Challenges in Planning, Design and Construction of Coastal and Inland Infrastructures to Adapt to New Flood Elevations and Climate Changes

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Presentation overview

- Introduction
  - Climate change
  - Design approach
- Case studies
  - Case Study No. 1
  - Case Study No. 2
- Questions

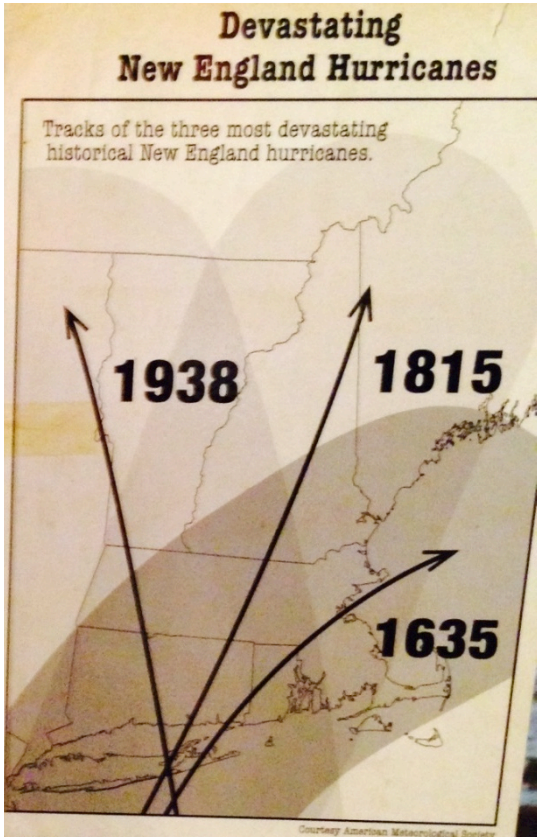
Climate change

U.S. Army Corps of Engineers

- Change in frequency and intensity of storms
- Global sea level rise
- Financial damages
  - National Weather Service and Insurance Information Institute: 9 out of the top 10 costliest natural disasters in the United States were climate related (hurricanes, floods, droughts) between 1980 and 2010
    - 7 were from hurricanes and floods
  - FEMA: 8 out of the top 10 costliest natural disasters in the United States were caused by coastal storms
- Importance of protecting equipment and infrastructure

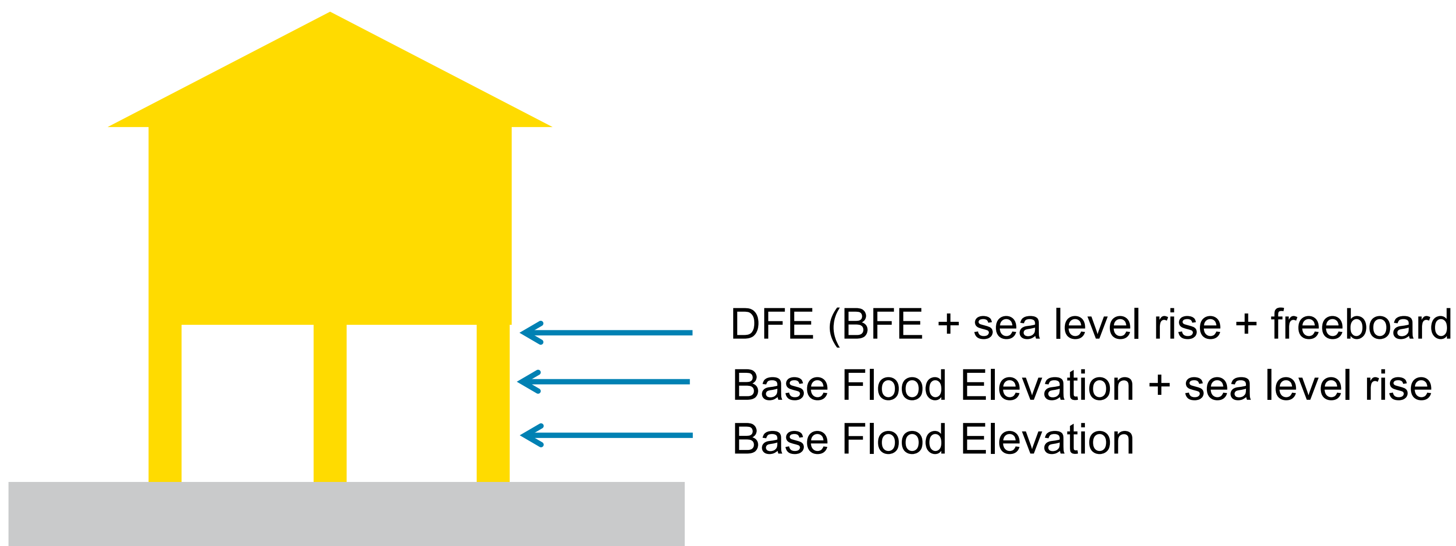
Past Devastating New England Hurricanes

- New England has been hit by a major hurricane approximately once every 100 years
- FEMA has recently updated its flood maps – Base Flood (1% annual chance) covers larger land area than in previous flood maps
- Flood elevations expected to continue to change with sea level rise

