Welcome

Leslie-Ann McGee
Director of Special Projects/ResilientWoodsHole Manager
Woods Hole Oceanographic Institution
Welcome
Review Woods Hole’s Coastal Vulnerability and Project Progress
Coastal Resilience and Adaptation Options
What are Dynamic Adaptation Pathways?
Workshop Instructions and Next Steps

*Question & Answer*

ResilientWoodsHole Adaptation Pathways Workshop
- **Nine (9) Coastal Management Area Stations**
  - Fay Rd, Nobska Pt, Juniper Pt, Waterfront, Penzance Pt, Spencer Baird,
    - Eel Pond & School St, Millfield and Gardiner, Gansett
- Review adaptation options and provide feedback
Coastal Vulnerability and Adaptation in Woods Hole

Joe Famely
Woods Hole Group
Extreme Water Levels in Woods Hole (Station 8447930)
The relative sea level trend is 2.95 millimeters/year with a 95% confidence interval of ±0.17 mm/yr based on monthly mean sea level data from 1932 to 2020 which is equivalent to a change of 0.97 feet in 100 years.
MA EOEEA Downscaled Climate Change Projections

https://resilientma.org/data/documents

WHAT MASSACHUSETTS MODELED

CURRENT TRAJECTORY (POST COP26)

https://climateactiontracker.org/
MA EOEEA Probabilistic Sea Level Rise Projections
Woods Hole Tide Gauge, Station 8447930 (DeConto & Kopp, 2017)

NOTES:
- Probabilistic Crosswalk:
  Confidence intervals indicate the probability (%) that SLR has not been underpredicted given various emissions and ice sheet melt contributions.

- Updated Baseline (1999-2017)
- NOAA Epoch (1983-2001)

MA EOEEA selected the High Scenario for planning

- High Scenario
  - >99.5%: RCP 4.5
  - 99.5%: RCP 8.5
  - 95%: RCP 4.5 + ice
  - 83%: RCP 8.5 + ice

- Intermediate Scenario
  - 95%: RCP 4.5
  - 83%: RCP 8.5
  - 50%: RCP 4.5 + ice
  - <50%: RCP 8.5 + ice

- MC-FRM Scenarios (High)
  - Observed Monthly Average
  - Extreme
  - High
  - Intermediate-High
  - Intermediate

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Massachusetts Coast Flood Risk Model (MC-FRM)

INPUTS

- Sea Level Rise
- Tropical / Extratropical Storms
- Landscape
- Elevation
- Changing Climate

PROBABILISTIC / HYDRODYNAMIC MODEL

Includes relevant physical processes: sea level rise, tides, storm surge, wind, wave setup / run-up / overtopping, future climate scenarios

OUTPUTS

- Flood Probability
- Flood Depth
- Flood Duration
- Flood Volumes
- Flood Pathways
- Winds
- Waves
- Currents
What are the potential impacts of climate change on scientific operations and research in Woods Hole?

Climate Change Vulnerability Assessment (WHOI/MBL/NOAA)

https://resilientwoodshole.org/news-and-events/#reports
### Lillie Laboratory

- **Asset Type:** Buildings
- **Critical Elevation (CE):** 5.12 FT NAVD88
- **Elevation:**
  - 1.2 FT NAVD88
  - 3.8 FT NAVD88
  - 4.9 FT NAVD88
  - 8.9 FT NAVD88

**Livelihood Description:**
- Loading dock slab entry from 2017 LEY CERT
- Additional CEs:
  - Lillie Fuel Tank (5.80 FT NAVD88)
  - Lillie/PMC Junction Box (9.85 FT NAVD88)
  - Lillie Transformer (11.87 FT NAVD88)

### Climate Vulnerability Assessment - Asset Profile

#### MC-FRM Probability - 2070

#### Asset Consequence Scores

#### Risk - 2070

### Probability of Exceedance Summary Table

<table>
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<tr>
<th>Probability</th>
<th>2030</th>
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<th>2050</th>
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<td>12.5</td>
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### Consequence of Exceedance

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<tr>
<td>2070</td>
<td>100</td>
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#### Risk Group

- Woods Hole Group
What are the potential impacts of climate change on the broader Woods Hole community?

