THE UNIVERSITY OF RHODE ISLAND

THINK BIG WE DO™

Evaluation of Storm Surge & Sea Level Rise in Wickford, RI

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Acknowledgments

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Presentation Outline

Background

Problem Statement

Study Objectives

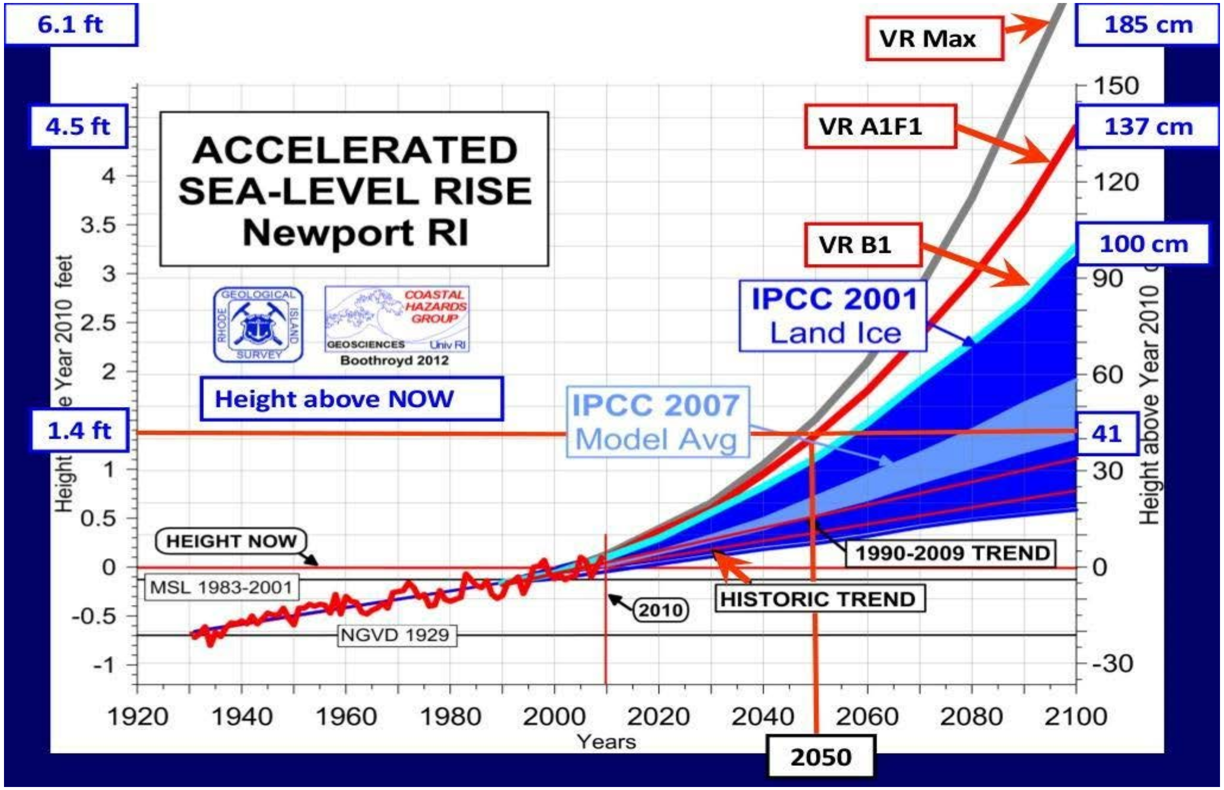
Analysis of Storm Return Probability

Recreation of FIRM

Mitigation

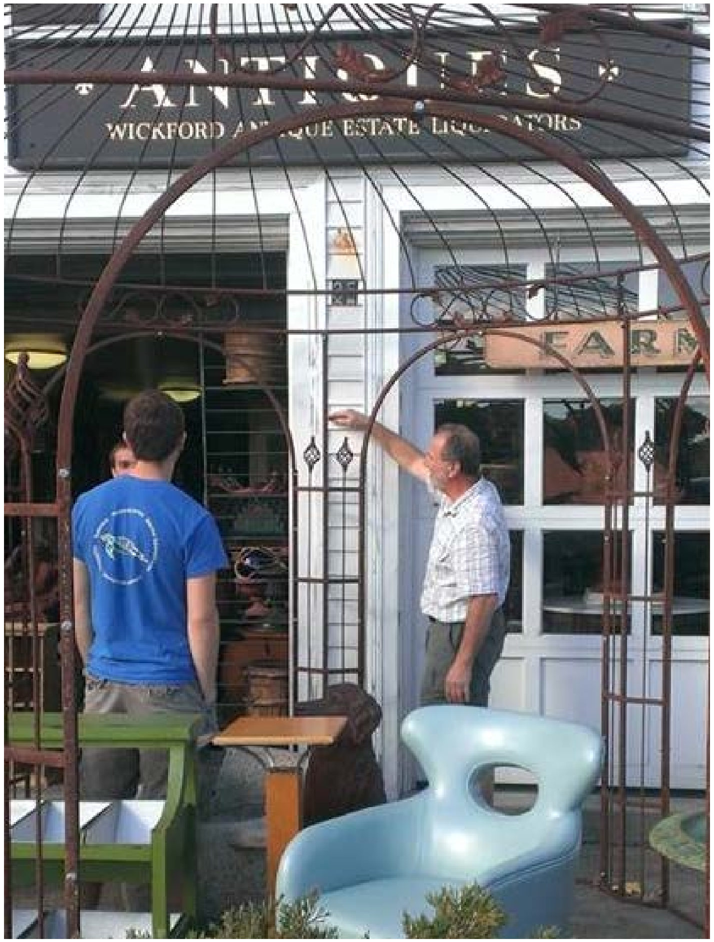
Background

- The Rhode Island Coastal Resources Management Council (CRMC) projects that sea-level will rise 3 to 5 feet over the next 100 years, causing more flooding from storm surge in Wickford.



