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

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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 help address difficult how-to-pay issues of providing environmental services.

Impacts from Flooding
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
There are only four options:

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)
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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)

Portland Tide gauge = global ocean over last century (1.8 mm/yr, IPCC (2007)).
In Maine, this is the fastest in past 3000 years

$y = 1.8609x - 3693.1$
$R^2 = 0.7453$

1.86 mm per yr or 0.61 ft (7.3") per century

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

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

And Portland during the same time period...

Portland, ME Sea Level Changes
4.31 mm/yr (1993-2011)
17.0 inches per century
The Old Port, 10/11 at high tide (M. Craig)
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.

![Graph showing sea level rise (cm)]
SLR Scenario Ranges

Use a “Scenario” Based Approach

Adapted from Rahmstorf (2010); and Williams (2012)
Projection of Sea Level Rise from 1990 to 2100

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.
# Data for Decision-Making

## Damage Functions for Single Family Residential Structures with Basement

<table>
<thead>
<tr>
<th>Depth (feet)</th>
<th>Mean of Damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>25.5%</td>
</tr>
<tr>
<td>1</td>
<td>32.0%</td>
</tr>
<tr>
<td>2</td>
<td>38.7%</td>
</tr>
<tr>
<td>3</td>
<td>45.5%</td>
</tr>
<tr>
<td>4</td>
<td>52.2%</td>
</tr>
<tr>
<td>5</td>
<td>58.6%</td>
</tr>
<tr>
<td>6</td>
<td>64.5%</td>
</tr>
</tbody>
</table>
## Expected costs and damages, 2010 - 2050

<table>
<thead>
<tr>
<th>SLR Scenario</th>
<th>Adaptation</th>
<th>Residual Damages ($ million)</th>
<th>Adaptation Cost ($ million)</th>
<th>Total Damages and Costs ($ million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No SLR</td>
<td>No Action</td>
<td>680</td>
<td>0</td>
<td>680</td>
</tr>
<tr>
<td></td>
<td>50 yr flood</td>
<td>3.4</td>
<td>52.4</td>
<td>55.8</td>
</tr>
<tr>
<td></td>
<td>100 yr flood</td>
<td>0</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Low</td>
<td>No Action</td>
<td>899.3</td>
<td>0</td>
<td>899.3</td>
</tr>
<tr>
<td></td>
<td>50 yr flood</td>
<td>28.3</td>
<td>52.4</td>
<td>80.7</td>
</tr>
<tr>
<td></td>
<td>100 yr flood</td>
<td>0</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>High</td>
<td>No Action</td>
<td>1016.6</td>
<td>0</td>
<td>1016.6</td>
</tr>
<tr>
<td></td>
<td>50 yr flood</td>
<td>67.8</td>
<td>52.4</td>
<td>120.2</td>
</tr>
<tr>
<td></td>
<td>100 yr flood</td>
<td>37.6</td>
<td>60</td>
<td>97.6</td>
</tr>
</tbody>
</table>
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
© Springer Science+Business Media B.V. 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
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. Oxford, 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
View Across the Marsh From Roof of Ogunquit Sewage Treatment Plant April 2007 Patriot’s Day Storm
Ogunquit Sewer District Treatment Facility
(2006 LiDAR; 2009 ArcGlobe Imagery)
Potential Inundation Analysis
Ogunquit, ME

1978 Storm + 0.6 m
Potential Flood Depths (ft)

- 0.0 - 2
- 2.1 - 4
- 4.1 - 6
- 6.1 - 8
- 8.1 - 14

For general planning purposes only.
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
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

Level of emergency route: 7.5 m

Level of harbour: 5.3 m

Emergency routes
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

High Sea Level Rise + High Tide
spatial extent of daily inundation
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
Projection of Sea Level Rise from 1990 to 2100

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.