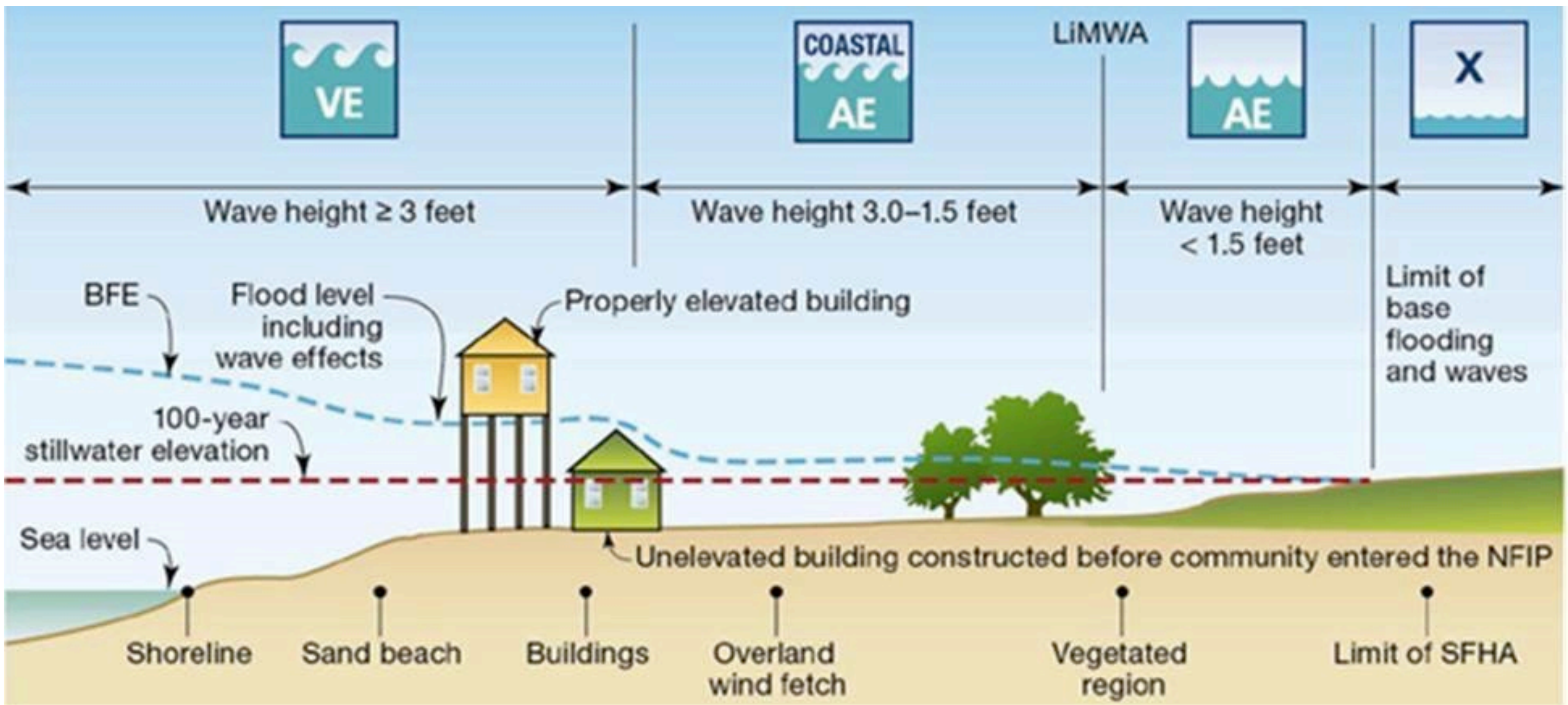


Design approach – determine design flood elevation

Design Flood Elevation (DFE) =
Base Flood Elevation (BFE) + sea level rise + freeboard

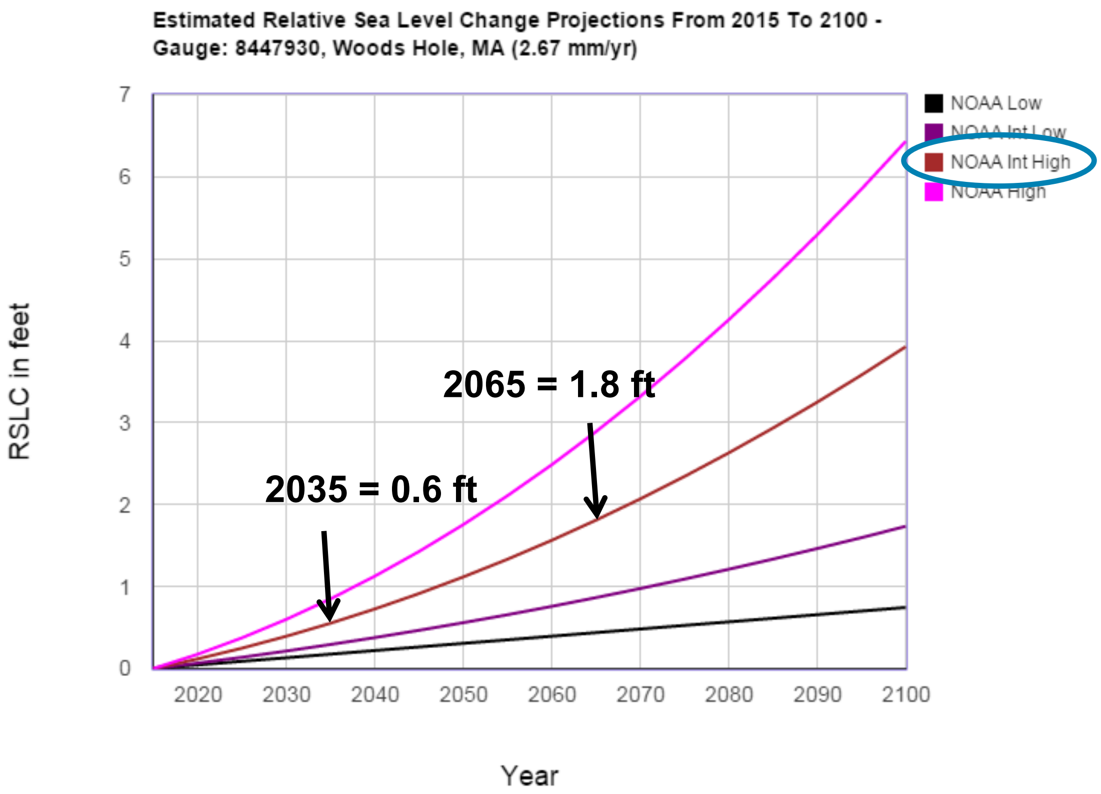


FEMA coastal flood hazard zones and base flood elevation



Sea level rise projections

- National Oceanic and Atmospheric Administration (NOAA) sea level change projections
- 2035 used for all proposed mechanical improvements
- 2065 used for all proposed structural improvements



Freeboard – ASCE & FEMA

FEMA's "Guidance for Applying ASCE 24 Engineering Standards to 6 HMA Flood Retrofitting and Reconstruction Projects" references ASCE 24 – Flood Resistant Design and Construction

- Determine classification of structures
  - Category I, II, III and IV
- Determine which FEMA flood zone the structures and equipment will be located
  - For example, AE zone, Coastal AE zone, etc.
- Look up corresponding table for minimum elevations for equipment and first floor
  - Include freeboard numbers

Freeboard for utilities, equipment and structures

- Example – structure category III & IV in AE zone

Structure category	Freeboard Requirements
I (low hazard to human life in event of failure)	No specific requirements. Use Design Flood Elevation (DFE)
II (not listed in Categories I, III & IV)	1 foot
III (substantial hazard to human life in event of failure)	1 foot
IV (essential facilities)	2 feet