Background

Town of Wickford, RI



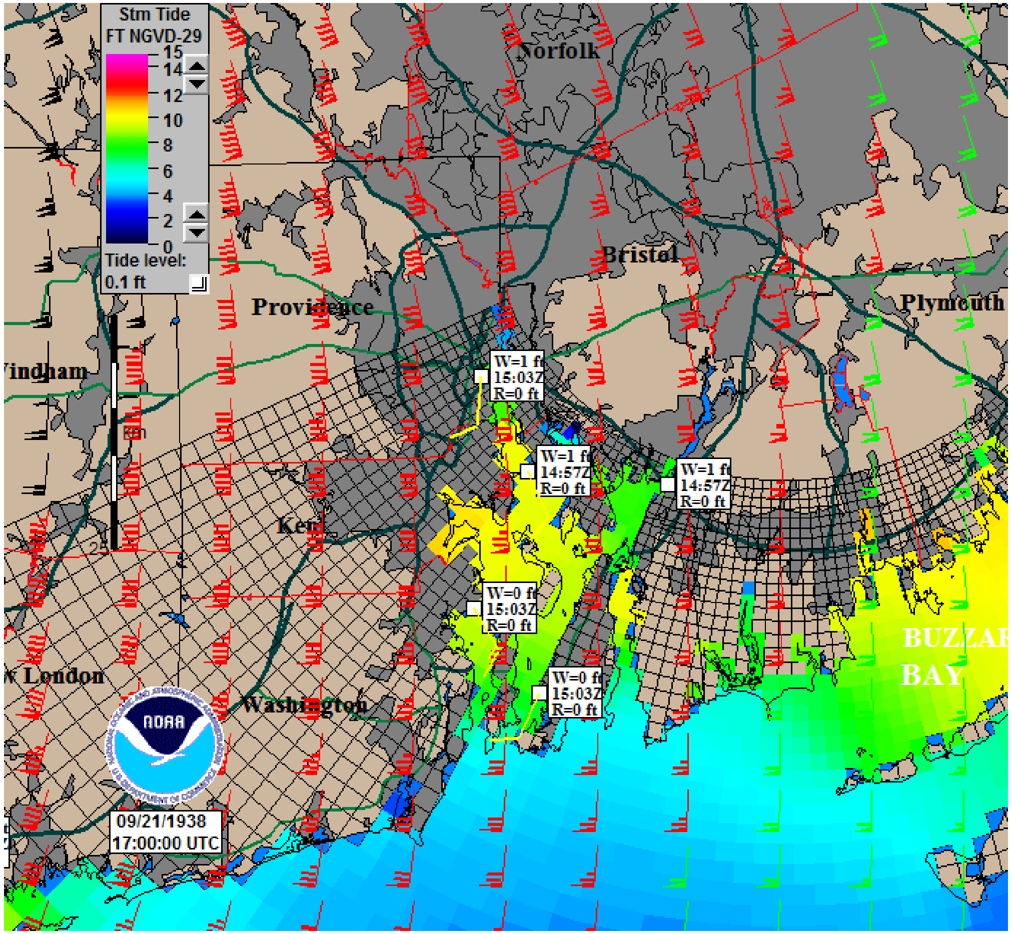
Hurricane of ’38 High Water Mark

- Prepare community for natural disasters
- Preserve the historic district of the town
- Emulates many small town coastal communities
- Wickford is no stranger to storm events

Flooded Parking lot during high tide
Photo :Teresa Crean

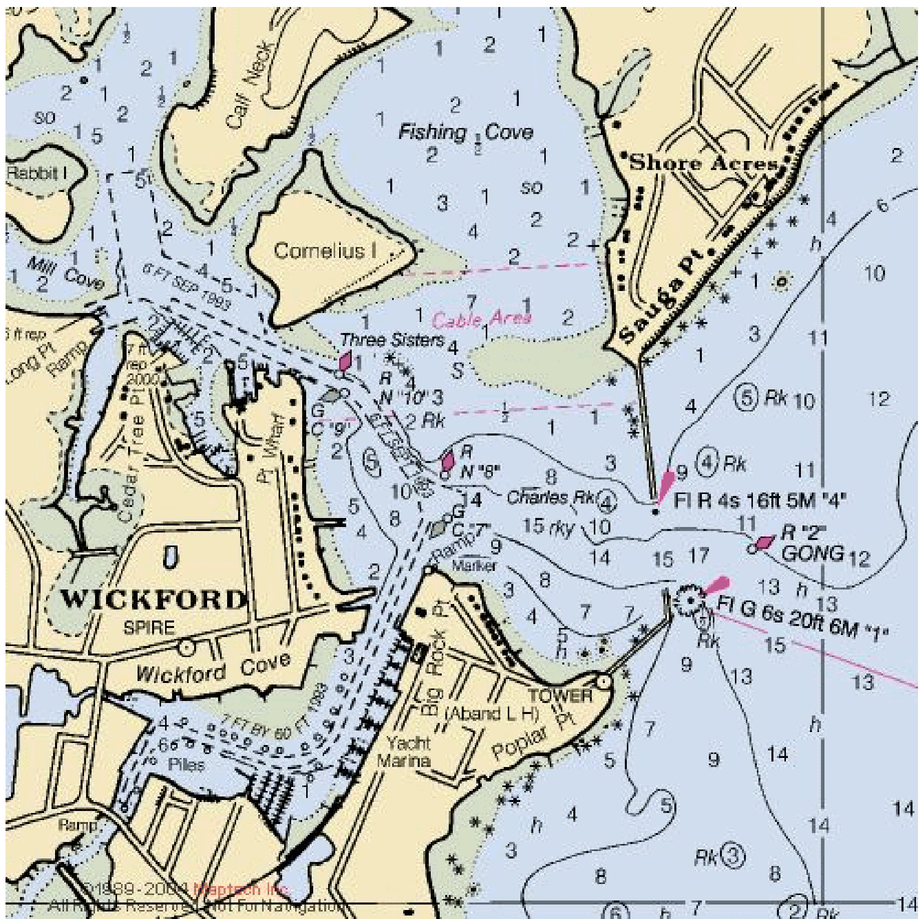
Background
Wickford, RI

- Storm surge has had significant affect on Wickford harbor and surrounding areas.
- The Federal Emergency Management Agency (FEMA) mandates the risk of flooding along with the National Flood Insurance Program (NFIP). Flood Insurance Studies (FIS) are then produced and provide Flood risk Analysis by Zoning Maps.
- Flood Insurance Rate Maps (FIRMs) have flooding zones determined by the local Flood Insurance Study.