Extended Climate Change Vulnerability Assessment (Woods Hole residential community, businesses, roadways, lifelines), supplemental adaptation planning (WHOI/MBL/NOAA) and initial outreach.

https://resilientwoodshole.org/news-and-events/#reports
Resilient Woods Hole Study Area
1% Probability Present

Residential (879) 220
Scientific (153) 27
Business (24) 14
Non-profit (19) 6
Lifelines (14) 10
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<tr>
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<td>Non-profit (19)</td>
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<tr>
<td>Lifelines (14)</td>
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Counts of Buildings Exposed to Projected Flooding

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<tr>
<th></th>
<th>Present</th>
<th>2030</th>
<th>2050</th>
<th>2070</th>
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<tbody>
<tr>
<td>WHOI-MBL-NOAA</td>
<td>LifeLines</td>
<td>Business</td>
<td>Residential</td>
<td>Non-Profit</td>
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<td>0%</td>
<td>117</td>
<td>3</td>
<td>6</td>
<td>634</td>
</tr>
<tr>
<td>0.1%</td>
<td>36</td>
<td>11</td>
<td>18</td>
<td>245</td>
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<td>33</td>
<td>10</td>
<td>16</td>
<td>237</td>
</tr>
<tr>
<td>0.5%</td>
<td>28</td>
<td>10</td>
<td>15</td>
<td>230</td>
</tr>
<tr>
<td>1%</td>
<td>27</td>
<td>10</td>
<td>14</td>
<td>220</td>
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<td>2%</td>
<td>25</td>
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<td>5%</td>
<td>19</td>
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<td>10%</td>
<td>8</td>
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<td>178</td>
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<td>20%</td>
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<td>25%</td>
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<td>137</td>
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<td>30%</td>
<td>1</td>
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<td>1</td>
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<tr>
<td>100%</td>
<td>1</td>
<td>0</td>
<td>6</td>
<td>55</td>
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</table>

Credit: Woods Hole Historical Museum
Vulnerable at 1% Annual Chance
Present 3.5/20.6 miles

2030 4.0/20.6 miles
2050 4.9/20.6 miles
2070 5.4/20.6 miles
Vulnerable at 1% Annual Chance

Present 3.5/20.6 miles
2030 4.0/20.6 miles
2050 4.9/20.6 miles
2070 5.4/20.6 miles
2050 MC-FRM Probability of Flood Exposure

Vulnerable at 1% Annual Chance
Present 3.5/20.6 miles
2030 4.0/20.6 miles
2050 4.9/20.6 miles
Vulnerable at 1% Annual Chance

Present  3.5/20.6 miles
2030  4.0/20.6 miles
2050  4.9/20.6 miles
2070  5.4/20.6 miles

2070 MC-FRM Probability of Flood Exposure
### Road Miles Exposed to Projected Flooding

1% annual chance event has a 9.6% chance of occurring in a 10-year period.

10% annual chance event has a 65.1% chance of occurring in a 10-year period.

25% annual chance event has a 94.4% chance of occurring in a 10-year period.

<table>
<thead>
<tr>
<th>Annual Chance</th>
<th>Present</th>
<th>2030</th>
<th>2050</th>
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<tr>
<td>0.1%</td>
<td>4.5</td>
<td>4.8</td>
<td>5.4</td>
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</tr>
<tr>
<td>0.2%</td>
<td>4.2</td>
<td>4.6</td>
<td>5.2</td>
<td>5.7</td>
</tr>
<tr>
<td>0.5%</td>
<td>3.8</td>
<td>4.3</td>
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<td>2%</td>
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<td>3.7</td>
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Adaptation Strategies – Building Scale

**Building Form + Access**
- Elevate on extended foundation walls or open foundation
- Elevate on fill
- Repurpose/Relocate Ground Floor Use
- Exterior circulation to SLR-DFE
- Interior circulation to SLR-DFE

**Building Adaptation**
- Wet Floodproofing
- Dry Floodproofing
- Flood Damage-Resistant Materials
- Enhanced Building Envelope

**Building Systems**
- Protecting Critical Systems
- Backflow Prevention
- Back-up Systems
- Resilient Elevators

**Site**
- Vegetated Berm
- Deployable Barriers
- Perimeter Wall

(Credit: Modified from Boston Planning & Development Agency, Coastal Flood Resilience Design Guidelines)
Adaptation Strategies – Landscape Scale

Protect (hardened infrastructure)
- Elevation of Land and Streets
- Floodwalls
- Bulkheads
- Revetments
- Seawalls
- Leves (or Dikes)
- Breakwaters
- Surge Barriers

Protect (natural or nature-based infrastructure)
- Beaches and Dunes
- Living Shorelines
- Constructed Wetlands
- Artificial Reefs
- Floating Islands
- Constructed Breakwater Islands

Protect (hybrid infrastructure)
- Waterfront Parks
- Multi-purpose Leves

Relocate/Retreat
- Strategic Retreat

(Credit: Modified from NYCPlanning, Coastal Climate Resilience Urban Waterfront Adaptive Strategies)
How can we work together to ensure the future of our vibrant and productive seaside community?

