Will the Cape Fall Into The Sea? Future Sea Level Rise and Coastal Change on Cape Cod

Rob Thieler, USGS
There is very high confidence (>90% chance) that sea-level will rise between 8 inches and 6.6 feet by 2100. This is higher and will be faster than the past 2000 years.

The coast does not flood like a bathtub. It's much more exciting.

Effective adaptation to rising sea level will require changing approaches to coastal management.
Sea-level rise rates since the Last Glacial Maximum

Thousands of $^{14}$C years before present

Rate of SLR (mm/yr)

U.S. Atlantic, U.K. wetland initiation; barrier island stability (Shennan and Horton, 2002; Engelhart et al., 2009)

Global delta initiation (Stanley and Warne, 1994)

Sea-level rise rates since the Last Glacial Maximum

Sea-level rise rates since the Last Glacial Maximum

(SLR rate based on Fairbanks, 1989; ice extent from Dyke, 2004)
Sea-level Rise on Cape Cod
12,000 yr BP to Present

12,000 yr BP
11,000 yr BP
10,000 yr BP
8,000 yr BP
6,000 yr BP
Present

(Shaw et al., 2002)
Past, present, and potential future rates of sea-level rise

“Geologic past” (Fairbanks, 1989; Horton et al. 2009)

“Instrumental record” (Church and White, 2006)

“Projections” (Rahmstorf, 2007)
Importance of Spatial Scale
Importance of Temporal Scale

Short-term Variance
(hours to decade)
- Storm impact/recovery
- Annual cycles
- El Niño

Long-term Trend
(decades to centuries)
- Sediment deficit or surplus
- Sea-level rise
So, what can happen?

- Bluff erosion
- Overwash
- Island Breaching
- Listed Species Impacts
- Threshold Crossing
- Urban Inundation
- Wetland Loss
- Water Quality Reduction
- Ecosystem Change
- Infrastructure Failure
- Listed Species Impacts
- Urban Inundation
- Wetland Loss
The coast is not like a bathtub...
Especially the Cape and Islands…

With a few exceptions, most of our coast is a dynamic, not static system.
Mid-Atlantic Assessment of Potential Dynamic Coastal Responses to Sea-level Rise

(Butierrez et al., 2009)
Coastal Wetlands Respond Dynamically to Environmental Change

(Cahoon et al., 2009)
Sea-Level Rise Impacts on Groundwater Systems

Water quality reduction

Infrastructure failure

Ecosystem change

John Masterson, USGS
Informing Decisions in a Changing Climate
National Research Council (2009)

The end of “Climate Stationarity” requires that organizations and individuals alter their standard practices and decision routines to take climate change into account. Scientific priorities and practices need to change so that the scientific community can provide better support to decision makers in managing emerging climate risks.

- Decision makers must expect to be surprised because of the nature of climate change and the incompleteness of scientific understanding of its consequences.
- An uncertainty management framework should be used because of the inadequacies of predictive capability.
Sea-level rise impacts: A multivariate problem with uncertainties everywhere

Driving Forces
- Climate Change & Sea Level Rise

Initial Conditions
- Physical & Biological Processes
  - Groundwater Impact
  - Wetland Loss
  - Coastal Erosion
  - Inundation

Potential Impacts
- Safety
- Habitat Loss

Adaptation, Planning, Response, Management Decisions
Bayesian Network for Predicting Coastal Vulnerability to Sea-level Rise

Geologic Constraints

Coastal Slope

Geomorphology

Tide Range

Wave Height

Relative Sea-level Rise

Shoreline Change

Coastal Response

(Gutierrez et al., 2011)
Mapping Erosion Risk Using Bayesian Networks
Probability of coastal erosion >2 m/yr

(Gutierrez et al., 2011)
Mapping Prediction Uncertainty
Higher probability = higher certainty of outcome

- Uncertainty map can be used to identify where better information is needed
- Areas of low confidence require
  - better input data
  - better understanding of processes
- Can use this map to focus research resources

(Gutierrez et al., 2011)
Cape and Islands (a very preliminary 1st attempt)
Probability of coastal erosion >1 m/yr

Max. Probability ("confidence")
Understanding Where We Are, and Where We Could Go
www.falmouthmass.us/depart.php?depkey=coastal

The Future of Falmouth’s South Shore
Report of the Coastal Resources Working Group to the Board of Selectmen, Falmouth, Massachusetts
May, 2003

Coastal Resources Working Group
Rob Thieler, Chairman
Dorothy Aspinwall
Bob Barker
Rocky Geyer
Jo Ann Muramoto
Beth Schwarzman
Charles Swan
Jane Tucker
Chris Weidman
George Calise, Town Engineer, ex officio
Jude Wilber, ex officio

The Future of Falmouth’s Buzzards Bay Shore
Report of the Coastal Resources Working Group to the Board of Selectmen, Falmouth, Massachusetts
22 October 2010

Coastal Resources Working Group
Jane Tucker, Chair
Bob Barker
Rocky Geyer
Jo Ann Muramoto
Beth Schwarzman
Doc Taylor
Rob Thieler
Chris Weidman
George Calise, Town Engineer (retired), ex officio
Jude Wilber, ex officio
About 50% of south coast parcels are armored. Half are Town parcels. There are 70 groins, 10 jetties, and 94 revetments on the south coast.
Nobska Point

(1950s)

(NOAA)

courtesy RJDick, www.noticetoairmen.com

2000s
Falmouth South Shore Erosion Rates

Year Interval

1845-1890
1800s-1948
1975-1994

Erosion Rate (ft/yr)

-3.0
-2.5
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0

1845-1890
1800s-1948
1975-1994

Year Interval
Green Pond Shoreline Change Since 1845

- Sediment supply decreased
- Uplands armored, beaches narrowed
- Barrier has migrated into the pond
Vision for Falmouth’s Coast  
(for the next 50-100 years)

- Beaches and dunes wide enough for protection from storms and public access and use.

- Sufficient sand in the coastal system.

- Sustained and enhanced water quality, habitat and fisheries resources.

- A minimum of hard structures (groins, seawalls, etc.).

- Public infrastructure will be relocated from the immediate coast.

- A proactive approach to shoreline management to prevent problems and provide a response protocol when shoreline damage occurs.
Achieving the Vision for Falmouth’s Coast

• Acquire coastal land for open space.

• Move or change vulnerable public infrastructure. Plan future infrastructure (e.g., roads, sewers) wisely.

• Conduct beach nourishment experiments at key “source” locations.

• Remove unnecessary, hazardous, or damaging coastal armoring structures.

• Create effective sand management systems.

• Improve regulations to protect coastal systems and beaches.

• Encourage landowners to obtain conservation easements that protect valuable coastal assets such as unarmored bluffs.
Summary

• Will the Cape fall into the sea?
  • No. But there will be major changes to the coast, ecosystems, and resources
  • Informed preparation is important

• Sea-level has been rising (at varying rates) for the past several thousand years and is an important component of coastal evolution.
  • The coast as we know it today is a product of sea-level rise

• Future sea-level rise is a certain impact
  • We have already made a commitment to several centuries of rise

• Future sea-level rise is an uncertain impact
  • Rates and magnitudes poorly constrained
  • Societal response unknown