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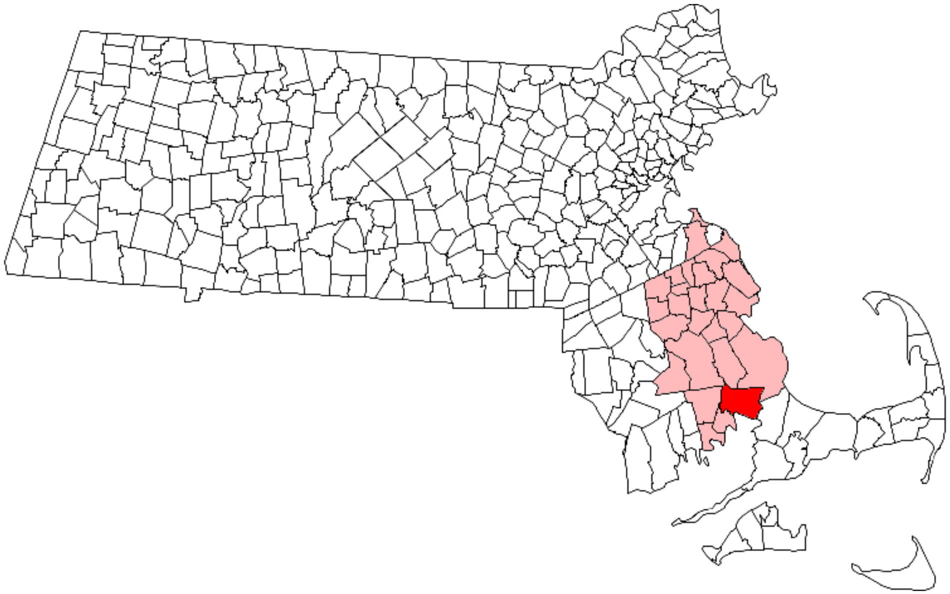
Case Study 1 general information

- Southeastern part of Massachusetts
- Coastal community
- 43 pump stations and 1 wastewater treatment plant
- Vulnerability report in draft form awaiting town approval



Case Study 1 challenges

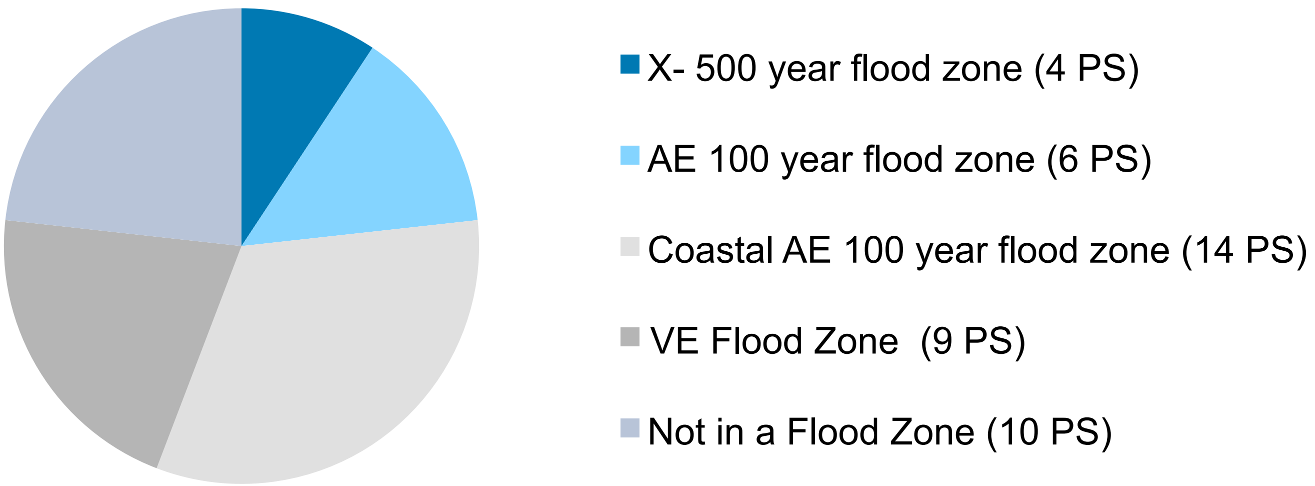
Challenges during study phase of the project

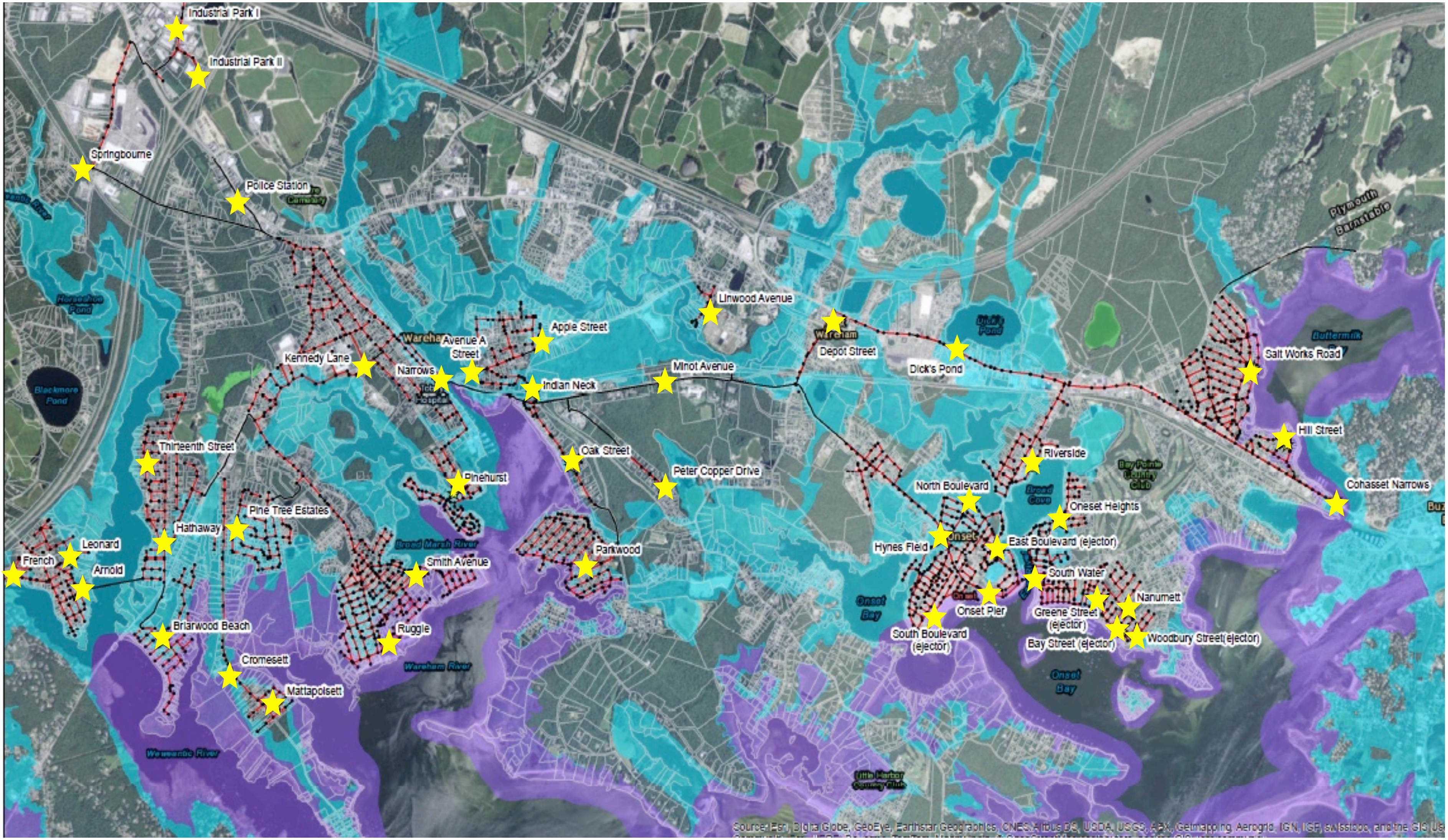
- Significant number of pump stations that need upgrades
- Prioritizing the upgrades
- Limitations on the Hazus® MH software developed by FEMA
  - Determines the loss estimation on the direct cost of damages and indirect economic impacts
- Feasibility to design and execute the proposed upgrades