Problem Statement

Conduct an analysis of storm surge and sea level rise for Wickford, RI and determine possible mitigation techniques to prevent flooding.



Study Effects of Storm Surge and Sea Level Rise

Study FEMA Methods

- Literature of FEMA stating their intentions and methods
- FEMA 2009, 2012 Flood Insurance Rate Maps(FIRM)

Storm Surge Analysis

- Extreme Value Analysis
- Confirmation of Linear Interpolation
- Return Probability Period

Coastal Model

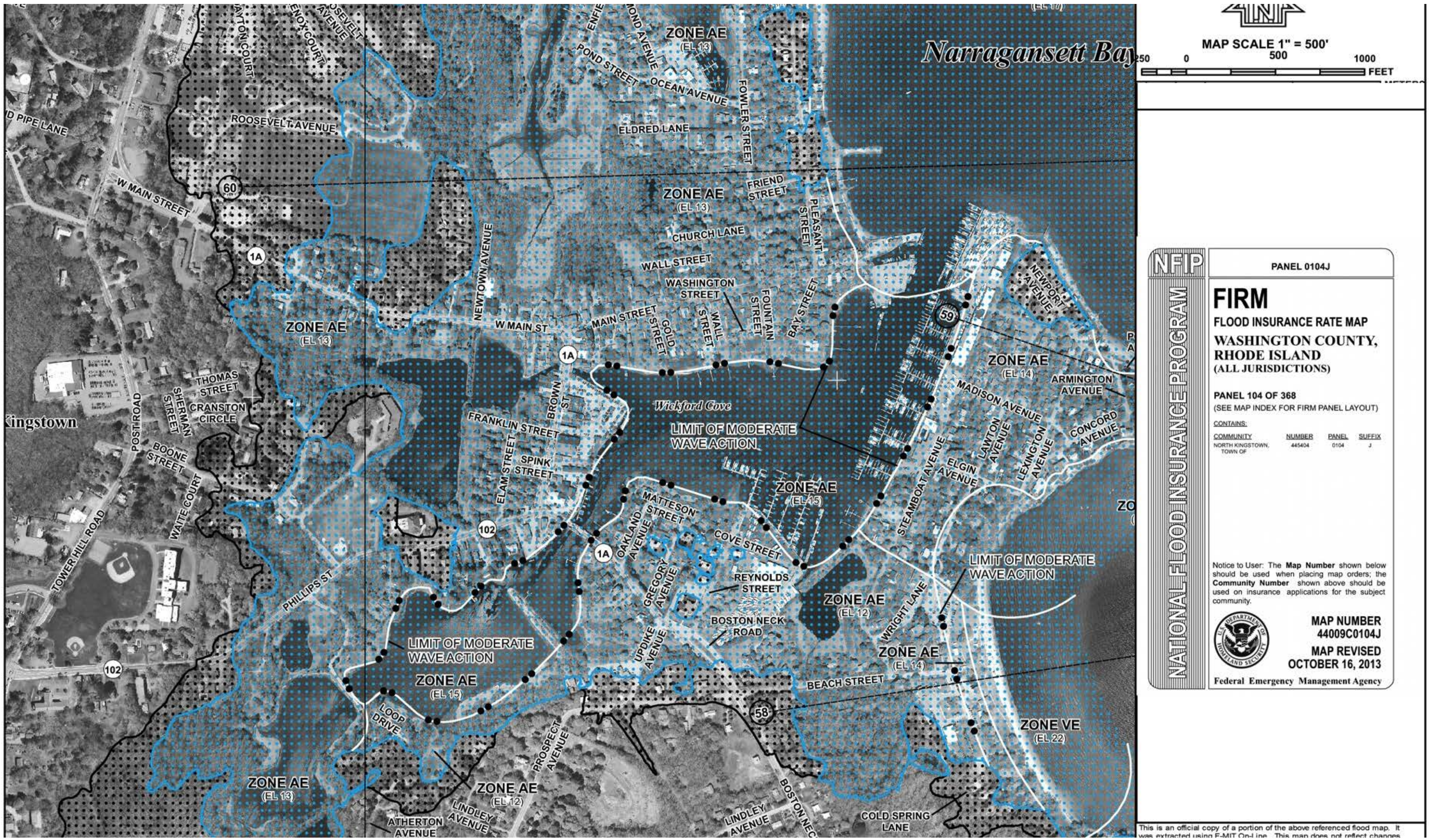
- Coastal Hazard Analysis Modeling Program
- Flood zone generation
- Recreation of 2012 FIRM

Mitigation Strategies

- Review of barrier options to prevent flooding
- Possible locations for barriers in choke points.
- Areas of where mitigation barriers are functional.