Comprehensive phased strategy for Woods Hole Village that integrates resilient design concepts and community visioning.

Develop community-wide understanding of local climate impacts.

Build effective partnerships for Village planning and visioning.

Develop short-, mid-, and long-term climate adaptation actions across strategic themes.

Identify key thresholds and transition points, based on adaptive management.

Chart dynamic adaptation pathways that optimize community outcomes over time, based on community preferences and scientific projections.

ResilientWoodsHole Phase 3

How can we work together to ensure the future of our vibrant and productive seaside community?
2/9/22 Public Forum (135 attendees)

Input Map: Important Features
tinyurl.com/RWHimportant

Input Map: Adaptation and Vision
tinyurl.com/RWHadaptation

Input Map: Flooding
tinyurl.com/RWHflooding

https://resilientwoodshole.org/
Stakeholder Survey: 41 Respondents

What is your connection(s) to Woods Hole?

- Year-round worker: 8
- Year-round resident: 12
- Visitor from further away: 17
- Visitor from Falmouth: 3
- Visitor from nearby town: 4
- Year-round business: 3
- Seasonal business: 2
- Friend of WHOI: 3
- Mooring: 0
- Other: 1
Stakeholder Survey: Important Features

All assets are important, but some have irreplaceable historical value, such as Woods Hole Library, Woods Hole Community Hall, Children’s School of Science, Woods Hole Historical Museum, Waterfront Park and sculptures, NPR building.

Community, yacht club, Community Hall, Library, Museum, Post Office, Nobska

Daily life, friends, MBL, cemetery and related church activities. might want to add science education/science school to your list

Historical, education and physical nature

The harbors Great Harbor and Eel Pond

Museum

Harbor

Baseball field
Stakeholder Survey: What do you value here?

Overall themes
- Scientific Community (intellectual diversity)
- Community/Nostalgia/Deep Ties to the Village/Energy
- History
- Natural Environment

Woods Hole is a special community in which year-round and summer residents have been there for 3 or more generations. This allows for deep ties to each other and to the community. This also promotes a vibrant, engaged community that sponsors and supports events (talks, music, film series) that are almost unparalleled in a community of this size.

The unique mix of science, natural beauty and culture

A unique blend of history, science, charm and leisure

It's a very nostalgic place for me. I love the small town feel, the scientific community, and the practical modesty of Woods Hole - no chain stores, no flashy businesses. I have spent my adult life thinking "maybe some day I can retire in Woods Hole" and the fact that I am now living here and may be able to for the rest of my life is amazing! I know and love every house on the walk between my family's house and Stony Beach, the bell tower, the bridge, going to watch ferries load and unload (I still do this as an adult.) I and my children have attended CSS and visited the Aquarium (still mourning Bumper and LuSeal). It just feels like a community where I want to spend my life.

nostalgic pride

Long family history in the area
Stakeholder Survey: Experience with Flooding

Have you experienced **high tide flooding** or **coastal storm flooding** in Woods Hole?

- **Yes** (34.1%)
- **No** (65.9%)

**Common Responses:**

- **High Tide**
  - Woods Hole Yacht Club and its docks
  - Beaches (spec. Vineyard Sound and Stoney beach)
  - Eel Pond

- **Coastal Storm**
  - Woods Hole Yacht Club and its docks
  - Gardner Rd
  - Millfield Street
  - Mill Pond and marsh

**Impacts:**
- My property is right on the water and high tide flooding eats away at the sand bank
- Localized street flooding
- Covered our dock
- Unable to drive through shoreline roads and parts of village
- On the docks.
- Eroded shoreline, killed vegetation
Stakeholder Survey: Adaptation Strategies

Nature-based solutions would build on the reasons that people come to Woods Hole in the first place – they would increase populations of fish, shellfish, shorebirds, etc. and perhaps create new areas for visitors and residents to explore and enjoy nature. Hardening the shoreline may be necessary in spots but would make it less, rather than more, pleasant for people and useless for wildlife. Doing nothing is not an option because Woods Hole as we know it would disappear.