Case Study 1 challenges – challenge 1

Significant number of pump station that need upgrades

- 29 of the Town's 43 pump stations are located within the 100-year flood plain
- 29 out of 43 pump stations arte in vulnerable locations



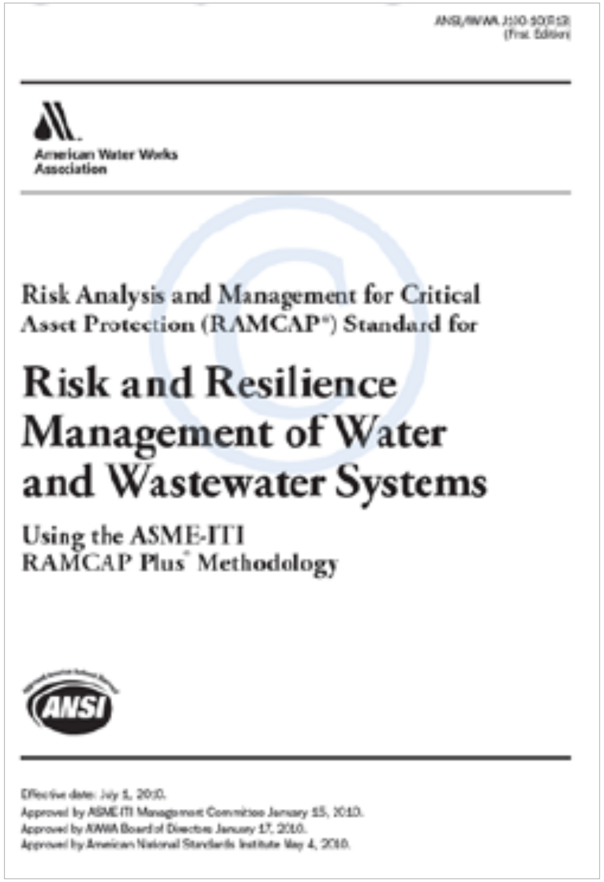

Industrial Park I
Industrial Park II
Springbourne
Police Station
Linwood Avenue
Apple Street
Avenue A
Street
Kennedy Lane
Narrows
Indian Neck
Minot Avenue
Depot Street
Dick's Pond
Salt Works Road
Hill Street
Thirteenth Street
Oak Street
Pinehurst
Peter Copper Drive
Riverside
North Boulevard
Onset Heights
Cohasset Narrows
Pine Tree Estates
Hathaway
Leonard
French
Arnold
Smith Avenue
Parkwood
Hynes Field
East Boulevard (ejector)
South Water
Nanumett
Onset Pier
Greene Street (ejector)
South Boulevard (ejector)
Bay Street (ejector)
Woodbury Street(ejector)
Briarwood Beach
Ruggle
Cromesett
Mattapoisett
Blackmore Pond
Horseshoe Pond
Broad Marsh River
Wareham River
Weweantic River
Onset Bay
Broad Cove
Buttermilk Bay
Bay Pointe Country Club
Plymouth
Barnstable


Wareham
Apple Street
Avenue A Street
Kennedy Lane
Narrows
Hospital
Indian Neck
Oak Street
Pinehurst
tes
Broad Marsh River
Parkwood
Smith Avenue
Ruggle

Case Study 1 challenges – challenge 2

Prioritizing the upgrades

- Calculate the flood risk for each pump station
- According to the J100 document
  - Flood risk = threat likelihood x total loss
  - Threat likelihood = 1% annual chance of flooding (base flood)
  - Total loss = “sum of repair and replacement costs and losses due to lost production capability and other first effects” (see Challenge 3 in upcoming slides)


American Water Works Association

Risk Analysis and Management for Critical Asset Protection (RAMCAP®) Standard for