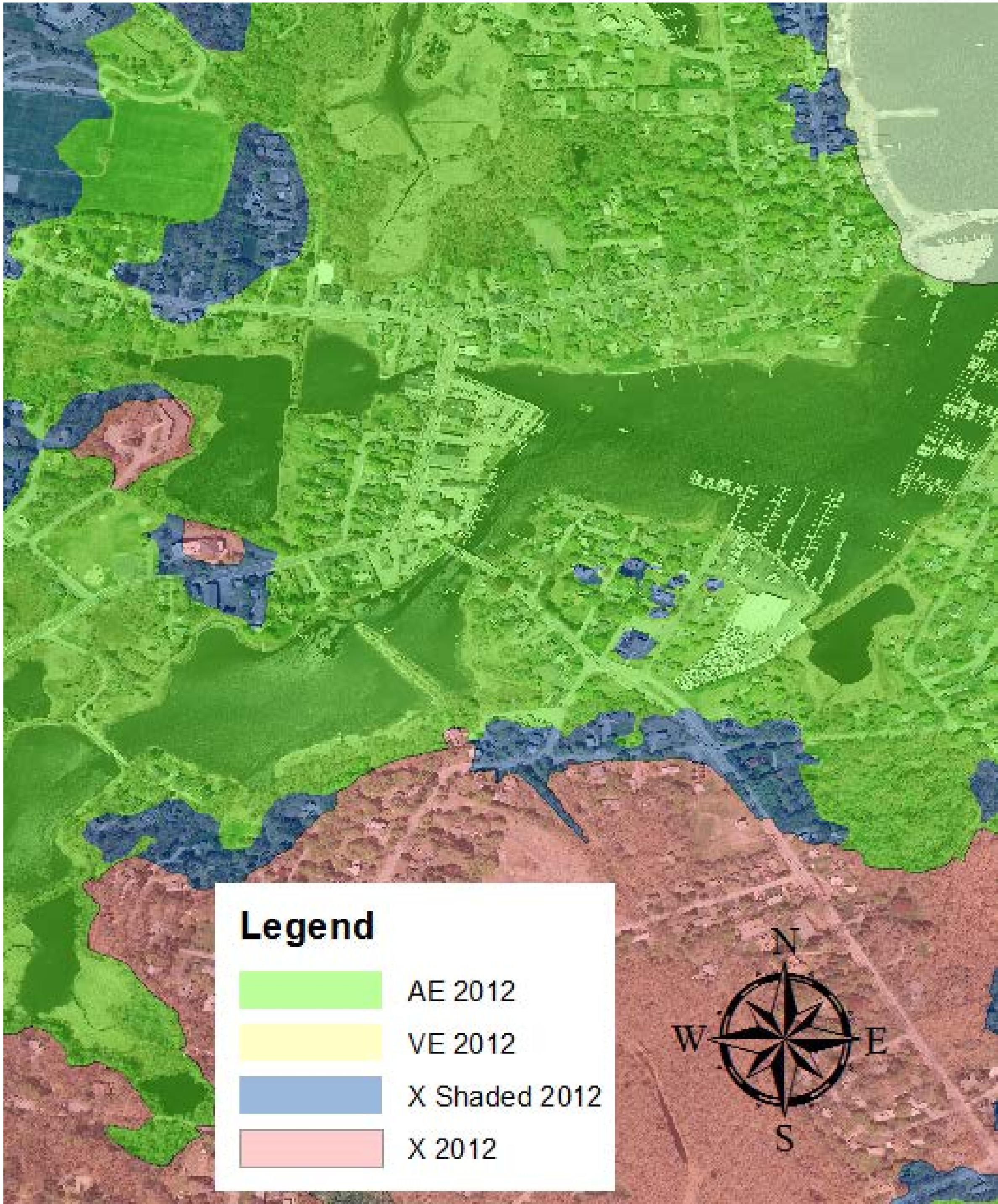
2012 FIRM

Inner Wickford Harbor



2012 FIRM

To make the FIRM more understandable ArcGIS was used.

