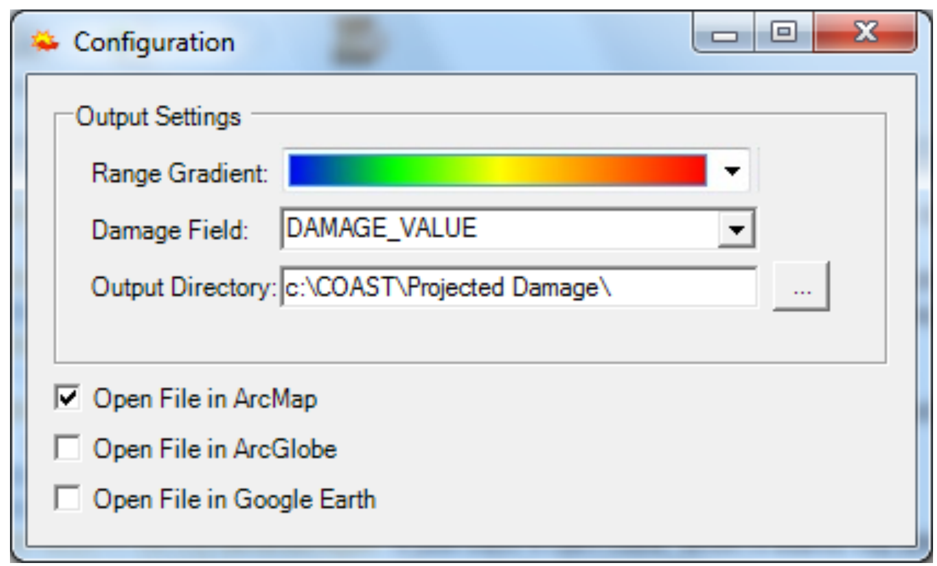
## Maine Sea Level, 1912-2100




COAST


Generation
File
Scenario Name: Agressive Sea Level Rise - 60 year
Start Date: Wednesday, June 15, 2011
End Date: Monday , May 18, 2071
Fixed Modifiers
Tidal Elevation - NOAA Chart 2492
Barrier Construction - Proposal 71237-C
Annual Storm Surge - NOAA Document 04152011
Dynamic Modifiers
SLR 2011 - Agressive
SLR 2011 - Moderate
SLR 2011 - Conservative
Cancel
Run


Exceedance curve generation
File
Elevation (M)
2.5
2
1.5
1
0.5
0
0.5
5
6.5
8
10
15
20
25
40
Exceedance Probablity(%)
Primary variable: Elevation (M)
Elevation (M)
Exceedance Probability
2.1 .005
1.0 .05
.8 .065
.75 .08
Add
Remove
Clear
Cancel
OK


Configuration
Output Settings
Range Gradient:
Damage Field: DAMAGE_VALUE
Output Directory: c:\COAST\Projected Damage\
...
Open File in ArcMap
Open File in ArcGlobe
Open File in Google Earth

Climatic Change
DOI 10.1007/s10584-011-0379-z

# Simplified method for scenario-based risk assessment adaptation planning in the coastal zone

**Paul Kirshen · Samuel Merrill · Peter Slovinsky · Norman Richardson**

Received: 16 November 2009 / Accepted: 14 November 2011

# COAST Programming Status

- Currently runs as an extension in ArcMap v.9 and 10
- Currently requires Spatial Analyst

- Converting to a subset of Global Mapper, no Arc required
- Will remain a free download, on the NE/EFC website
- Expected online release date for v1.0: Q2 2013

BLUE MARBLE GEOGRAPHICS
MIND THE GAP BETWEEN WORLD AND MAP

## The COAST Process

1. Specify location and vulnerable asset
2. Select time horizons, SLR and SS thresholds
3. Select adaptation action, estimate costs
4. Input Depth Damage Function
5. Input reference data (parcel, elevation, etc)
6. Run the model
7. Use maps and tables in public process

# The COAST Process

## Has been or **is being used** in

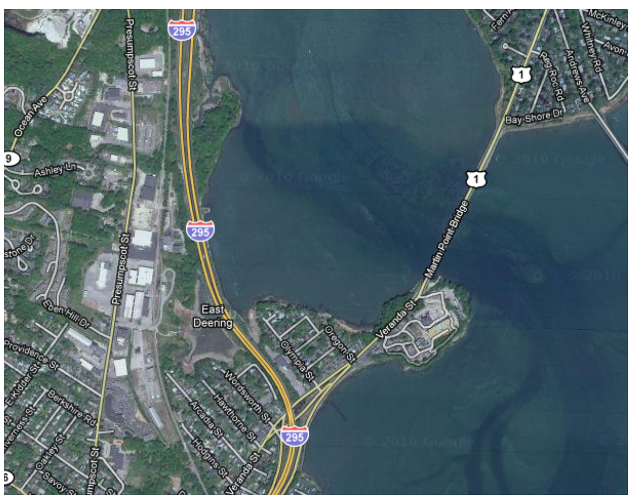
1. Old Orchard Beach, ME
2. Portland, ME
3. Falmouth, ME
4. East Machias, ME
5. Seabrook, NH
6. Hampton, NH
7. Hampton Falls, NH
8. **Tybee Island, GA**
9. **Cambridge, MA**
10. **Kingston, NY**
11. **Oxdford, MD**

# Possible Assets to Model

- Real estate values
- Economic output
- Public health impacts
- Displaced persons, vulnerable demographics
- Natural resources values
- Cultural resources values
- Community impacts
- Infrastructure (transportation, energy, facilities, telecommunications)


Machias Bridge, Machias

(pressure transducer placed in 8/11)