Risk and Resilience Management of Water and Wastewater Systems

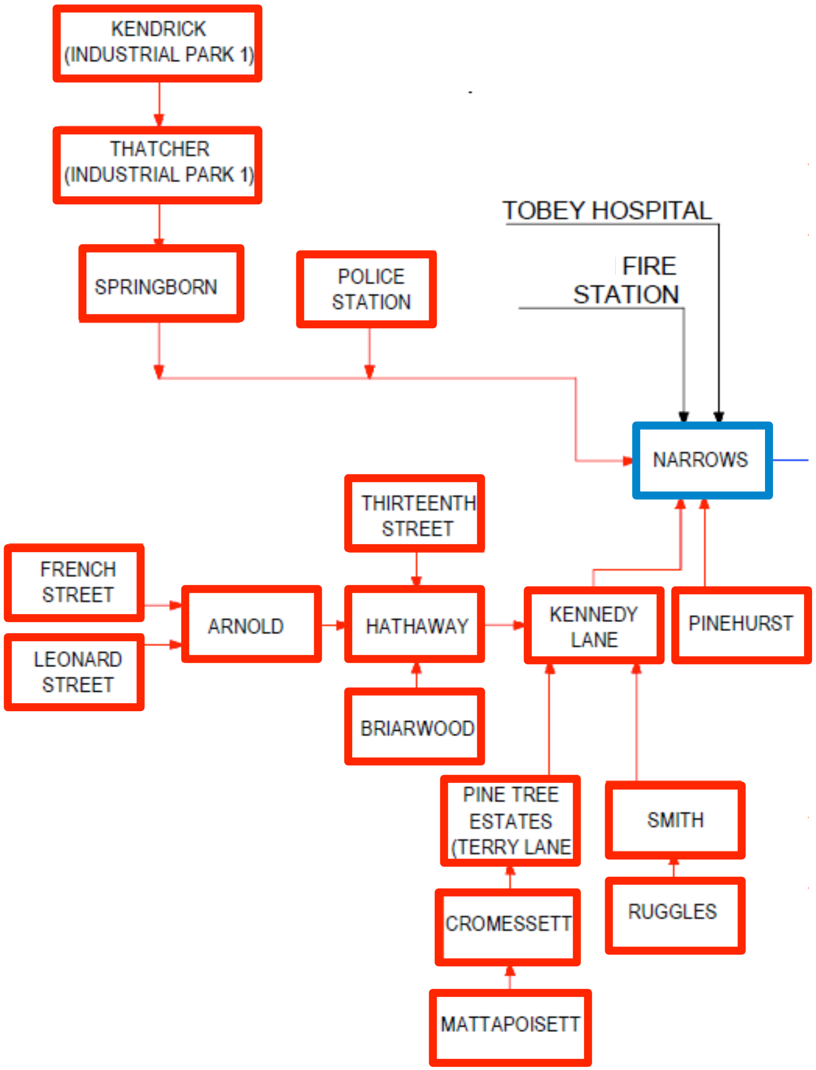
Using the ASME-ITI RAMCAP Plus® Methodology

ANSI

Wareham challenges – challenge 2

Example – Narrows Pump Station

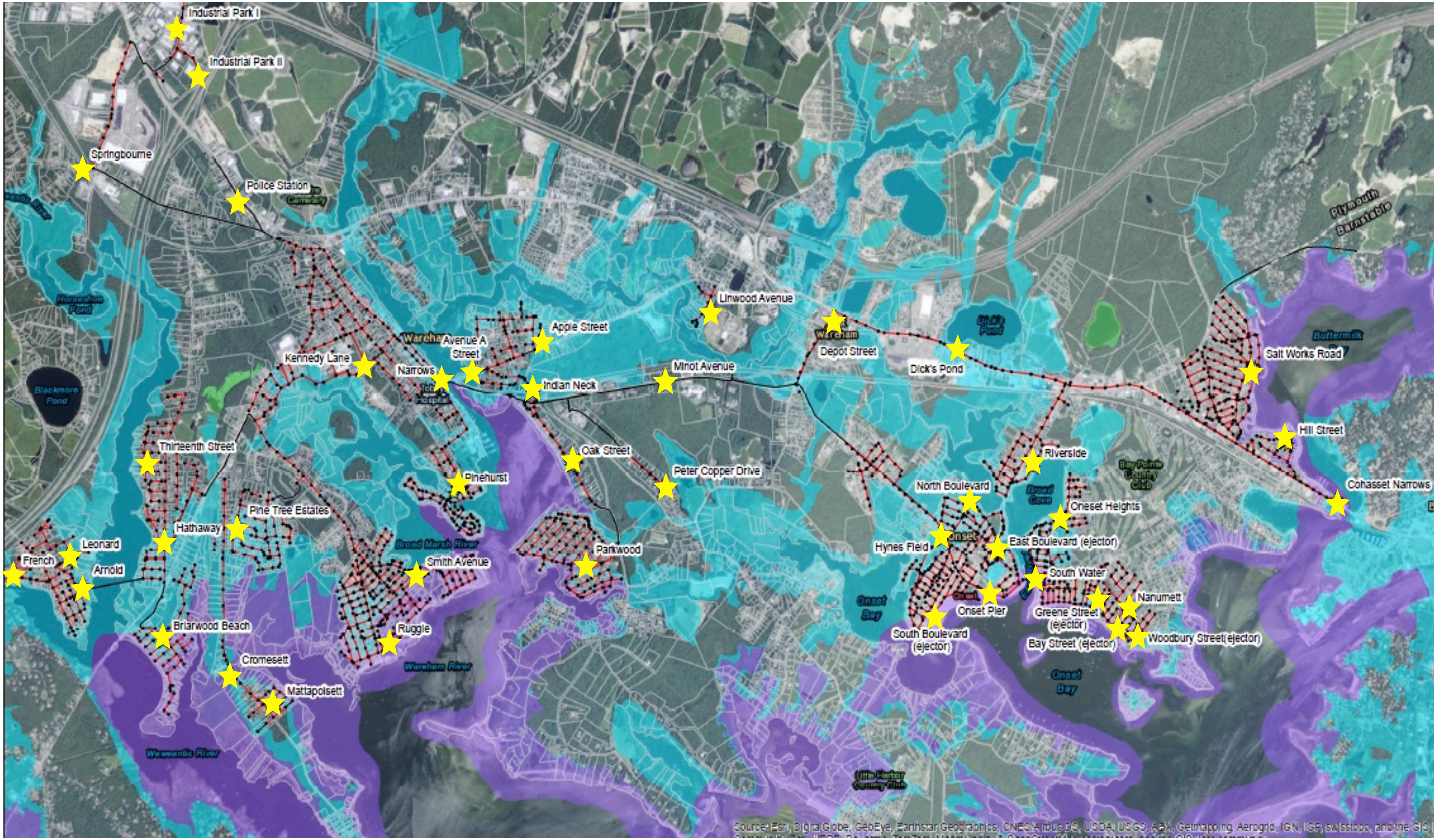
- 17 pump stations, 1 hospital and 1 fire station contribute flows into Narrows Pump Station
- More significant damage if Narrows Pump Station is down
- Higher in priority list



Case Study 1 challenges – challenge 3

Limitations on the Hazus® MH software developed by FEMA

- Two options to determine total loss estimation
  - Hazus® MH software developed by FEMA
    - Complex coastlines
    - Difficult to use in this project
    - Better experience with a simpler coastline in California
  - Benefit Cost Analysis (BCA) software developed by FEMA
    - Used in this project
    - Produces a benefit-cost ratio (BCR)
    - Proposed mitigation justifies proposed project costs if BCR greater or equal to 1.0



GHD

GHD @ NEWEA 2016

Case Study 1 challenges – challenge 3

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Case Study 1 challenges – challenge 4