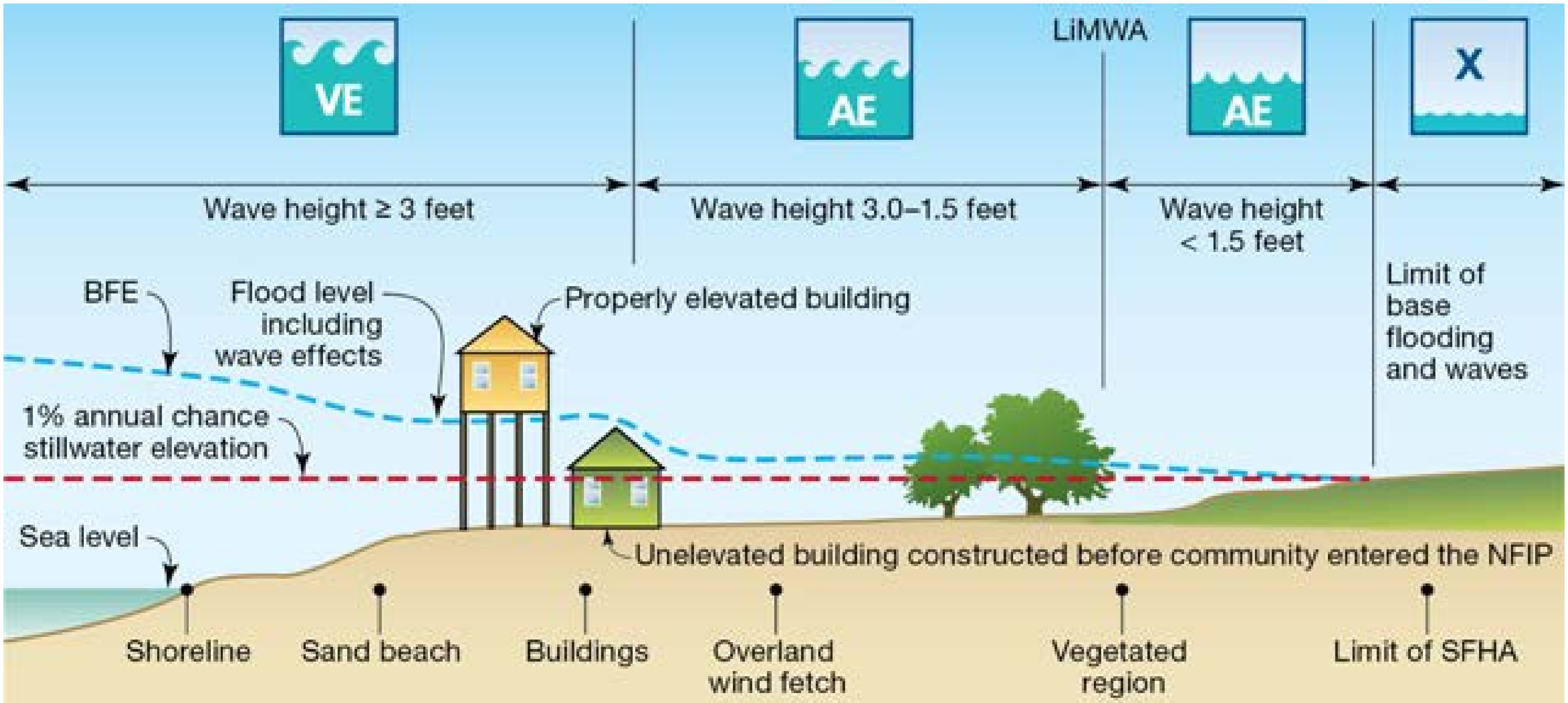


Federal Emergency Management Agency

- The creation of Flood Insurance Rate Map (FIRM) are beneficial to risk assessment for coastal communities

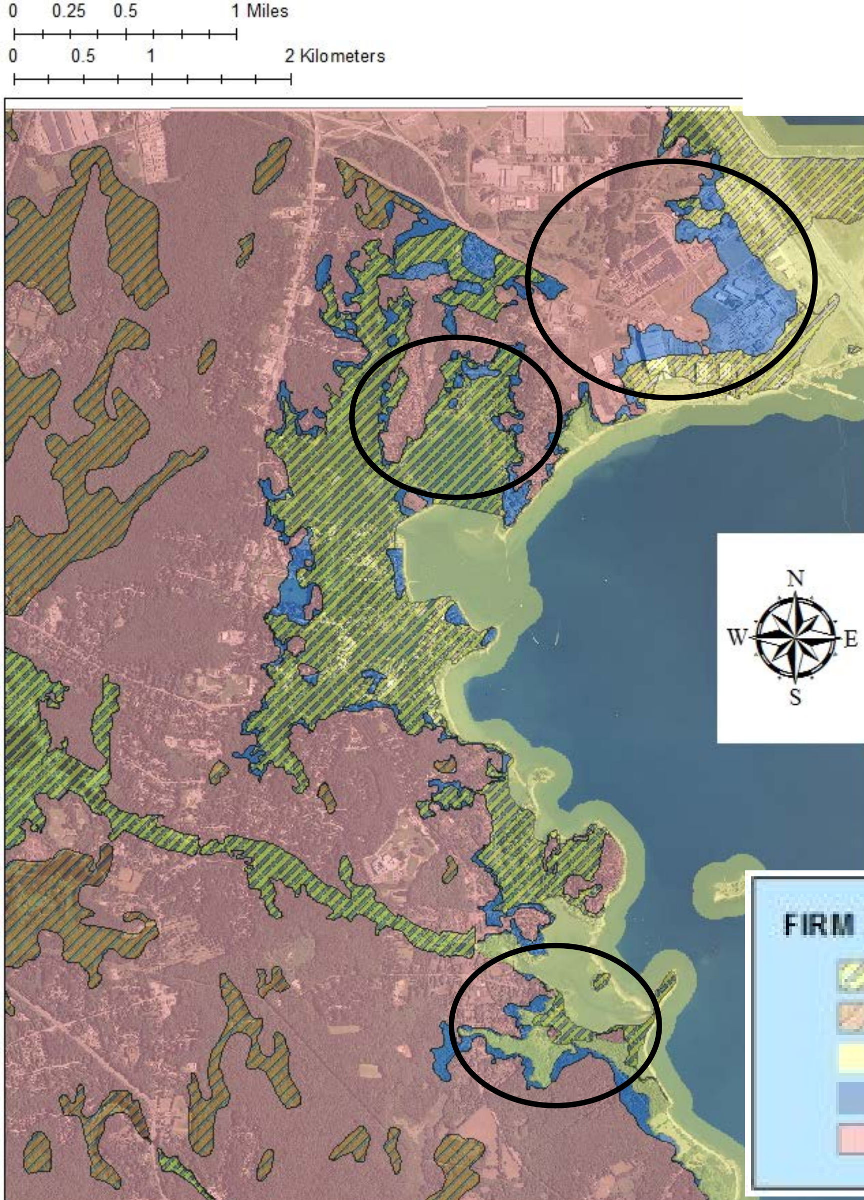
VE Zone	Flooded area with more than three feet of wave action from 100 year storm
AE Zone	Flooded area with less than three feet of wave action from 100 year storm
X Shaded	This area is flooded by the 500 year storm but not the 100 year
X	This area is not flooded at all