Hard infrastructure approaches to protection are short-term and expensive. Retreat is inevitable, just a matter of when.

It will likely take all aspects to remain resilient to the negative affects from sea level rise and I think fortify existing costly infrastructure as we plan a phased retreat.

*preferences in response to storms were nearly identical to preferences in response to SLR
Stakeholder Survey: What should remain?

Overall themes
- Science Institutions need to be protected
- Utilities that help the village run protected
- Keep the golf course as is
- Tourism-based shops, events, etc. should be relocated
- Non-useful infrastructure should cease to exist (playground, fields)

Science centers should stay in place to maintain the history of Woods Hole. Tourism-only shops may be able to be moved back from at-risk areas with little impact to their business if traffic could be directed inland.

Infrastructure such as water mains, sewer lines and pump stations, power lines, roads are required for the village to survive. The research institutes which provide much of the reason for the village to be, also seem critical. Features like the ball park and playground are not as unique or important to me and could be allowed to flood. I enjoy Stoney Beach but realize that it may be difficult to maintain with rising sea levels.

Science institutions. Coastal home, beaches, historical buildings, etc. can be found many places, but the scientific institutions of Woods Hole are unique and similar concentrations of oceanographic research organizations only exist at a few locations on Earth.
Interviews: what we heard from Town/Residents/Institutions

Key Themes

- Residents, institutions, businesses and Town rely on one another for support, need to adapt together rather than in silos.
- Near-term preference for solutions that enhance ability to ride out storms and rebound, rather than walls or retreat.
- Long-term recognition that some non-water dependent functions can relocate, but not universally feasible.
- Long-term recognition that other assets that are water-dependent or limited alternatives may need to explore protection.
- Strong preference to maintain the existing character of the Village and maintain “third places” that facilitate innovation.
- Identity of Woods Hole Village is tied to close-knit community, working waterfront, science, business/tourism, open space.
- Desire to reduce traffic and congestion, which could enhance character and accessibility as well as open space.
- Desire to increase access to and engagement with outdoors, waterfront, and institutions (community and scientific).
Adaptation Theme: Maintain Character

Goal:
› Preserve the existing uses, historic character and community resources

Strategy:
› Leverage moderate and incremental strategies to steward the seaside community and the blue economy village identity

Representative Actions:
› wet floodproofing
› deployable site protection strategies
› building systems protection
Adaptation Theme: **Nature-based Focus**

**Goal:**
- Use nature-based solutions to enhance resiliency and ecosystem services

**Strategy:**
- Where feasible, extend the effectiveness and potential longevity of coastal green infrastructure and open space by facilitating the preservation, restoration, and migration of natural resource systems

**Representative Actions:**
- salt marsh migration/restoration
- beach/dune nourishment
- living shorelines
Adaptation Theme: **Protect/Connect**

**Goal:**
- Emphasize protection and maintenance of existing infrastructure and ensure vital connectivity

**Strategy:**
- Use hard and/or hybrid infrastructure solutions to reduce exposure of important features (municipal infrastructure, waterfront scientific assets, businesses and the residential community) and preserve critical accessways (within Woods Hole and to the waterfront)

**Representative Actions:**
- seawalls
- bulkheads
- flood walls
- landscaped berms and terracing
- elevation of land/roads/buildings/infrastructure
- dry floodproofing
Adaptation Theme: **Adaptive Realignment**

**Goal:**
- Reimagine Woods Hole through the lens of living with water

**Strategy:**
- Where existing uses and configurations cannot reasonably continue (increasing cost/risk from daily tides or common storms), develop a multi-phased plan to accommodate water with lateral or vertical relocation based on shared understanding of risk tolerance

**Representative Actions:**
- strategic elevation/relocation of buildings/infrastructure
- change in use or program
- undevelopment (retreat/buyout) for resilient open space
Adaptation Actions: Management Areas

- Fay Road
- Nobska Point
- Juniper Point
- Waterfront
- Penzance Point
- Spencer Baird
- Eel Pond / School Street
- Millfield/Gardiner
- Gansett
Adaptation Options Maps