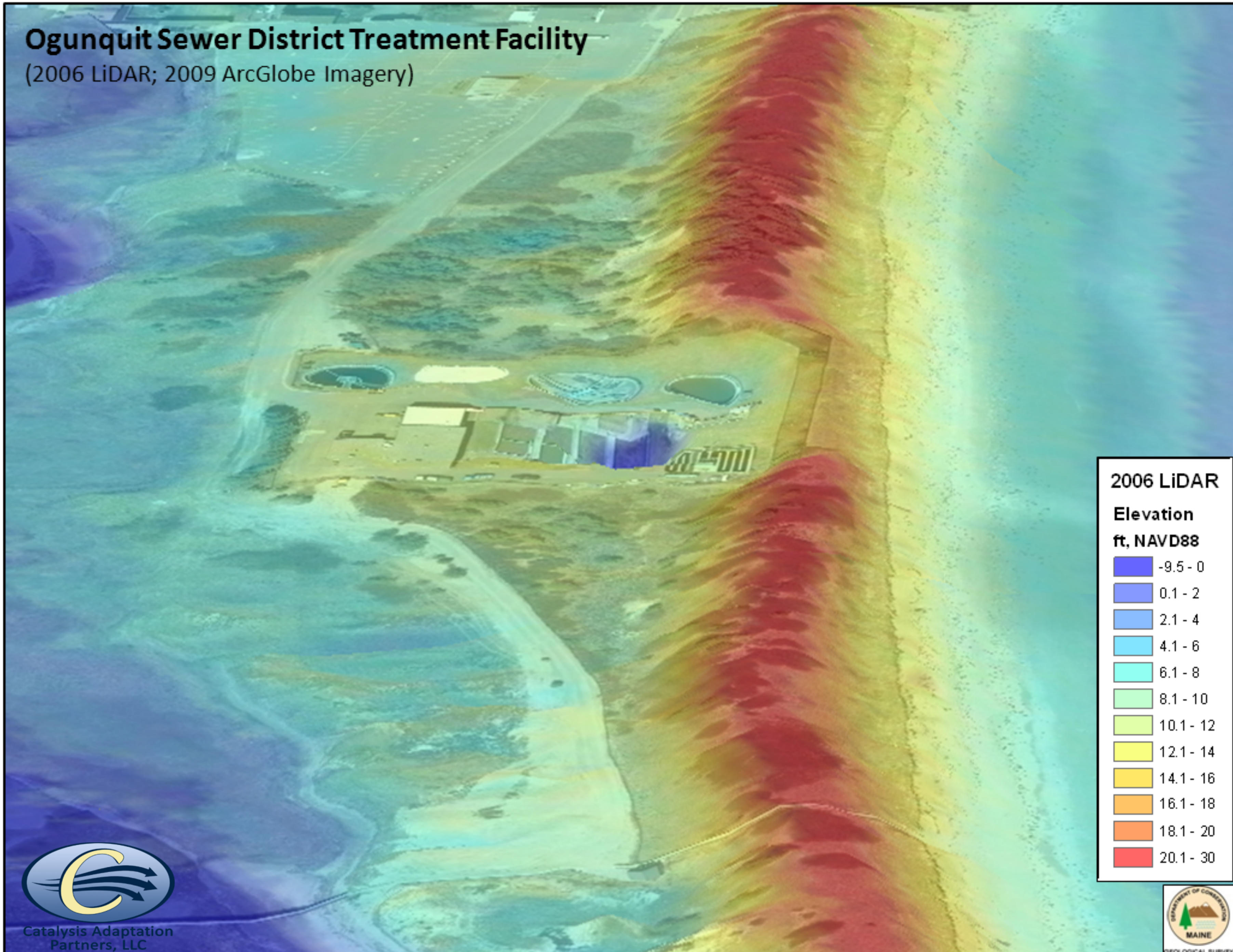


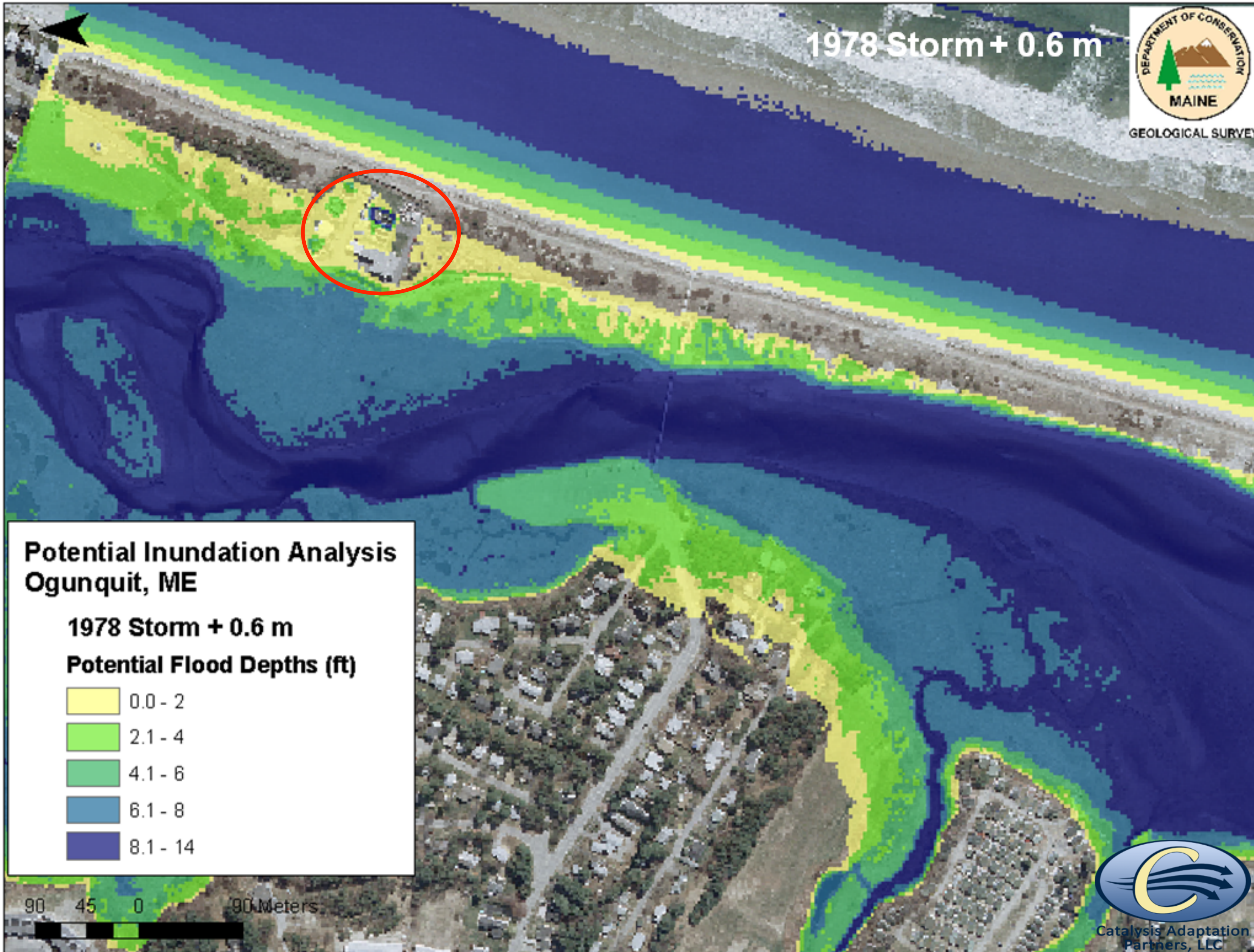

Martin’s Point Bridge, Falmouth

Catalysis Adaptation Partners, LLC
SOUTHERN MAINE REGIONAL PLANNING COMMISSION
Ogunquit Sewage Treatment Plant
2006 Aerial Photography
1 inch = 50 feet
0
500
Feet
N
E
S
W
Treatment Plant
Ogunquit
Wells