Background
Stillwater Elevation Level

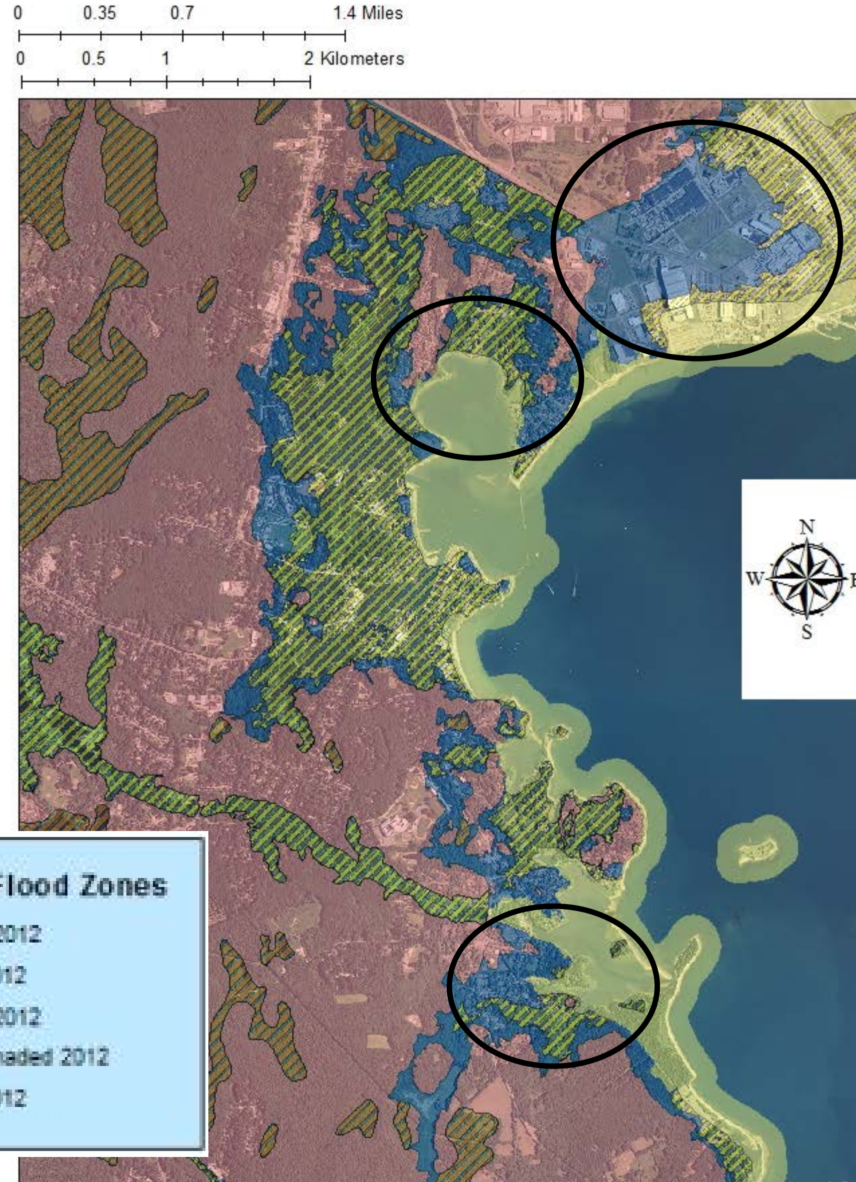


http://www.r3coastal.com/home/coastal-hazard-analysis-mapping/coastal-flood-hazard-mapping