**Storm**

- **2022**: Not applicable
- **2030**: Not applicable
- **2050**: Not applicable
- **2070**: Not applicable
- **2100**: Not applicable

**Tidal**

- **2022**: Not applicable
- **2030**: Not applicable
- **2050**: Not applicable
- **2070**: Not applicable
- **2100**: Not applicable

Legend:

- **Solid Black**: Strategy is effective in reducing impacts from a 1% chance storm event
- **Solid Gray**: Strategy is effective in reducing impacts from tidal inundation
- **Light Gray**: Strategy may be effective for some storm protection
- **White**: Strategy is no longer effective for reducing impacts from storm or tidal inundation
- **White with Line**: Strategy could be effective at an earlier time frame but is not necessary
**Management Area**

**Eel Pond School Street**

**Wet Floodproofing**
- Wet floodproofing low-lying homes. No longer effective if water floods 3rd floor. Consider elevating and wet floodproofing 3rd floor (above grade).

**Deployable Barriers**
- Deployable flood protection strategies up to 4ft for low-lying Netti/SE homes and structures along southwest face of Eel Pond, School Street, identify locations for communal storage.

**Maintain Character**
Option: Marsh Migration

Elevate School Street and increase size of culvert. Connect to School Street high water mark and south at -32.919116,59583.
Dynamic Adaptation Pathways

KEY:
- Transfer Station (can change to a different adaptation action)
- Adaptation Tipping Point (Terminal – Adaptation no longer meets goals)

- Maintain Character pathway
- Nature-based Solutions pathway
- Protect/Connect pathway
- Adaptive Realignment pathway

Change in action function

Reduced storm performance (>1%)
Addresses tidal inundation only
## Eel Pond Area

**Comments**

<table>
<thead>
<tr>
<th>Deployable Barriers (sci., mun.) +48&quot;</th>
<th>Wet Floodproofing (res.)</th>
<th>School St increase culvert and elevate</th>
<th>Dry Floodproofing (sci., com.)</th>
<th>Elevate Eel Pond bulkheads</th>
<th>Elevate Millfield Rd and parcels (res.)</th>
<th>Elevate Water St and parcels (com.)</th>
<th>Flood Barrier at Eel Pond Channel</th>
<th>Reprogram 1st fl. floodable (sci.)</th>
<th>Move ops, develop park</th>
<th>Elevate Structures (res.)</th>
<th>Buyouts &amp; convert to open space (res.)</th>
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<tbody>
<tr>
<td><img src="Smiley.png" alt="emoji" /> <img src="Smiley.png" alt="emoji" /> <img src="Sad.png" alt="emoji" /></td>
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</table>

- **Name (optional):** _____________________________________
- **Are you a resident of this area?** YES NO
- **Are you a business owner or employee in this area?** YES NO

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**RESILIENT WOODS HOLE**
Resilient Woods Hole Phase 3 Schedule

SC Mtg #1
Kickoff
10/19/21

SC Mtg #2
Plan Outreach
DEC ‘21

SC Mtg #3
Review Designs
MAR ‘22

SC Mtg #4
Review Plans
APR ‘22

SC Mtg #5
Review Report
JUN ‘22

Design Flood Elevations
Adaptation Designs and Graphics
NOV-MAR

Phasing Plan
Costing
MAR-APR

Reg. Plan
Case Studies
MAR-APR

Draft / Final Report
MAY-JUN

Site Visits
Stakeholder Interviews
OCT-NOV ‘21

Develop Outreach Materials
Story Map
DEC-MAY

Workshop #1
Vulnerability
JAN ‘22

Workshop #2
Adaptation
MAY ‘22

Final Submittal
6/30/22

CZM FY22 Due Date: June 30, 2022
How do I engage further?

- Input Map: Important Features
  tinyurl.com/RWHimportant

- Input Map: Adaptation and Vision
  tinyurl.com/RWHadaptation

- Input Map: Flooding
  tinyurl.com/RWHflooding

https://resilientwoodshole.org/
Questions?
Workshop: Coastal Management Area Stations

Room 1 (this room)
- Fay Road
- Gansett
- Nobska Point
- Juniper Point
- Penzance Point

Room 2 (next door)
- Spencer Baird
- Eel Pond / School Street
- Millfield/Gardiner
- Waterfront
Thank you

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