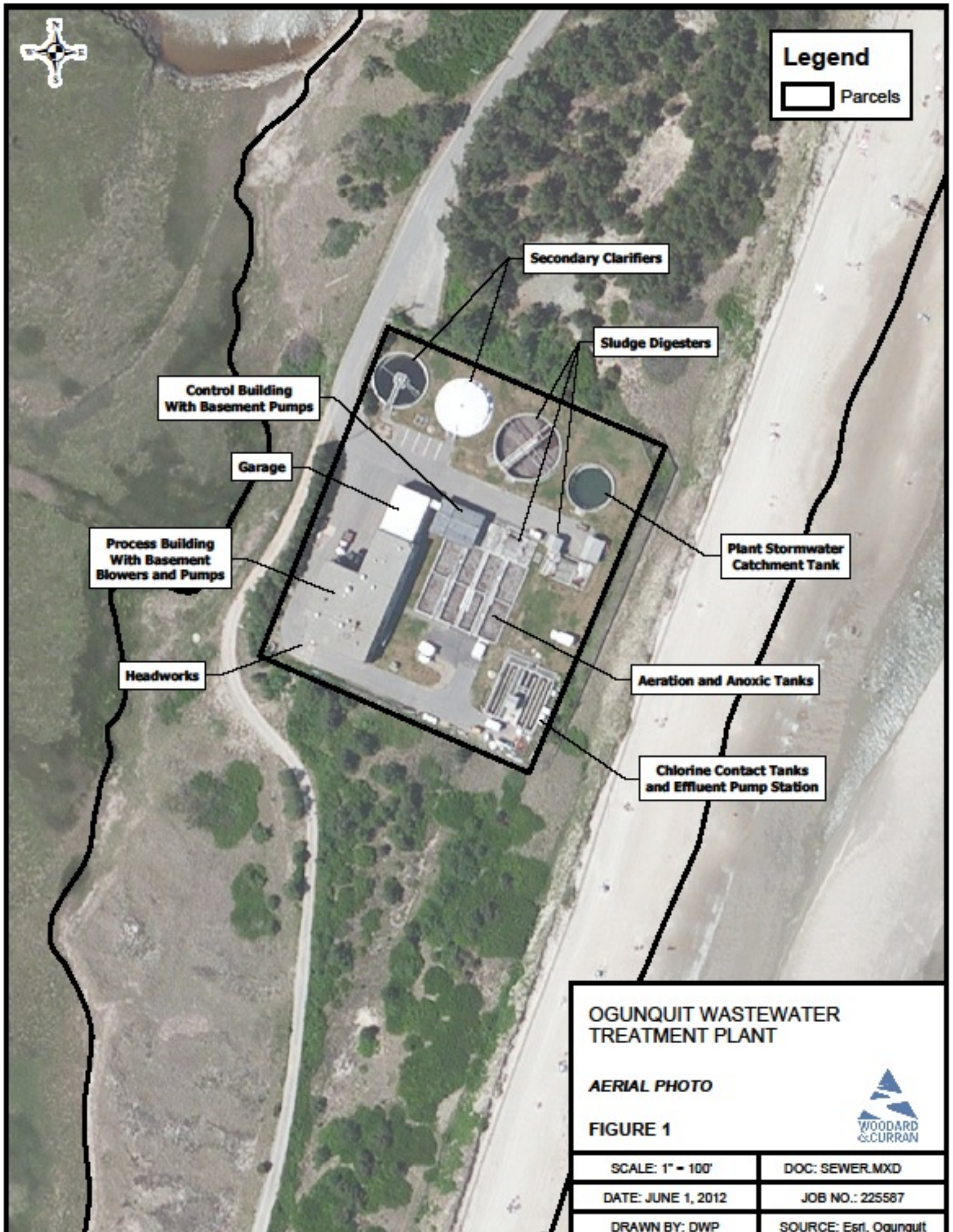

**View Across the Marsh From Roof of Ogunquit Sewage Treatment Plant April 2007 Patriot's Day Storm**

Catalysis Adaptation Partners, LLC

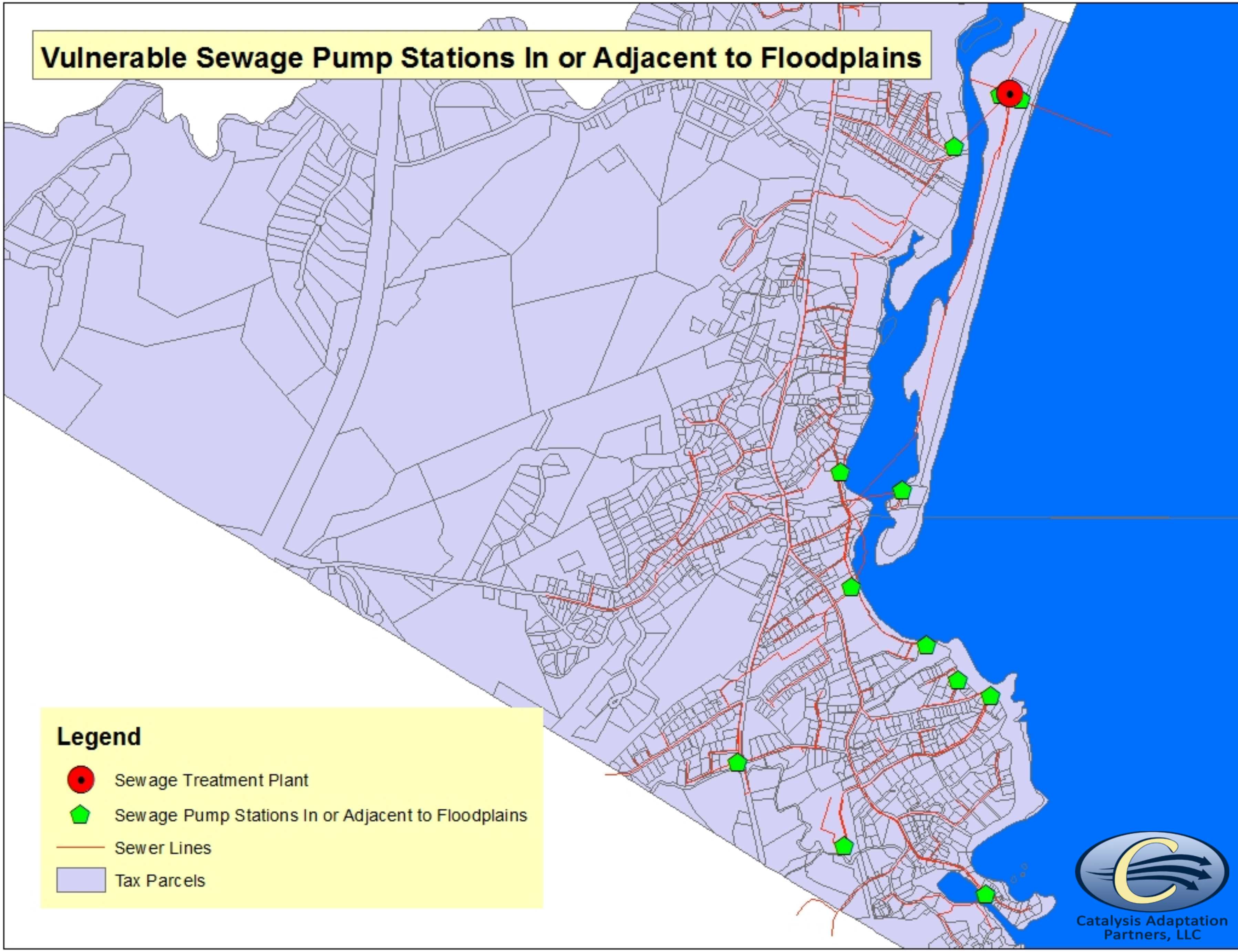

Ogunquit Sewer District Treatment Facility
(2006 LiDAR; 2009 ArcGlobe Imagery)
2006 LiDAR
Elevation
ft, NAVD88
-9.5 - 0
0.1 - 2
2.1 - 4
4.1 - 6
6.1 - 8
8.1 - 10
10.1 - 12
12.1 - 14
14.1 - 16
16.1 - 18
18.1 - 20
20.1 - 30
Catalysis Adaptation Partners, LLC




*For general planning purposes only.*




Catalysis Adaptation Partners, LLC


Vulnerable Sewage Pump Stations In or Adjacent to Floodplains
Legend
Sewage Treatment Plant
Sewage Pump Stations In or Adjacent to Floodplains
Sewer Lines
Tax Parcels
Catalysis Adaptation Partners, LLC

# Controversial Adaptation Solution?

# Adaptation Actions: Hard or Soft

- Revetments

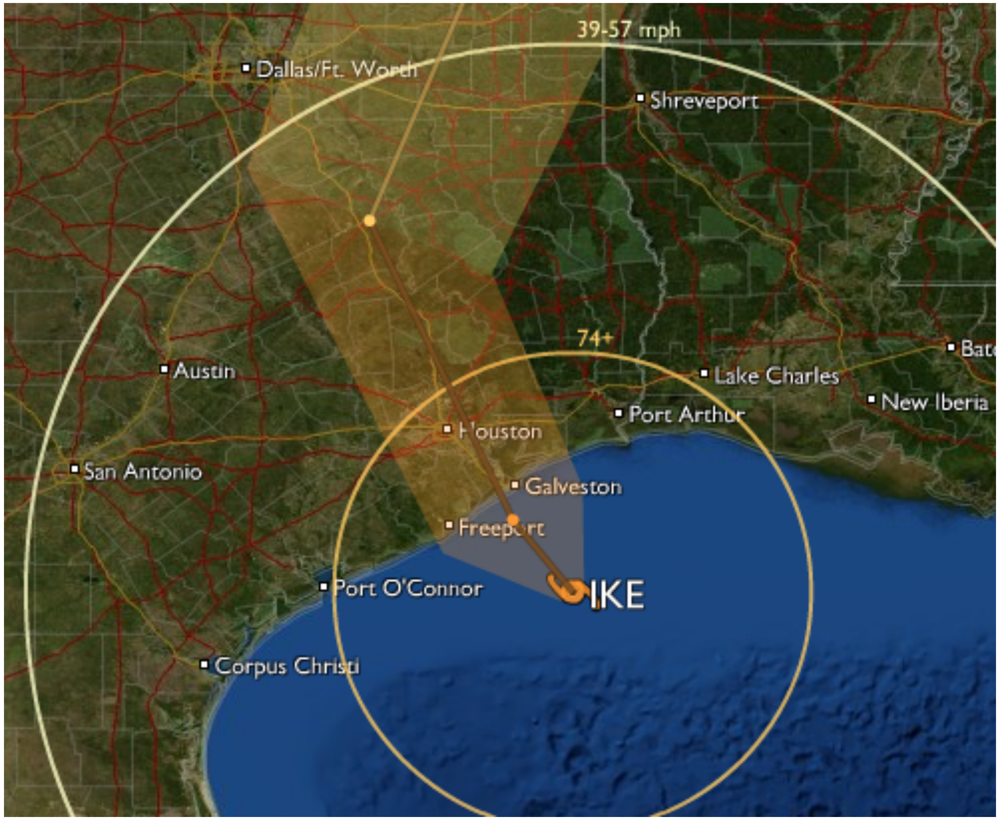
**Pea Patch Island, DE (Delaware River)**

# Adaptation Actions: Hard or Soft

- Revetments
- Geotextile tubes

# Adaptation Actions: Hard or Soft

- 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 Actions: Hard or Soft

- Revetments
- Geotextile tubes
- Sea walls
- Jetties
- Other creative approaches

Floodwalls with removable aluminum or steel gates. Cologne, Germany (Rhine).

Buildings have a "hardened" 1st story along a wide pedestrian walkway.

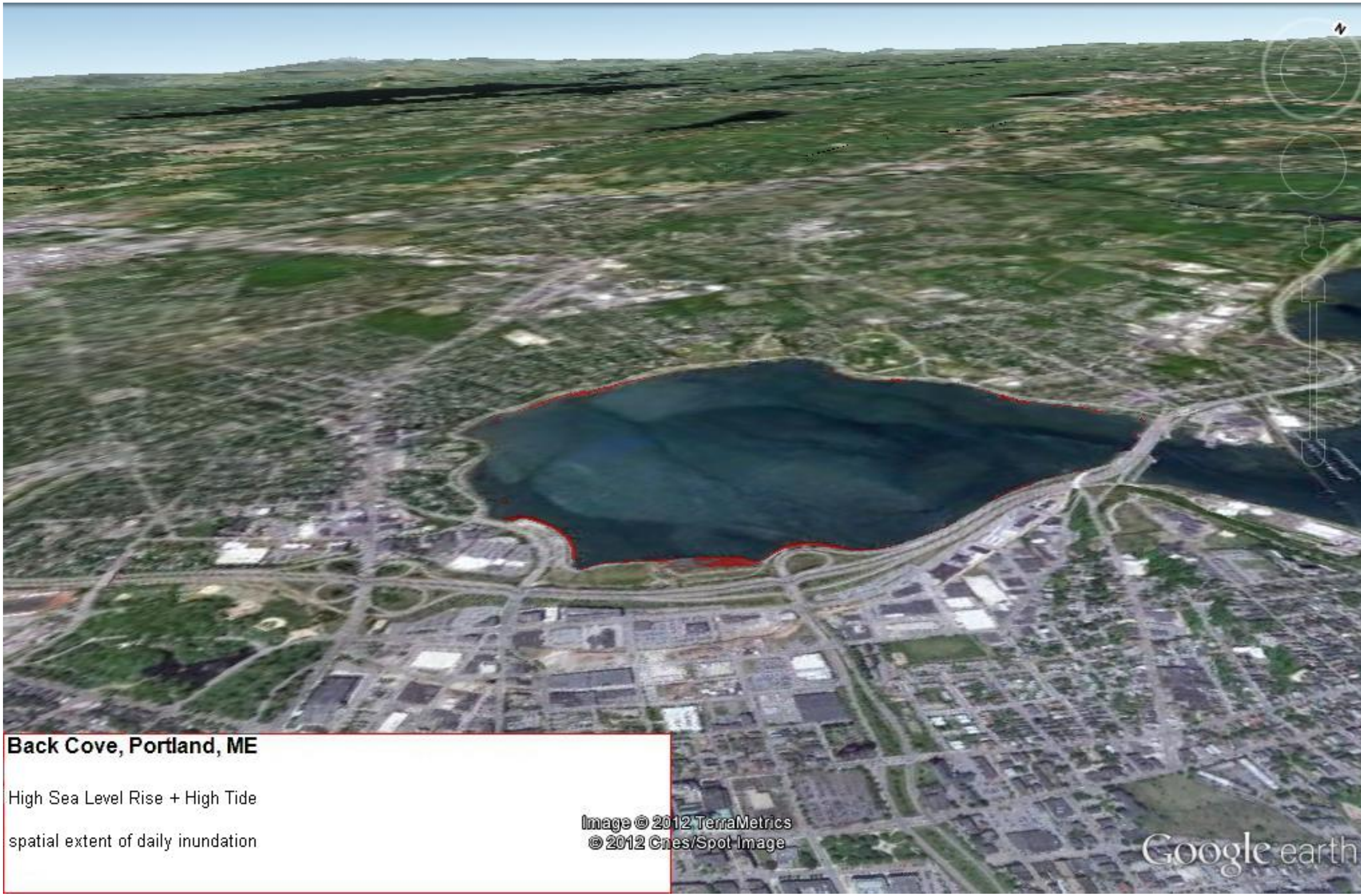
# Urban design strategy: Hamburg, city on the water

# Adaptation Actions: Hard or Soft

- Revetments
- Geotextile tubes
- Sea walls
- Jetties
- Other creative approaches