FIRM 2009 Flood Zones



FIRM 2012 Flood Zones

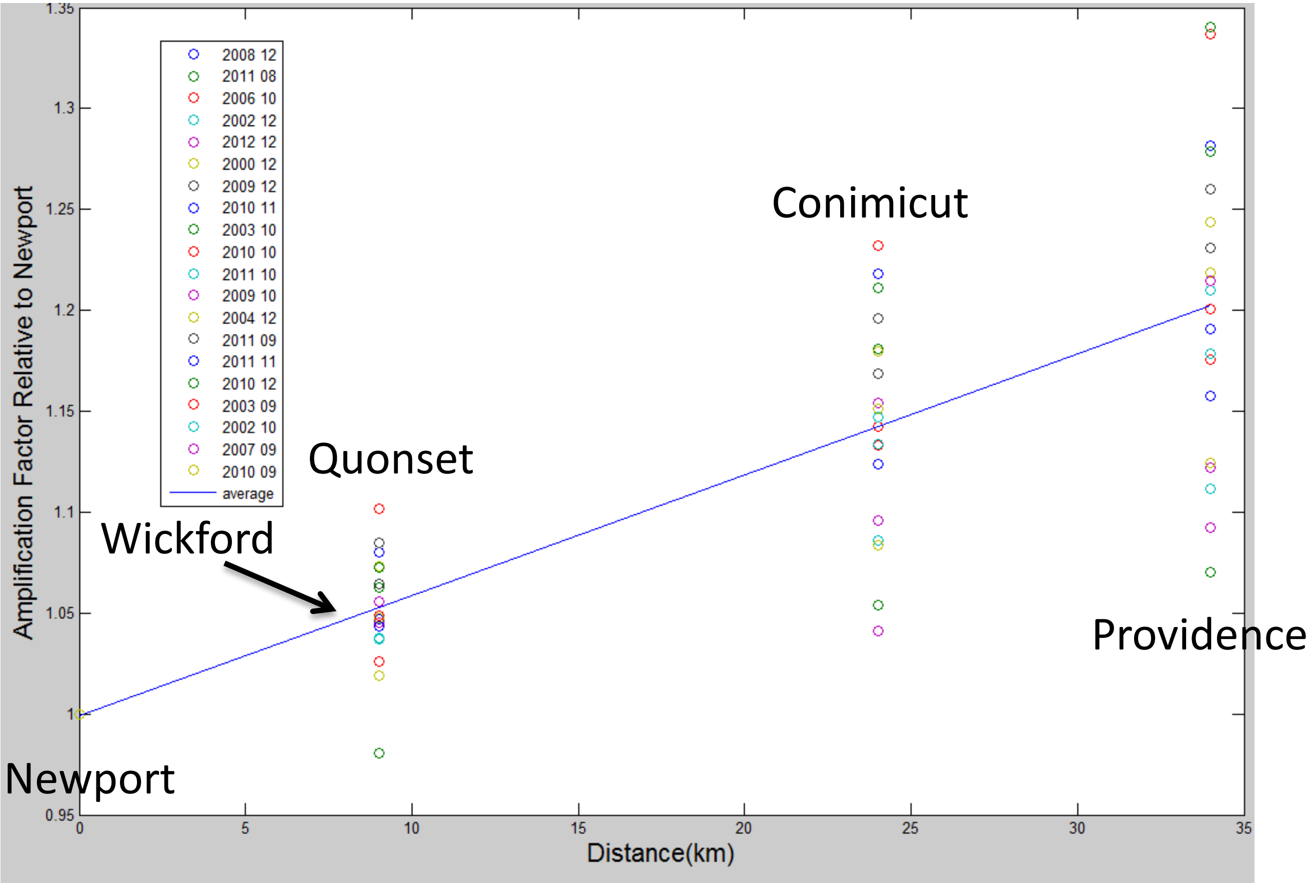


Amplification Factor Process To Determine The 100 year SWEL at Wickford

- Confirmed 2012 FIS determined a SWEL value for Wickford by Linear interpolation.

- The top 20 largest hurricane storm surges (SWEL values) were analyzed by progression south to north along Narragansett Bay

Linear Mean Hurricane Amplification as a function of distance N to S in Narragansett Bay

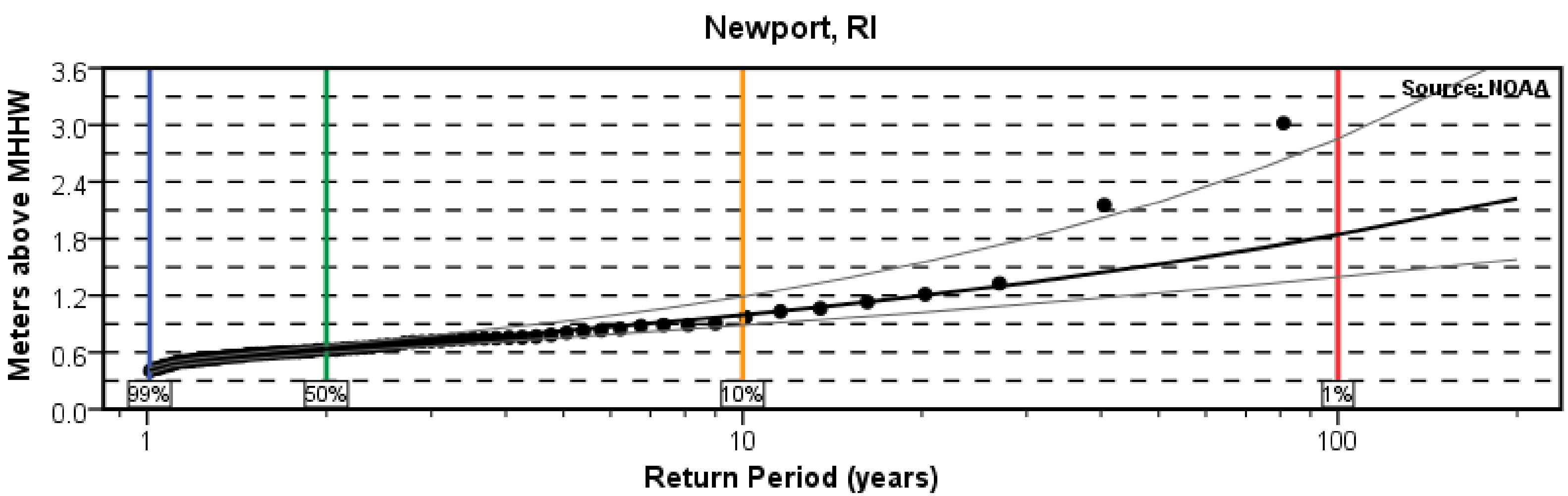


	FIS 100 yr SWEL Value (m)
Wickford	3.4
Newport	3.2

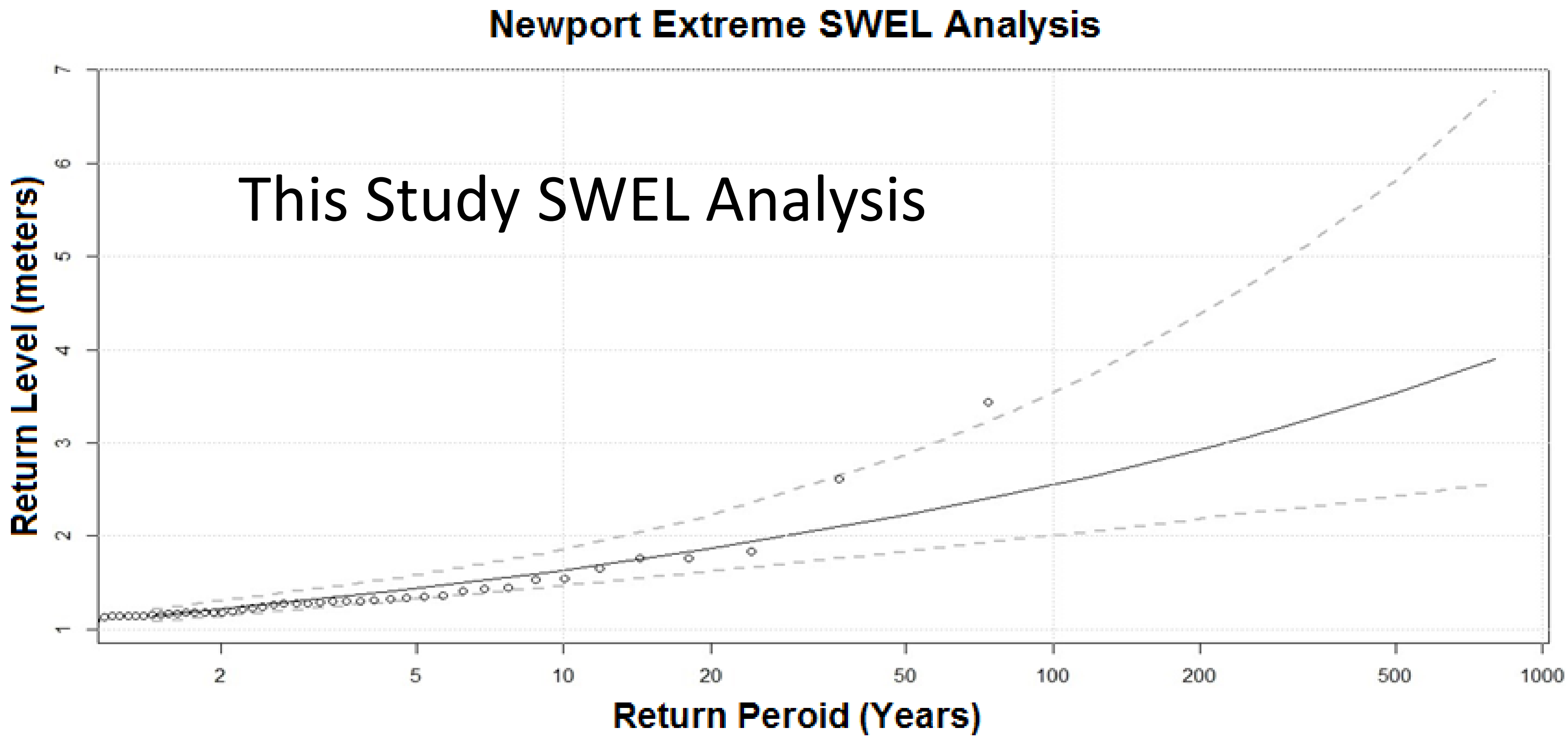
	Amplification Factor
This Study	1.05
FIS	1.06