Feasibility to design and execute the proposed upgrades

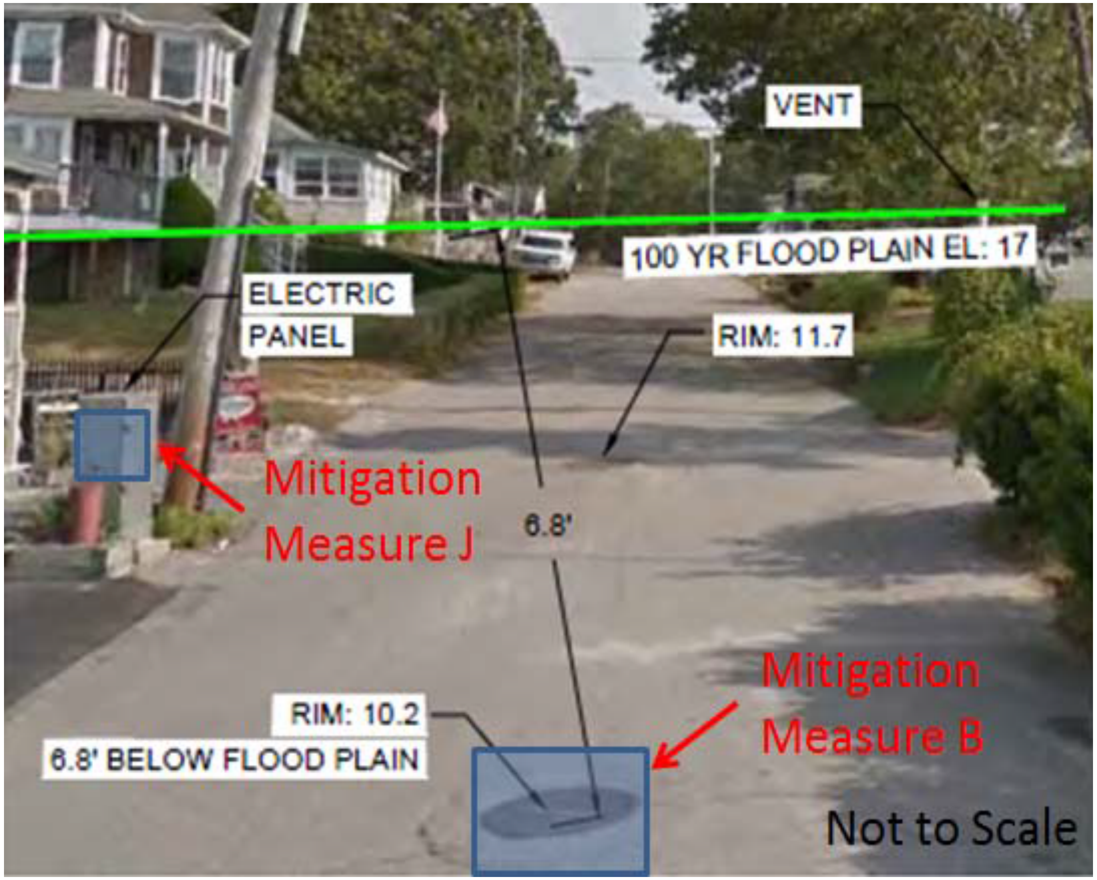
- Equipment at least 8 feet above grade to be protected from flood damage in many cases

Some of the mitigation methods

- Dry flood proofing
- Wet flood proofing

Case Study 1 challenges – challenge 4

Example 1 – Bay Street Pump Station



Case Study 1 challenges – challenge 4

Example 2 – Leonard Street Pump Station

Case Study 1 next steps

Seek funding to perform the following

- Town-wide Hazard Mitigation Plan in order to quality for FEMA funding
- Conceptual design on the top 3 most critical pump stations
  - Conduct meetings with building code officials to discuss potential code variances

Conduct follow-up educational workshops with hazard planning agencies

- National Weather Service, FEMA, MEMA, CZM, department heads, building code official
  - FEMA does not recommend dry flood proofing for areas where flood depths are greater than 2-3 feet above finished floor) and where flooding is expected to persist over 12 hours

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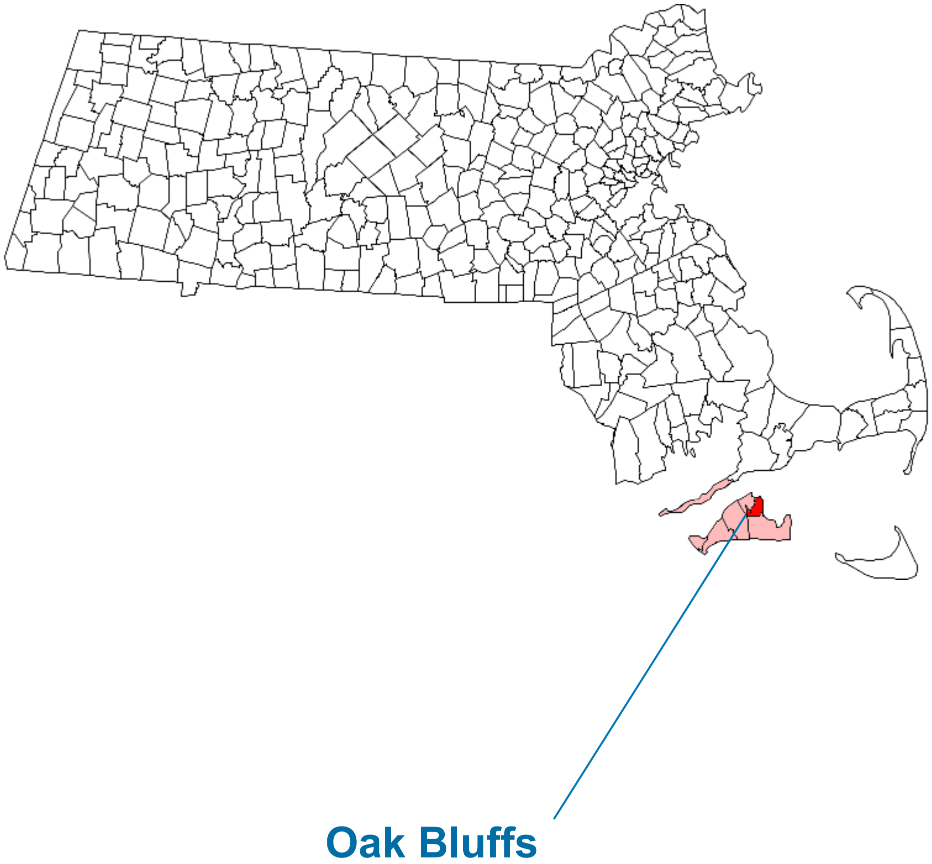
Case Study 2 general information