- Wet or dry floodproofing
- Incentives, zoning, and other regulatory changes

# Back Cove, Portland Maine

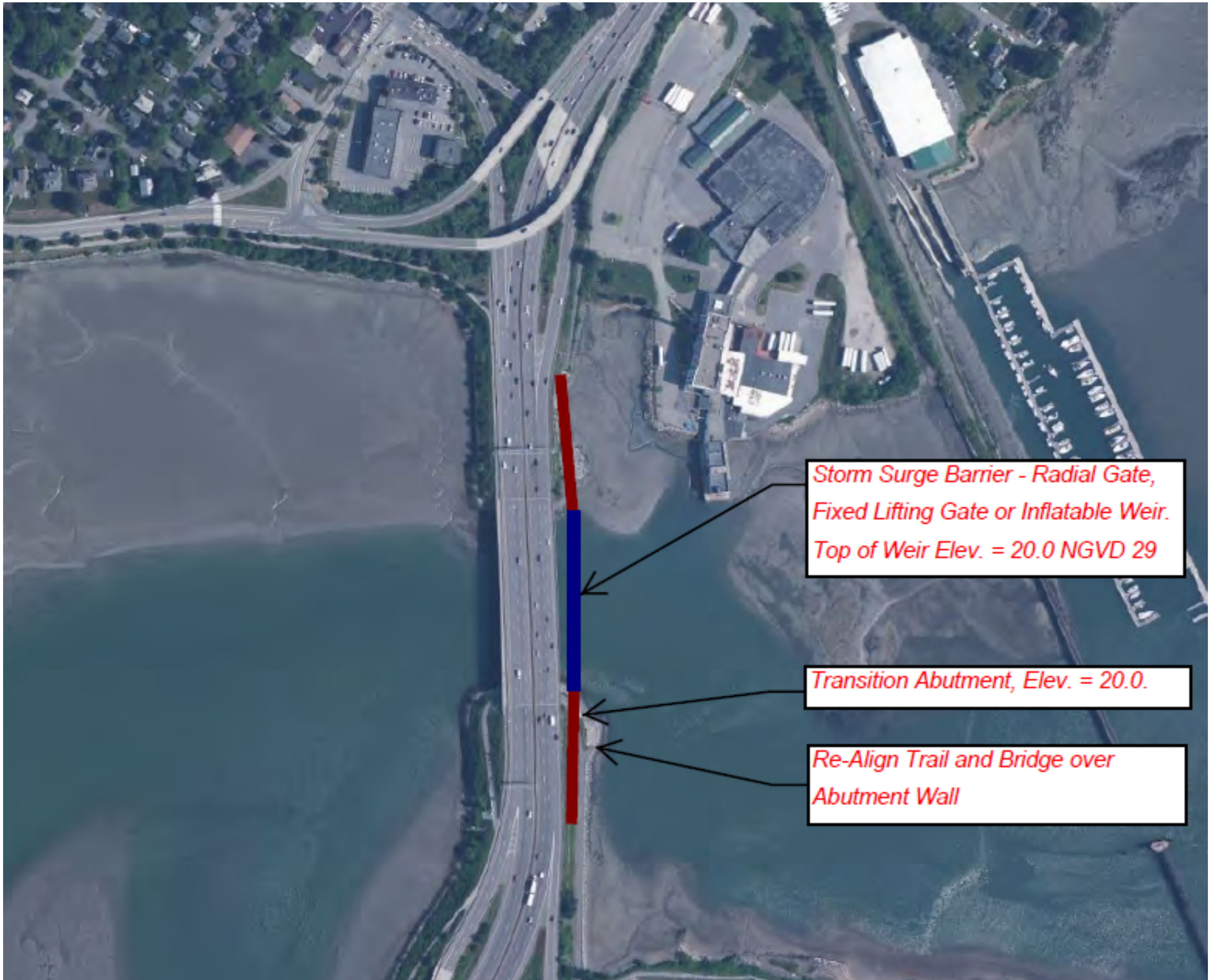


# 2100, high sea level rise and mean higher high water

**Now the Portland Case:**

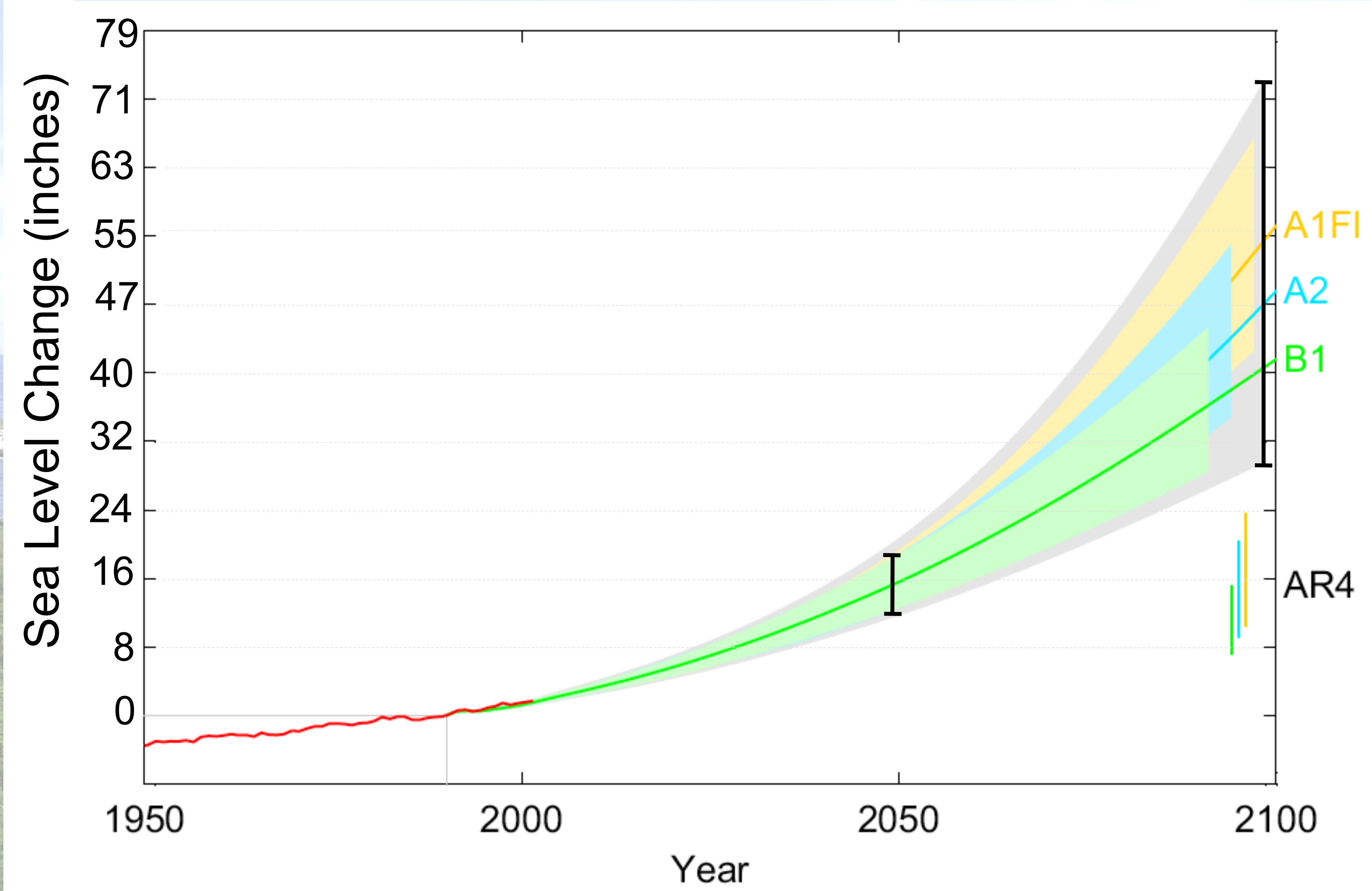
**The four options:**

1) Do nothing
2) Fortify assets
3) Relocate assets
4) Accommodate higher water levels


Storm Surge Barrier - Radial Gate,
Fixed Lifting Gate or Inflatable Weir.
Top of Weir Elev. = 20.0 NGVD 29
Transition Abutment, Elev. = 20.0.
Re-Align Trail and Bridge over
Abutment Wall