<table>
<thead>
<tr>
<th>2050 SLR Scenario</th>
<th>Adaptation</th>
<th>Cost (M)</th>
<th>Damage (M)</th>
<th>Percent of damage from</th>
<th>Storm surge (ft)</th>
<th>SLR (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No SLR</td>
<td>No Action</td>
<td>$0</td>
<td>$356</td>
<td>100%</td>
<td></td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>Surge Barrier / Levee</td>
<td>$103 / $0</td>
<td>$0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low SLR (7.9&quot;)</td>
<td>No Action</td>
<td>$0</td>
<td>$407</td>
<td>100%</td>
<td></td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>Surge Barrier / Levee</td>
<td>$103 / $0</td>
<td>$0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High SLR (19.7&quot;)</td>
<td>No Action</td>
<td>$0</td>
<td>$447</td>
<td>100%</td>
<td></td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>Surge Barrier / Levee</td>
<td>$103 / $0</td>
<td>$0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2100, low sea level rise, 10 year storm

Back Cove, Portland, ME
Lost real estate value for scenario: Year 2100, Low SLR, 10Y Storm
Financial Scale: Maximum Damage (height) = $24.3M*
*Includes discounting and anticipated future development.

- Costs from Sea Level Rise and Mean Higher High Water
- Costs from Storm Surge

Image © 2012 TerraMetrics
©2012 Cnes/Sen-Ocean
2100, high sea level rise, 100 year storm

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
Back Cove, Portland, Maine

Adaptation Costs and Cumulative Expected Damages, through 2100.

<table>
<thead>
<tr>
<th>2100 SLR Scenario</th>
<th>Adaptation</th>
<th>Cost (M)</th>
<th>Damage (M)</th>
<th>Percent of damage from Storm surge</th>
<th>Percent of damage from SLR</th>
</tr>
</thead>
<tbody>
<tr>
<td>No SLR</td>
<td>No Action</td>
<td>$0</td>
<td>$1,791</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>Surge Barrier / Levee</td>
<td>$0 / $40</td>
<td>$0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low SLR (27.6&quot;)</td>
<td>No Action</td>
<td>$0</td>
<td>$2,674</td>
<td>97%</td>
<td>3%</td>
</tr>
<tr>
<td></td>
<td>Surge Barrier / Levee</td>
<td>$0 / $40</td>
<td>$0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High SLR (70.9&quot;)</td>
<td>No Action</td>
<td>$0</td>
<td>$3,680</td>
<td>71%</td>
<td>29%</td>
</tr>
<tr>
<td></td>
<td>Surge Barrier / Levee</td>
<td>$0 / $40</td>
<td>$0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Consider hurricane barriers for storm surge protection
Cumulative Damage: $8,768,776

Mystic, No Action
2070, 10 Year Event, Low SLR

Flood Level (ft)
- 6: 2
- 5: 1
- 4: 0
- 3: 2

Flood Damage in Dollars
- $0 - $51,976
- $51,976 - $98,670
- $98,670 - $207,761
- $207,761 - $606,502
- $606,502 - $841,579
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea level rise, normal tides</td>
<td>A 3.2 – 4.0</td>
<td>No action up to minimal flood proofing and infrastructure elevation along river.</td>
<td>Insignificant</td>
<td>Insignificant</td>
</tr>
<tr>
<td></td>
<td>B 5.5 – 6.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100-year storm event in 2010</td>
<td>C 5.4</td>
<td>Hurricane Barrier at Mystic River entrance.</td>
<td>$18 Million</td>
<td>$75,000</td>
</tr>
<tr>
<td></td>
<td>D 7.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10-year storm in 2070, Hi SLR</td>
<td>E 7.0</td>
<td>Hurricane Barrier at Mystic River entrance.</td>
<td>$27-30 Million</td>
<td>$100,000</td>
</tr>
<tr>
<td></td>
<td>F 8.9</td>
<td>ADDITIONAL FORTIFICATION and elevating the railroad, as well as increased diking to east.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100-year storm in 2070, Hi SLR</td>
<td>G 8.6</td>
<td>Hurricane Barrier at Mystic River entrance.</td>
<td>$35 Million</td>
<td>$120,000</td>
</tr>
<tr>
<td></td>
<td>H 10.5</td>
<td>FURTHER FORTIFICATION and elevating the railroad, as well as increased diking to east.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Transit Applications
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

Buttons:
- Calculate
- Close
Fly to e.g., 94043

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 Metro Higher High Water
- Costs from Storm Surge
Sea Isle City, NJ

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

- Chogyam Trungpa Rinpoche
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207-228-8596

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