- Town of Oak Bluffs
- Northern part of Martha's Vineyard
- 3 pump stations in vulnerable locations and 1 wastewater treatment plant



Case Study 2 location of existing pump stations

Case Study 2 FEMA flood map (location of existing pump stations)

Case Study 2 Lake Avenue Pump Station

Area Served by this pump station

- Main business/commercial district in Oak Bluffs

Problems

- Generator connection point inaccessible during flood (Town has portable generator)

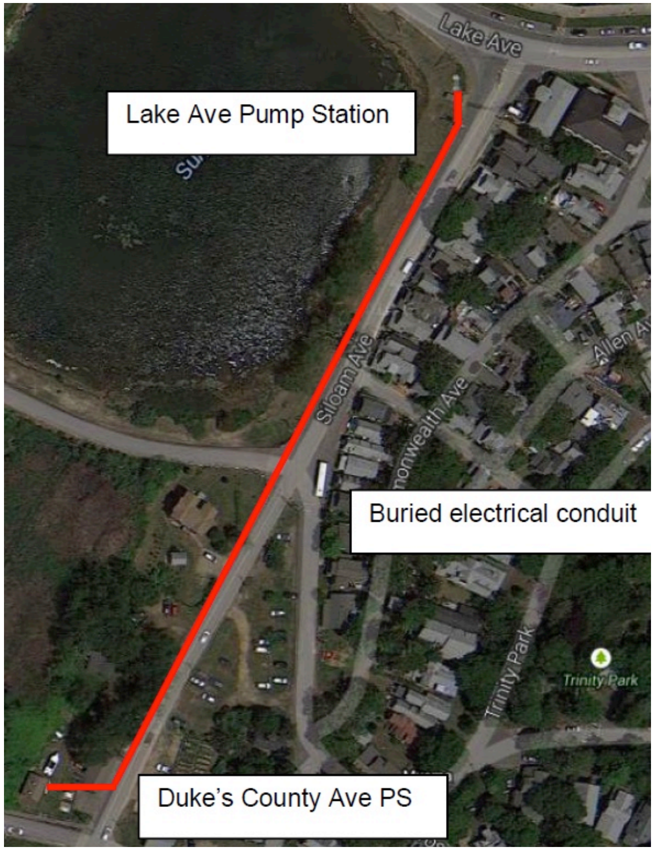
Challenges

- Groundwater table is about 2 feet below grade

Case Study 2 Lake Avenue Pump Station

Mitigation (this project)

- Install power conduit from Duke's County Avenue Pump Station to Lake Avenue Pump Station
  - Nearly 1000 linear feet of electrical ductbank



Case Study 2 Duke's County Avenue Pump Station

Area served by this pump station

- Largest pump station in Oak Bluffs
- Serves nearly the entire sewered population

Problems

- Codes prohibit generator to be indoors

Challenges

- Proposed generator in wetland
- Proposed generator location owned by Martha's Vineyard Campground

Case Study 2 Duke's County Avenue Pump Station

Mitigation (this project)

- New diesel generator
  - Outdoors adjacent to the pump station building
  - On steel platform on concrete pad

Case Study 2 next steps

Seek funding to address the long term mitigation solutions for three vulnerable pump stations

- Our Market Pump Station
  - Watertight hatch in submersible pump station
  - Install controls in an immersible enclosure (NEMA 6P)
- Lake Avenue Pump Station
  - Watertight hatch in submersible pump station
  - Mount new control panel in Duke’s County Ave Pump Station
- Duke’s County Avenue Pump Station
  - Wooden building in vulnerable location putting electrical equipment at risk


Thank you!
Questions?
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Wareham general information

Local hurricanes

- Great New England Hurricane of 1938
  - 1.18 annual percent chance of occurrence
  - “85 year” flood
- Hurricane Carol (1954)
  - 1.43 annual percent chance of occurrence
  - “70 year” flood

Design for 100 year flood per TR-16

- Conservative enough

Wareham project information

Base flood elevation

- 14 ft

Sea level rise

- 0.6 ft for mechanical equipment and wooden buildings
- 1.8 ft for concrete and masonry

Freeboard

- As recommended per ASCE 24-14
- Depending on application, FEMA flood zone, flood design class
- 1 ft or 2 ft for this project

FEMA flood zones

- Special flood hazard area
- Moderate flood hazard area
- Minimal flood hazard area

FEMA flood zones – special flood hazard area

Zone	Brief descriptions
V	Areas along coasts subject to inundation by the 1%-annual-chance flood event (100-year flood) with additional hazards associated with storm-induced waves. No Base Flood Elevations (BFEs) or flood depths shown.
VE & V1-30	Areas subject to inundation by the 1%-annual-chance flood event with additional hazards due to storm-induced velocity wave action. BFEs shown.
A	Areas subject to inundation by the 1%-annual-chance flood event. No BFEs or flood depths shown.
AE & A1-30	Same as Zone A with BFEs shown
AH	Areas subject to inundation by 1%-annual-chance shallow flooding (usually areas of ponding) where average depths are between 1 and 3 feet. BFEs shown.

FEMA flood zones – special flood hazard area

Zone	Brief descriptions
AO	Areas subject to inundation by 1%-annual-chance shallow flooding (usually sheet flow on sloping terrain) where average depths are between 1 and 3 feet. Average flood depth shown.
AR	Areas that result from the decertification of a previously accredited flood protection system that is determined to be in the process of being restored to provide base flood protection.
A99	Areas subject to inundation by the 1%-annual-chance flood event, but which will ultimately be protected upon completion of an under-construction Federal flood protection system. These are areas of special flood hazard where enough progress has been made on the construction of a protection system, such as dikes, dams, and levees, to consider it complete for insurance rating purposes. Zone A99 may only be used when the flood protection system has reached specified statutory progress toward completion. No BFEs or depths shown.

FEMA flood zones – moderate flood hazard area

Zone	Brief descriptions
B or X (shaded on Flood Insurance Rate Map)	Areas between the limits of the base flood and the 0.2%-annual-chance (or 500-year) flood.

FEMA flood zones – minimal flood hazard area

Zone	Brief descriptions
C or X (unshaded on Flood Insurance Rate Map)	Areas outside the Special Flood Hazard Area and higher than the elevation of the 0.2%-annual-chance flood.