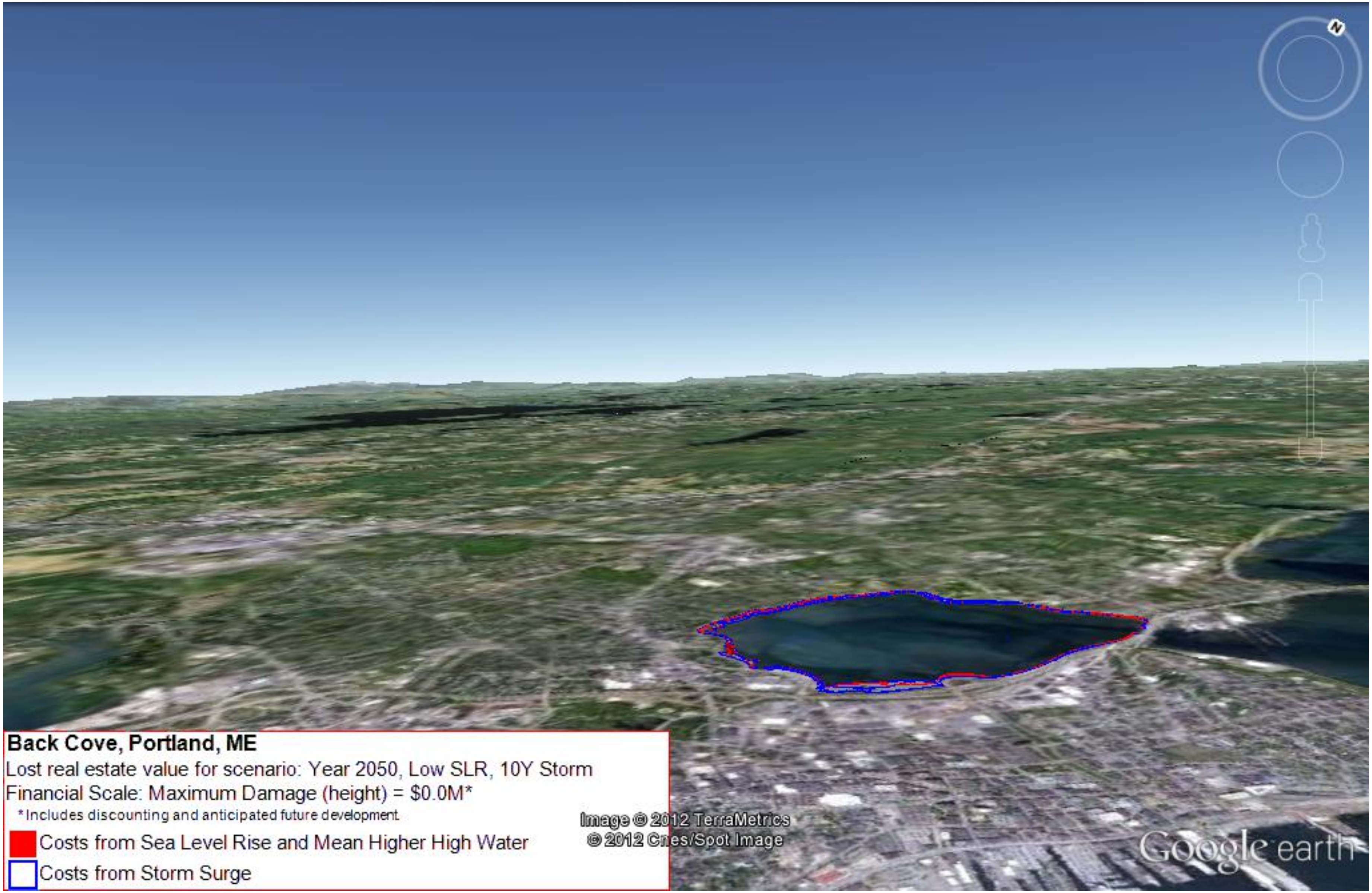

Levee Construction to Include Relocation of Back Bay Trail. Landside Stormwater Management System Also Required.
Storm Surge Barrier - Constructed at 2050 Condition
YEAR 2100 CONDITION
Levee Design Criteria - Mean High Higher Water (MHHW) + Sea Level Rise
Predicted Elevation = 7.85 to 11.30 feet NGVD 29
Levee Construction Expected Year 2100 Condition - Top of Berm Elevation = 14.0 (11.30 feet plus Wave Protection and Freeboard). Storm Surge Addressed at Tukey's Bridge Barrier

# Projection of Sea Level Rise from 1990 to 2100

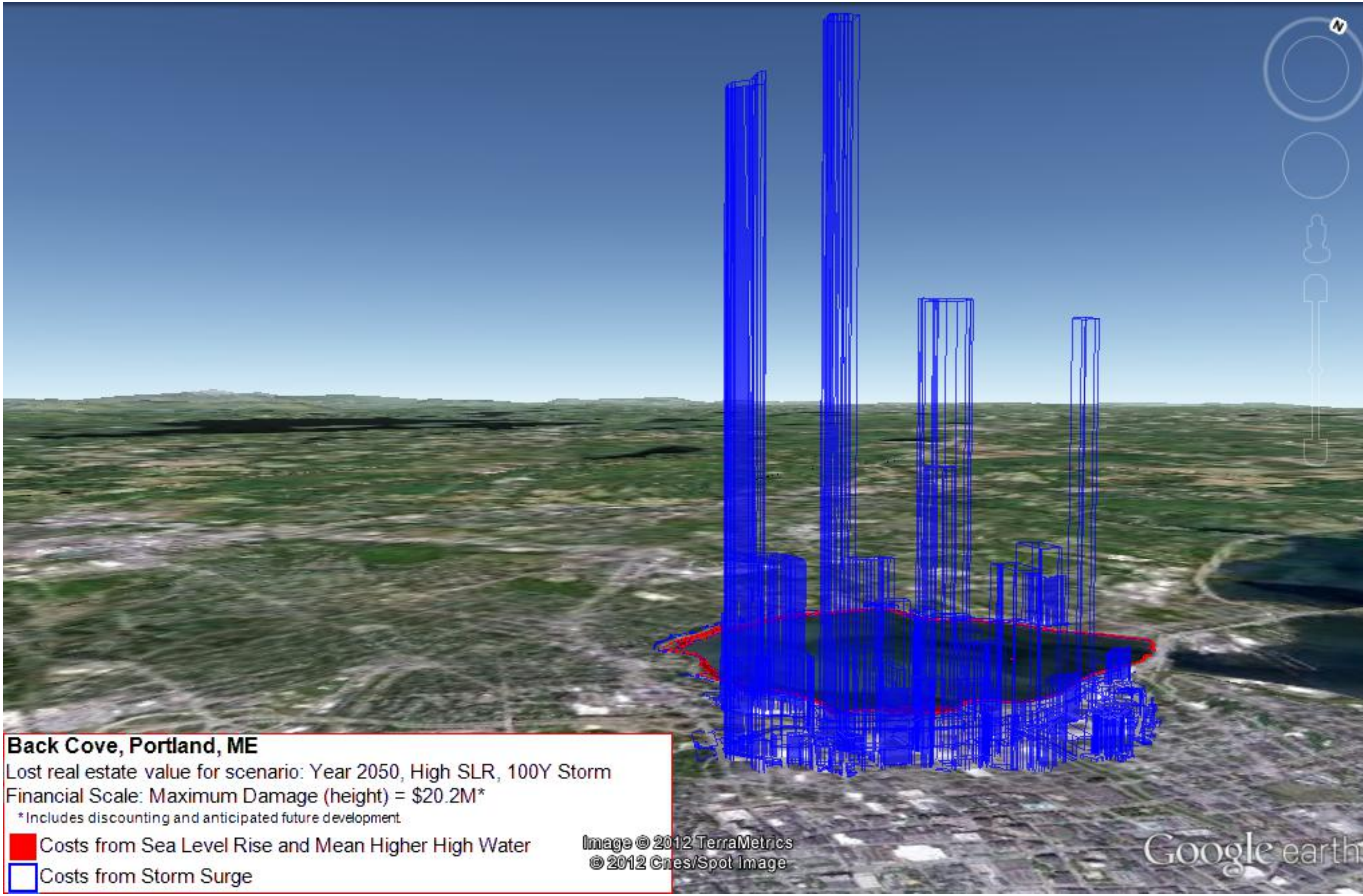



Vermeer and Rahmstorf (2009) Global sea level linked to global temperature. PNAS 106, 21527–21532.

# 2050, low sea level rise, 10 year storm



# 2050, high sea level rise, 100 year storm

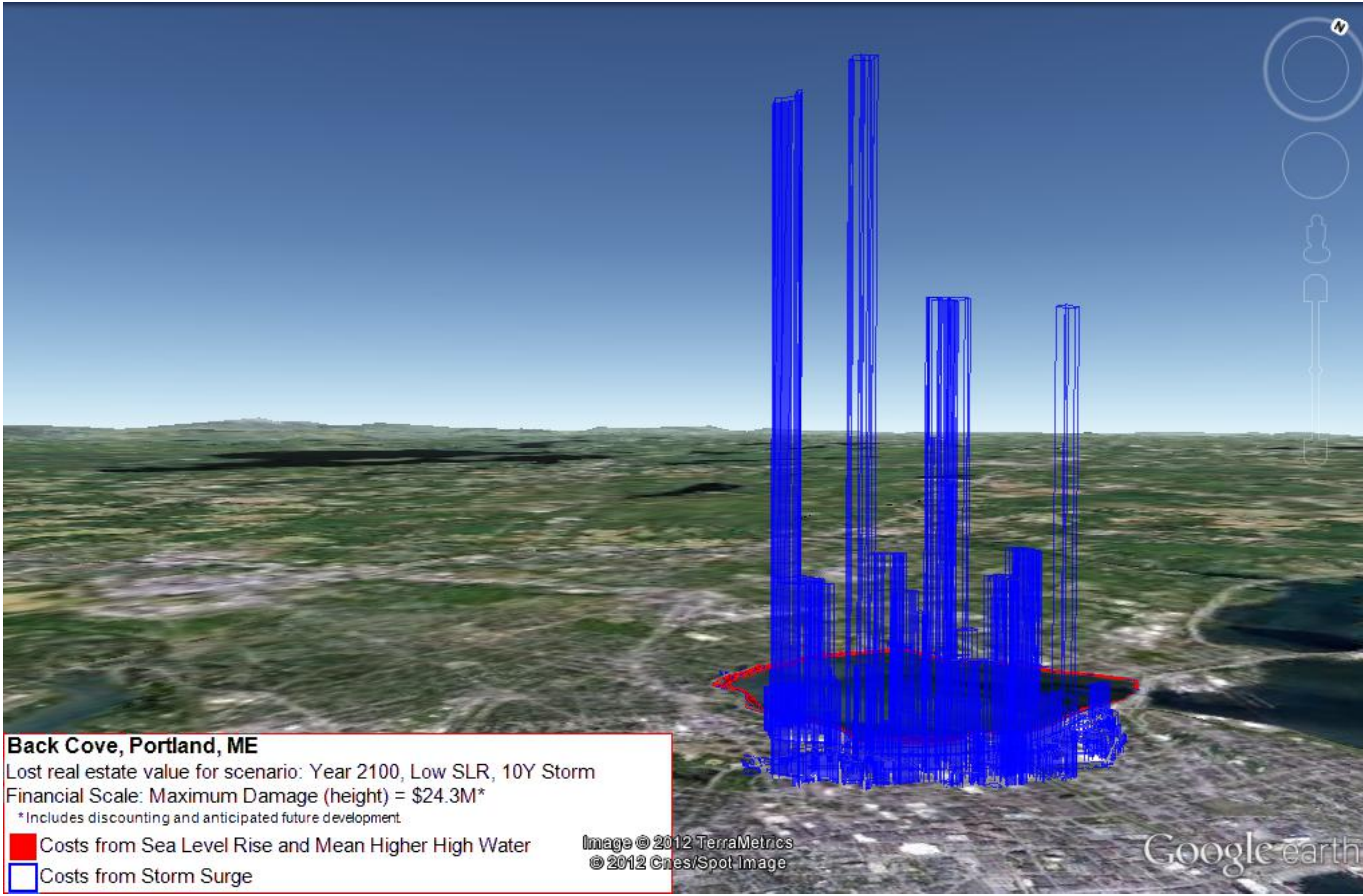


## Back Cove, Portland, Maine

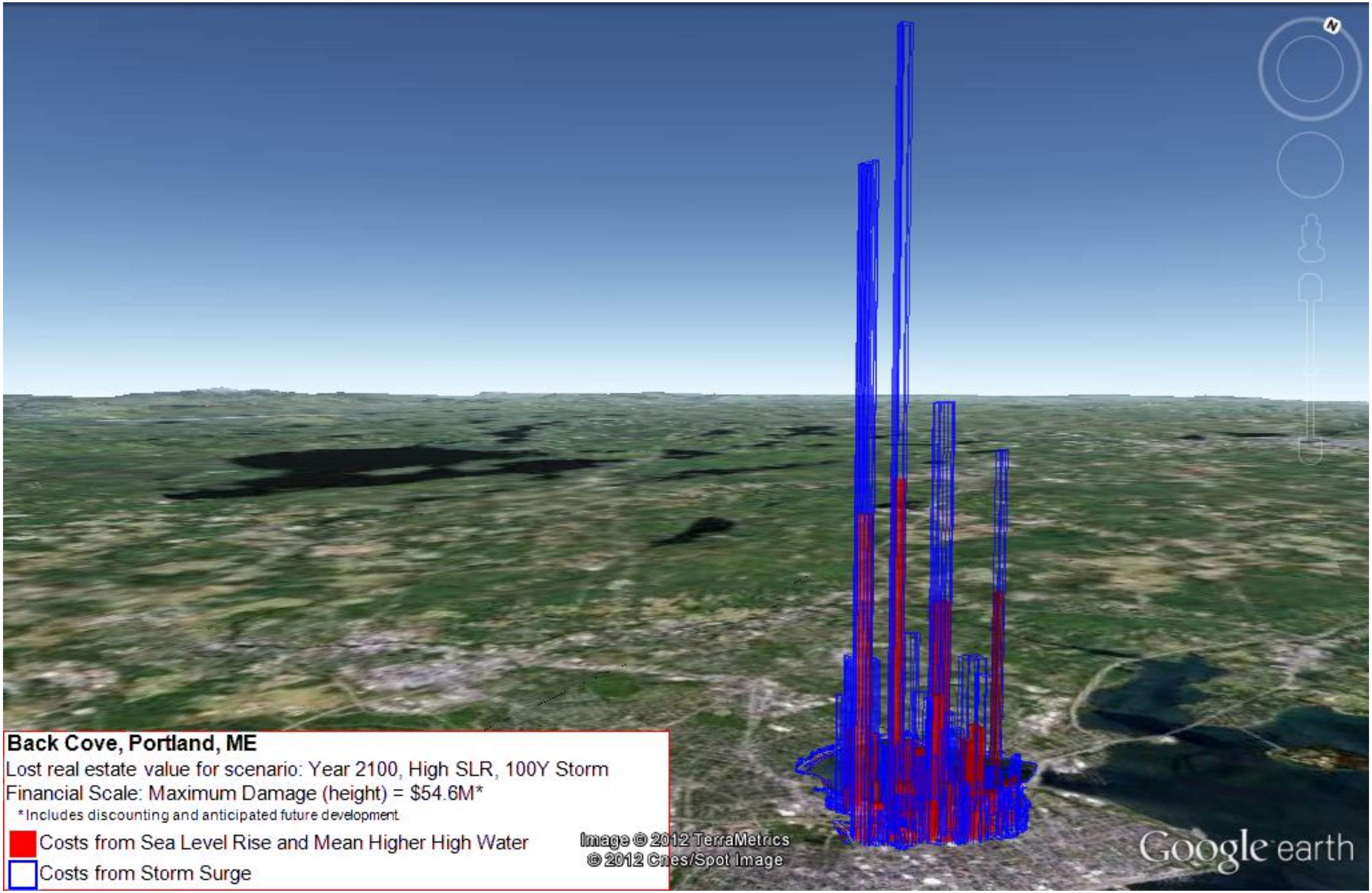
## Adaptation Costs and Cumulative Expected Damages, through 2050.

| 2050 SLR Scenario | Adaptation | Cost (M) | Real Estate Damage (M) | Percent of damage from Storm surge | Percent of damage from SLR |
|---|---|---|---|---|---|
| No SLR | No Action | $0 | $356 | 100% | 0% |
| | Surge Barrier / Levee | $103 / $0 | $0 | | |
| Low SLR (7.9") | No Action | $0 | $407 | 100% | 0% |
| | Surge Barrier / Levee | $103 / $0 | $0 | | |
| High SLR (19.7") | No Action | $0 | $447 | 100% | 0% |
| | Surge Barrier / Levee | $103 / $0 | $0 | | |