Oak Bluffs our market pump station

Area served by this pump station

- A market
- Residential
- Lone Restaurant – remained open after Hurricane Sandy

Problems

- Existing electrical panel is installed too low

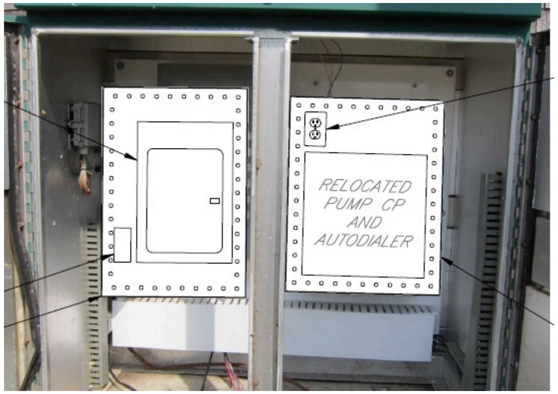
Challenges

- Location of panel is in a tourist location
- Visibility of panel at new location

Oak Bluffs our market pump station

Mitigation (this project)

- Install controls in an immersible enclosure
  - NEMA 6P
  - Heavy duty, stainless steel construction

Wareham project information

Objectives of the project

- Conduct a risk and vulnerability assessment as it relates to coastal flooding and climate change
- Provide recommended improvements for the pumps stations to help them be more resilient to coastal flooding events
- Develop emergency management plan for WW infrastructure as it relates to coastal flooding and climate change

Study phase completed in January 2016

Project cost - $125,000

- 75% grant funding through Coastal Community Resilience Grant Program administered by MA Office of Coastal Zone Management
- 25% town cost sharing

Freeboard for structures

- Example – structure category III & IV in AE zone
- Table 2-1 minimum elevation of the top of lowest floor relative to BFE or DFE flood hazard areas other than coastal high hazard areas and coastal A Zones

Structure category [1]	Flood hazard areas
I	DFE
II	BFE + 1 ft or DFE, whichever is higher
III	BFE + 1 ft or DFE, whichever is higher
IV	BFE + 2 ft or DFE, whichever is higher

[1] See table 1-3 in this document for structure category descriptions.
BFE = Base Flood Elevation
DFE = Design Flood Elevation
Ft = feet
Source: ASCE 24-05, table 7-1

Sea level rise – general

Primary factors of sea level changes

- Thermal expansion of sea water due to ocean warming
- Melting of glacier / ice sheets

Basis of design

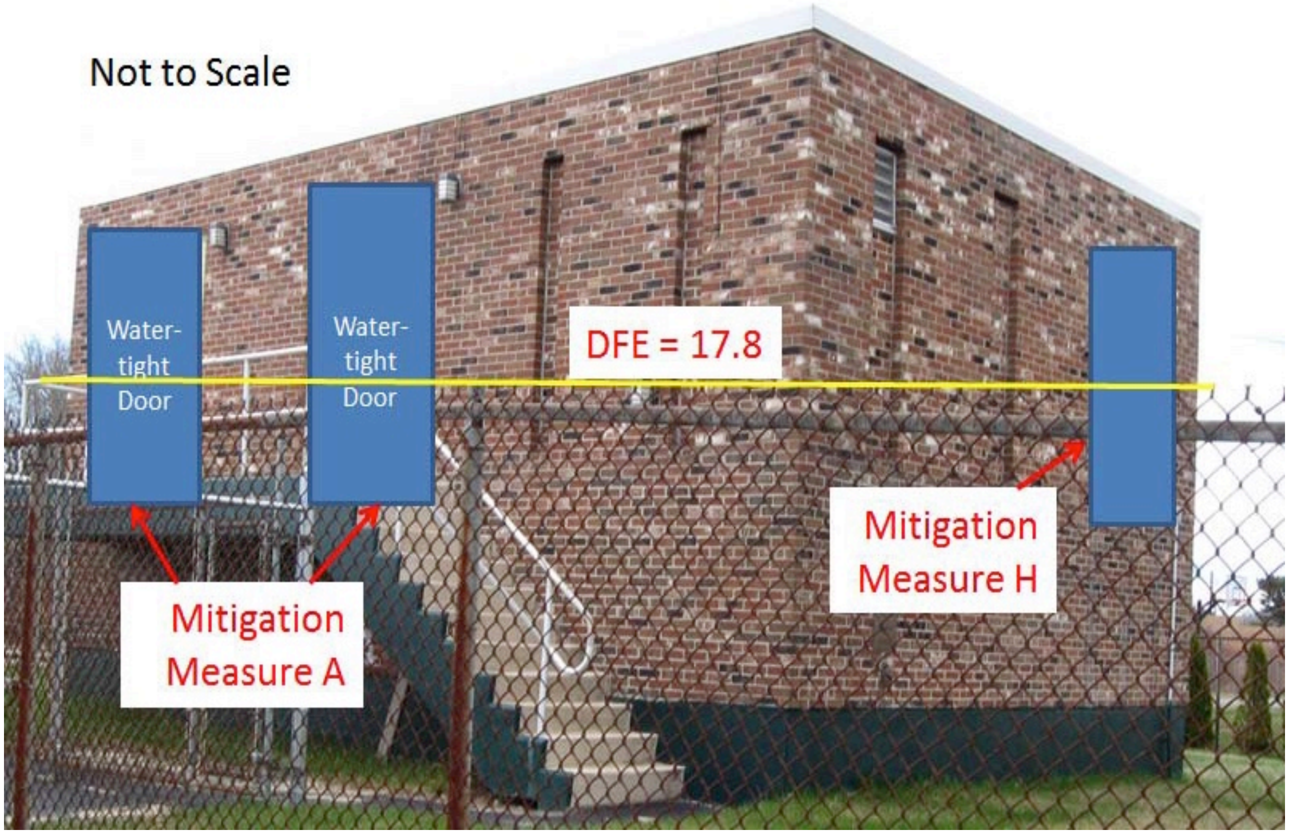
- Equipment are designed to have a 20-year life span
- Masonry and concrete structures are designed to have a 50 to 100-year life span

Case Study 2 project information

- Objective
  - Address short term mitigation solutions
- Construction completed in July 2015
- Project cost - $250,000
  - 75% grant funding through Coastal Community Resilience Grant Program administered by MA Office of Coastal Zone Management
  - 25% town cost sharing
  - Additional funding will be needed to address long term mitigation solutions

Case Study 1 challenges – challenge 4

Example 3 – Hynes Field Pump Station



Wareham challenges – challenge 4

Example 4 – Saltworks Road Pump Station

Case Study 2 Lake Avenue Pump Station

Additional big challenges

- High water table
  - Only 2 feet below grade
- Material costs, especially gravel and concrete, are higher on the island than in-land

Construction alternatives

- Perform directional drilling in lieu of traditional trenching for the ductbank
  - Lower costs and faster installation
  - Installation completed in just 2 days