# 2100, low sea level rise, 10 year storm



# 2100, high sea level rise, 100 year storm



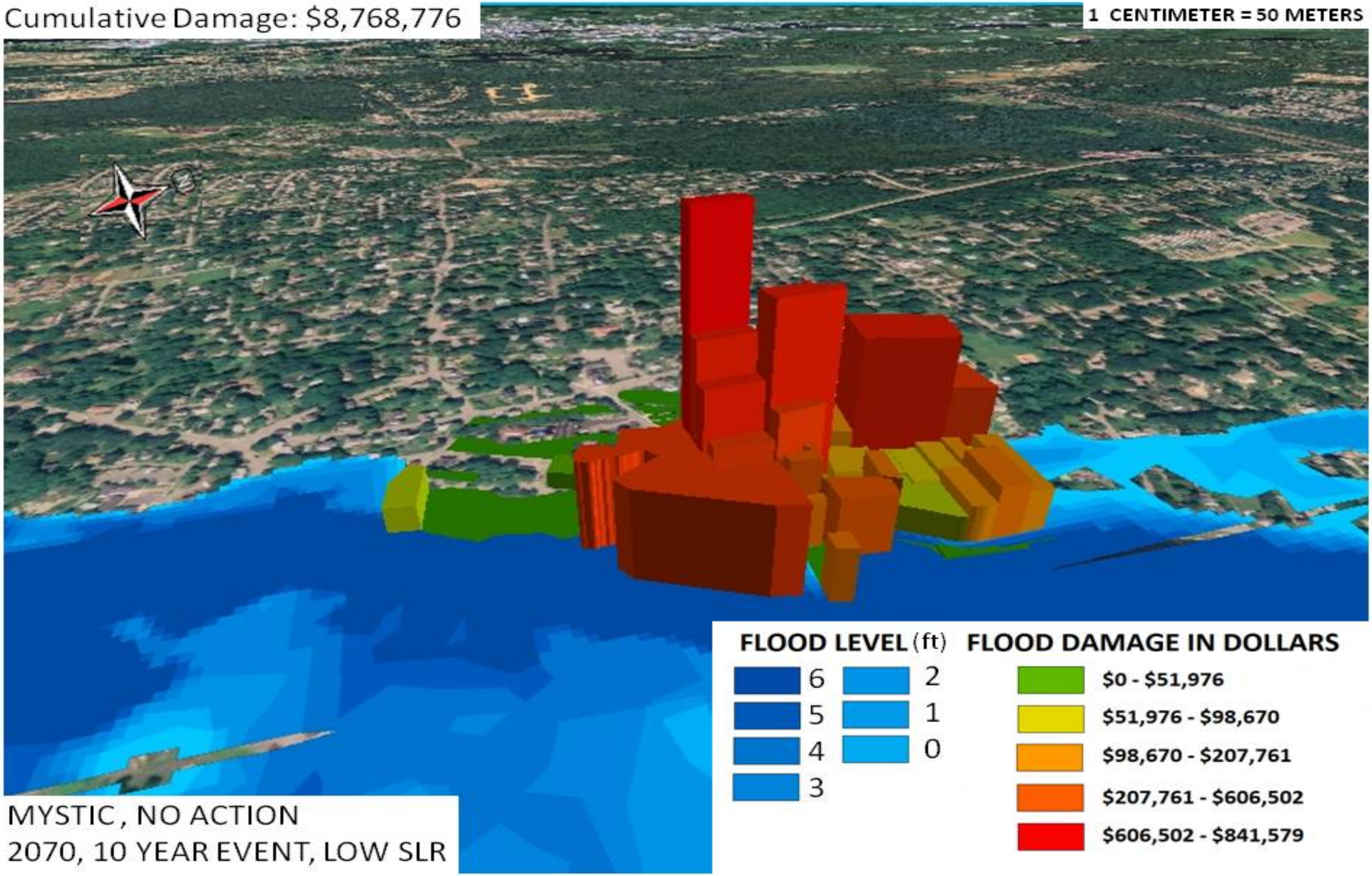
## Back Cove, Portland, Maine

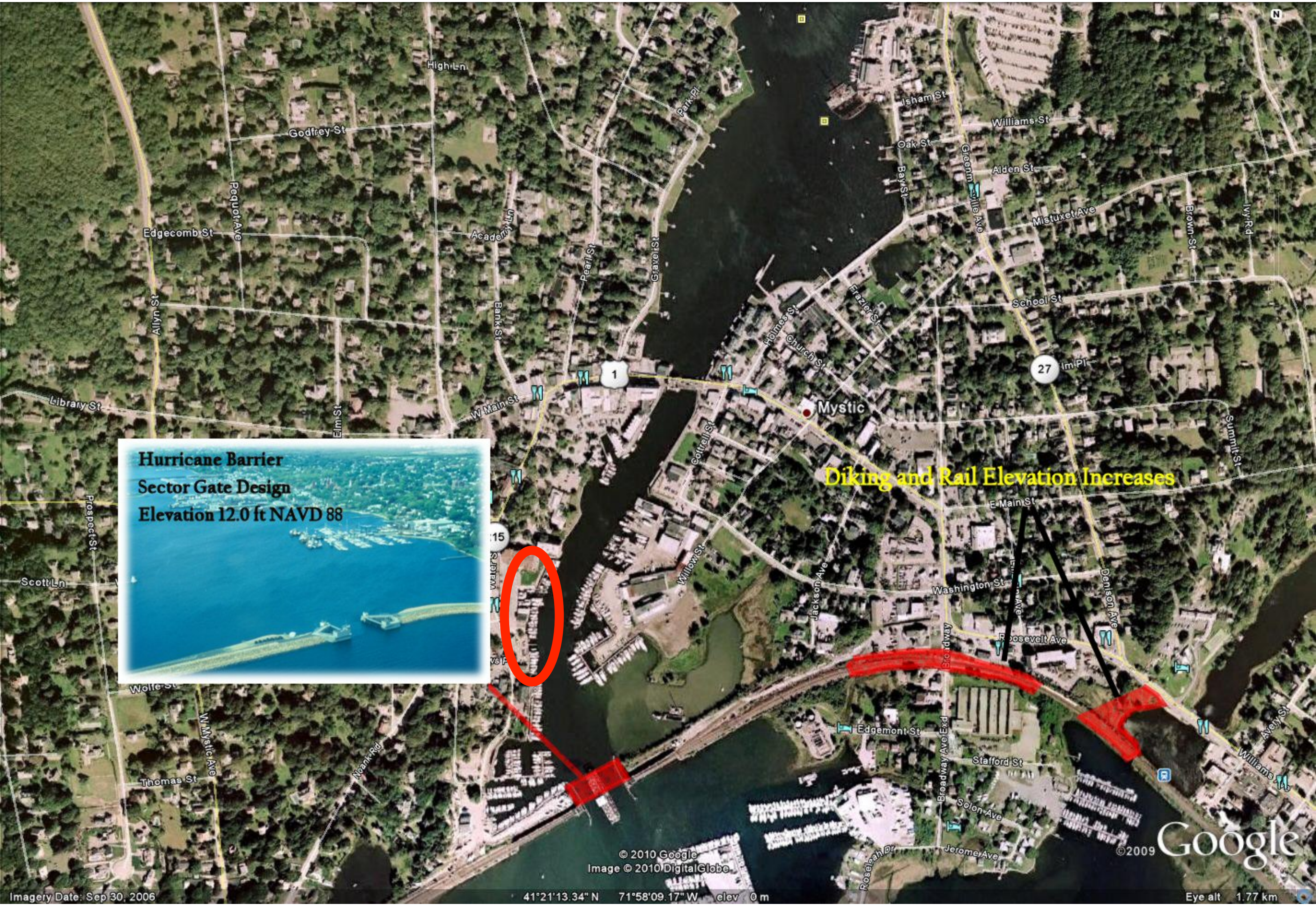
## Adaptation Costs and Cumulative Expected Damages, through 2100.

| 2100 SLR Scenario | Adaptation | Cost (M) | Real Estate Damage (M) | Percent of damage from Storm surge | Percent of damage from SLR |
|---|---|---|---|---|---|
| No SLR | No Action | $0 | $1,791 | 100% | 0% |
| | Surge Barrier / Levee | $0 / $40 | $0 | | |
| Low SLR (27.6") | No Action | $0 | $2,674 | 97% | 3% |
| | Surge Barrier / Levee | $0 / $40 | $0 | | |
| High SLR (70.9") | No Action | $0 | $3,680 | 71% | 29% |
| | Surge Barrier / Levee | $0 / $40 | $0 | | |


PORTLAND WATER DISTRICT
225 Douglass Street
Portland, ME 04104
Invert Data
Back Cove Intercepting Sewer
October 24th, 2011
0
500
1,000
2,000
Feet
N
Portland
Back Cove
Baxter Blvd
10TH Mountain Division Hwy
Marginal Way
Washington Ave
Forest Ave
Deering Ave
Park Ave
Bedford St
Deering Oaks
Loring Memorial Park
University of Southern Me-Portland
Ocean Ave
Clifton St
Brookside Rd
George St
Austin St
Mackworth St
Parsons Rd
Bay View Dr
Preble St Ext
State St


Consider hurricane barriers for storm surge protection
Stamford, CT
USACE


Cumulative Damage: $8,768,776
1 CENTIMETER = 50 METERS
FLOOD LEVEL (ft)
6
5
4
3
2
1
0
FLOOD DAMAGE IN DOLLARS
$0 - $51,976
$51,976 - $98,670
$98,670 - $207,761
$207,761 - $606,502
$606,502 - $841,579
MYSTIC, NO ACTION
2070, 10 YEAR EVENT, LOW SLR

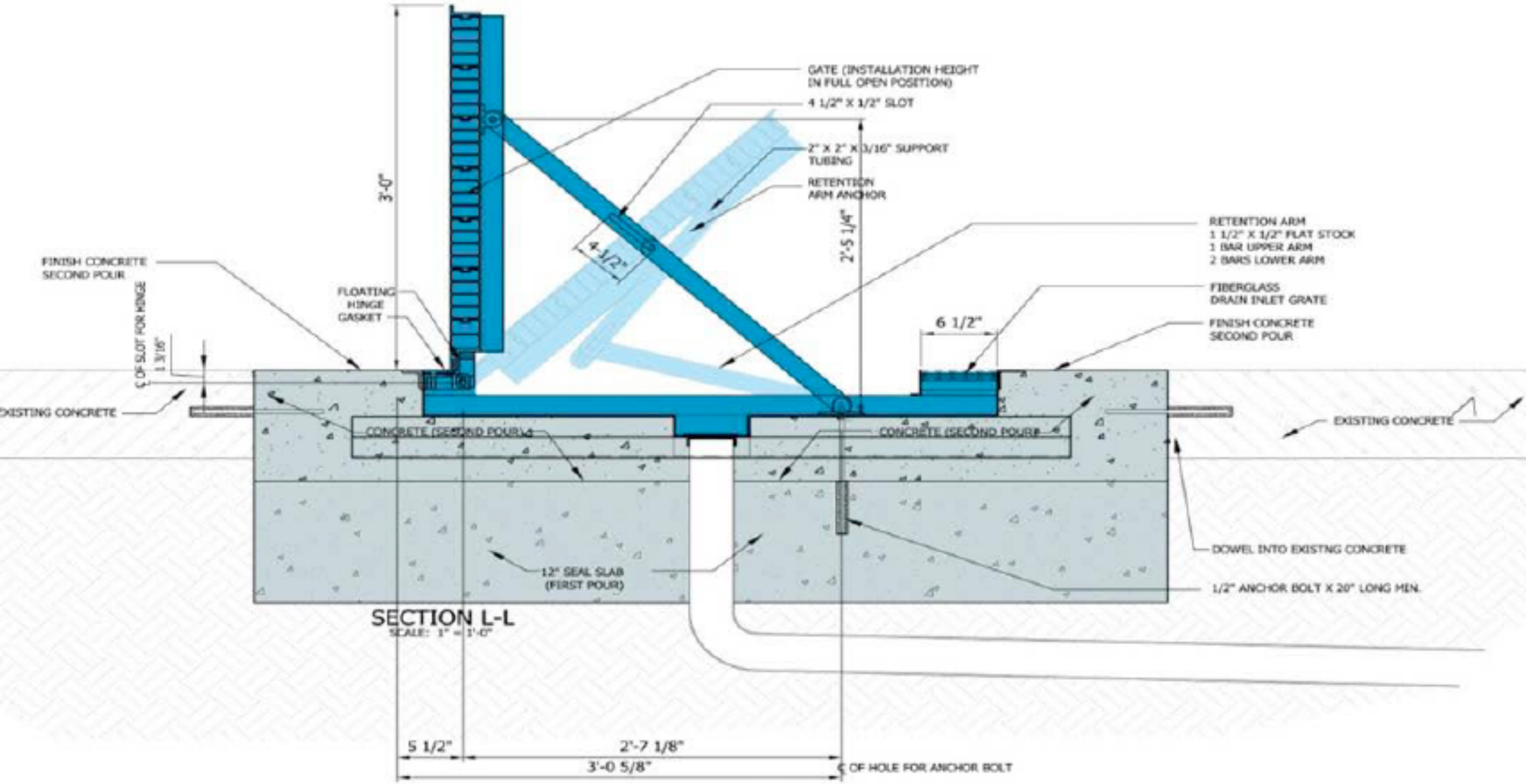

Hurricane Barrier
Sector Gate Design
Elevation 12.0 ft NAVD 88
Diking and Rail Elevation Increases
Mystic
High Ln
Godfrey St
Edgecomb St
Pequot Ave
Allyn St
Library St
Elm St
Academy Ln
Bank St
Pearl St
Gravel St
Park Pl
W Main St
Isham St
Williams St
Oak St
Bay St
Alden St
Mistuxet Ave
Brown St
Ivy Rd
School St
Holmes St
Church St
Frazier St
Cottrell St
Willow St
Jackson Ave
E Main St
Washington St
Roosevelt Ave
Denison Ave
Broadway
Edgemont St
Stafford St
Solon Ave
Jerome Ave
Avery St
Summit St
Prospect St
Scott Ln
Wolfe St
W Mystic Ave
Thomas St
Noank Rd
© 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.<br>*ADDITIONAL FORTIFICATION 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.<br>*FURTHER FORTIFICATION and elevating the railroad, as well as increased diking to east.* | $35 Million | $120,000 |

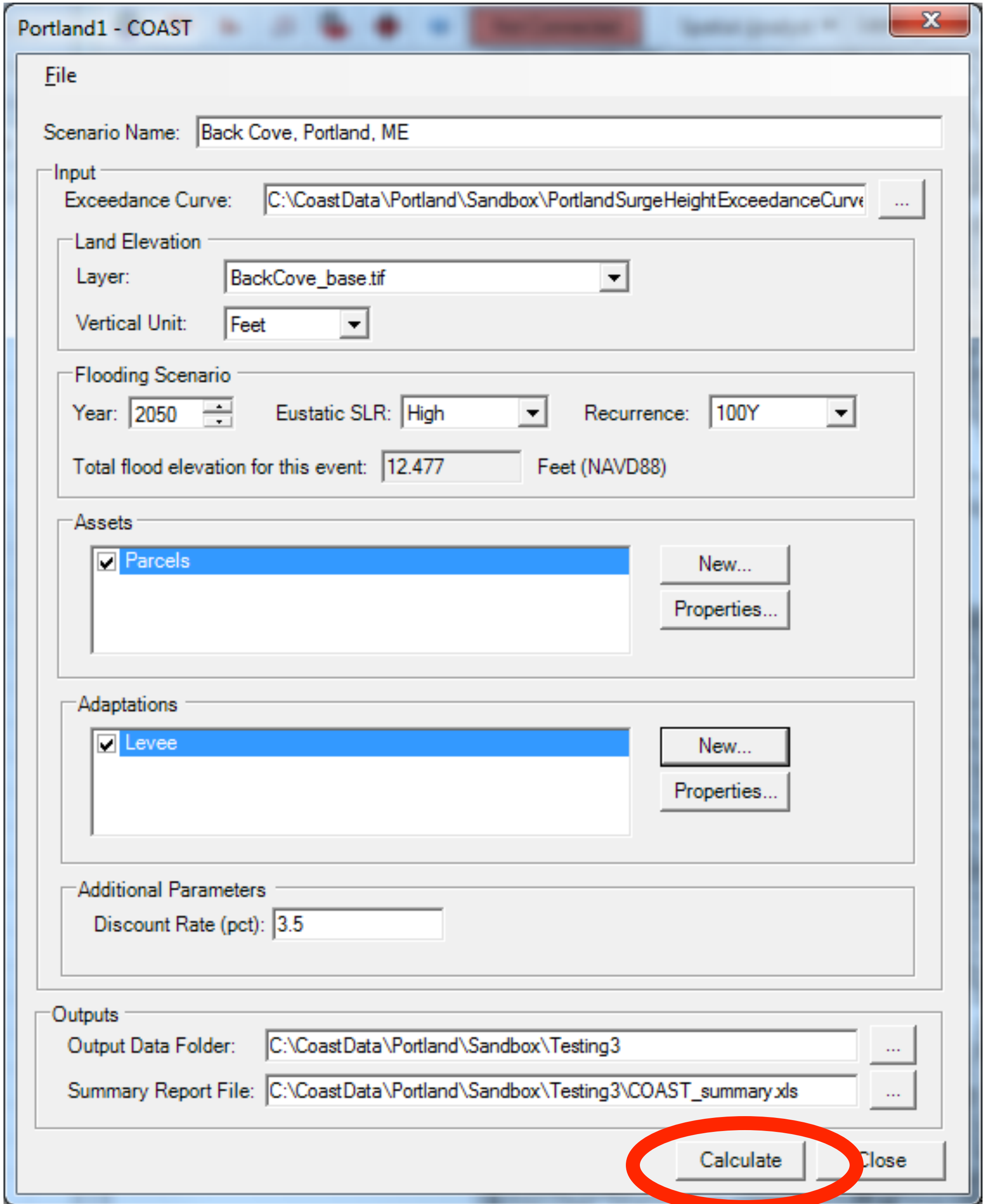
# Transit Applications

New England Environmental Finance Center

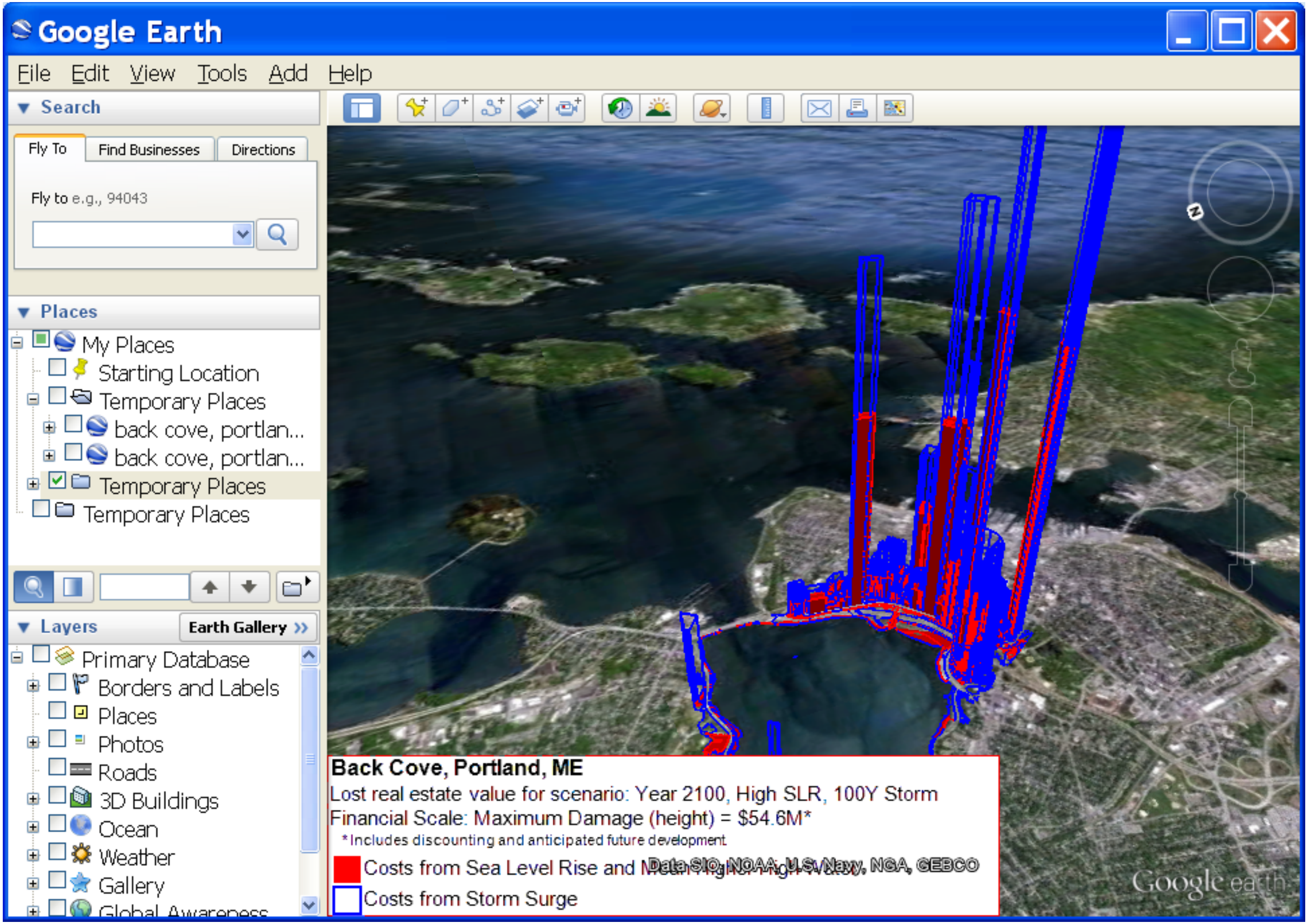

CLEARANCE 8'-2"




SECTION L-L
SCALE: 1" = 1'-0"


Portland1 - COAST
File
Scenario Name: Back Cove, Portland, ME
Input
Exceedance Curve: C:\CoastData\Portland\Sandbox\PortlandSurgeHeightExceedanceCurve
Land Elevation
Layer: BackCove_base.tif
Vertical Unit: Feet
Flooding Scenario
Year: 2050
Eustatic SLR: High
Recurrence: 100Y
Total flood elevation for this event: 12.477 Feet (NAVD88)
Assets
Parcels
New...
Properties...
Adaptations
Levee
New...
Properties...
Additional Parameters
Discount Rate (pct): 3.5
Outputs
Output Data Folder: C:\CoastData\Portland\Sandbox\Testing3
Summary Report File: C:\CoastData\Portland\Sandbox\Testing3\COAST_summary.xls
Calculate
Close

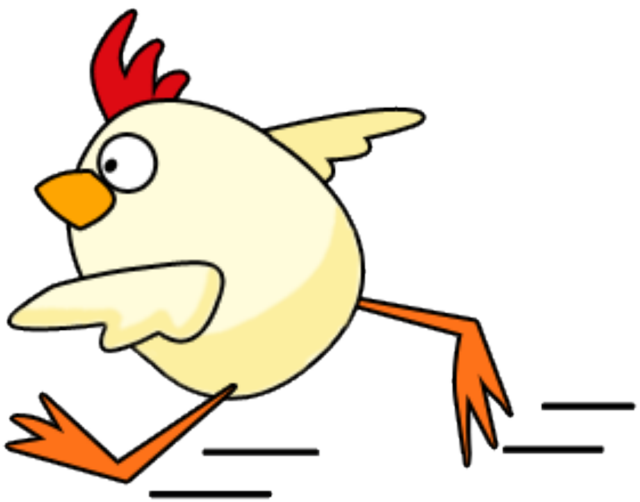

Google™
Earth


Google Earth
File Edit View Tools Add Help
Search
Fly To
Find Businesses
Directions
Fly to e.g., 94043
Places
My Places
Starting Location
Temporary Places
back cove, portlan...
back cove, portlan...
Temporary Places
Temporary Places
Layers
Earth Gallery
Primary Database
Borders and Labels
Places
Photos
Roads
3D Buildings
Ocean
Weather
Gallery
Back Cove, Portland, ME
Lost real estate value for scenario: Year 2100, High SLR, 100Y Storm
Financial Scale: Maximum Damage (height) = $54.6M*
*Includes discounting and anticipated future development
Costs from Sea Level Rise and Mean Higher High Water
Costs from Storm Surge
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google earth


Sea Isle City, NJ
Geotextile Tubes

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

- Chogyam Trungpa Rinpoche



# Contact info:

Sam Merrill

smerrill@usm.maine.edu

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

207-228-8596

UNIVERSITY OF SOUTHERN MAINE
Muskie School of Public Service

Catalysis Adaptation Partners

info@catalysisadaptationpartners.com

http://www.catalysisadaptation.com

207-615-7523

Catalysis Adaptation Partners, LLC