Extreme Analysis

- Completed an extreme probability analysis on annual maximum SWEL values at the Newport Water Level Station.
- Ideally want to confirm Generalized Extreme Value (GEV) distribution curves produced by NOAA.



NOAA's annual exceedence GEV referenced to MHHW (NOAA)



100 Yr SWEL Values For Newport Using Maximum Likelihood Estimation

	Lower 95% (m)	Mean (m)	Upper 95% (m)
NOAA	1.85	2.4	3.35
This Study	1.85	2.4	3.33

FIS 100 year SWEL value for Newport is 3.2 m (10.5 ft)

Our calculated upper 95% SWEL value is 0.13 meters or 5 inches greater than the FIS value of 3.2 m

SWEL Values at Wickford

Wickford SWEL Values Based On Just Hurricanes Amplification Curve Fit (Amplification of 1.05)

Storm Return Period (Years)	Lower 95% (m)	Mean (m)	Upper 95% (m)
10	1.52	1.66	1.84
25	1.69	1.96	2.34
50	1.83	2.23	2.88
100	1.94	2.52	3.5

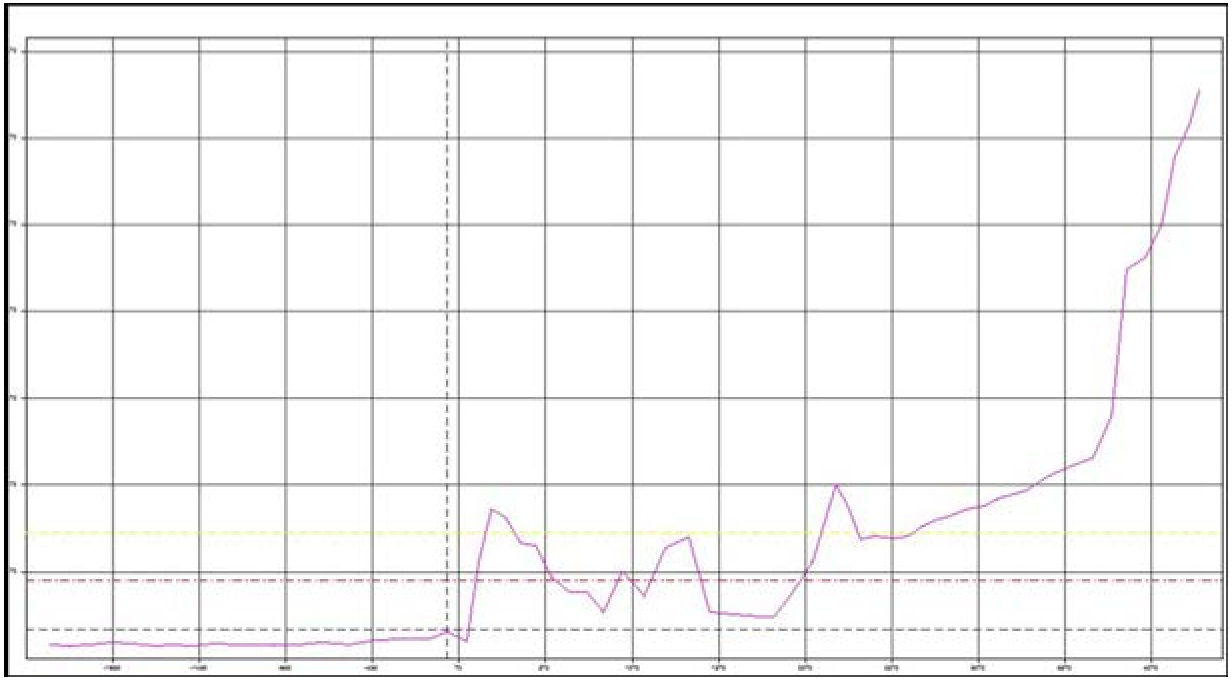
The FIS value for Wickford is 3.4 m (11.2 ft) which is 0.1 m (3.8 inches) smaller than this study's upper 95% SWEL value of 3.5 m (11.5 ft).

CHAMP and WHAFIS

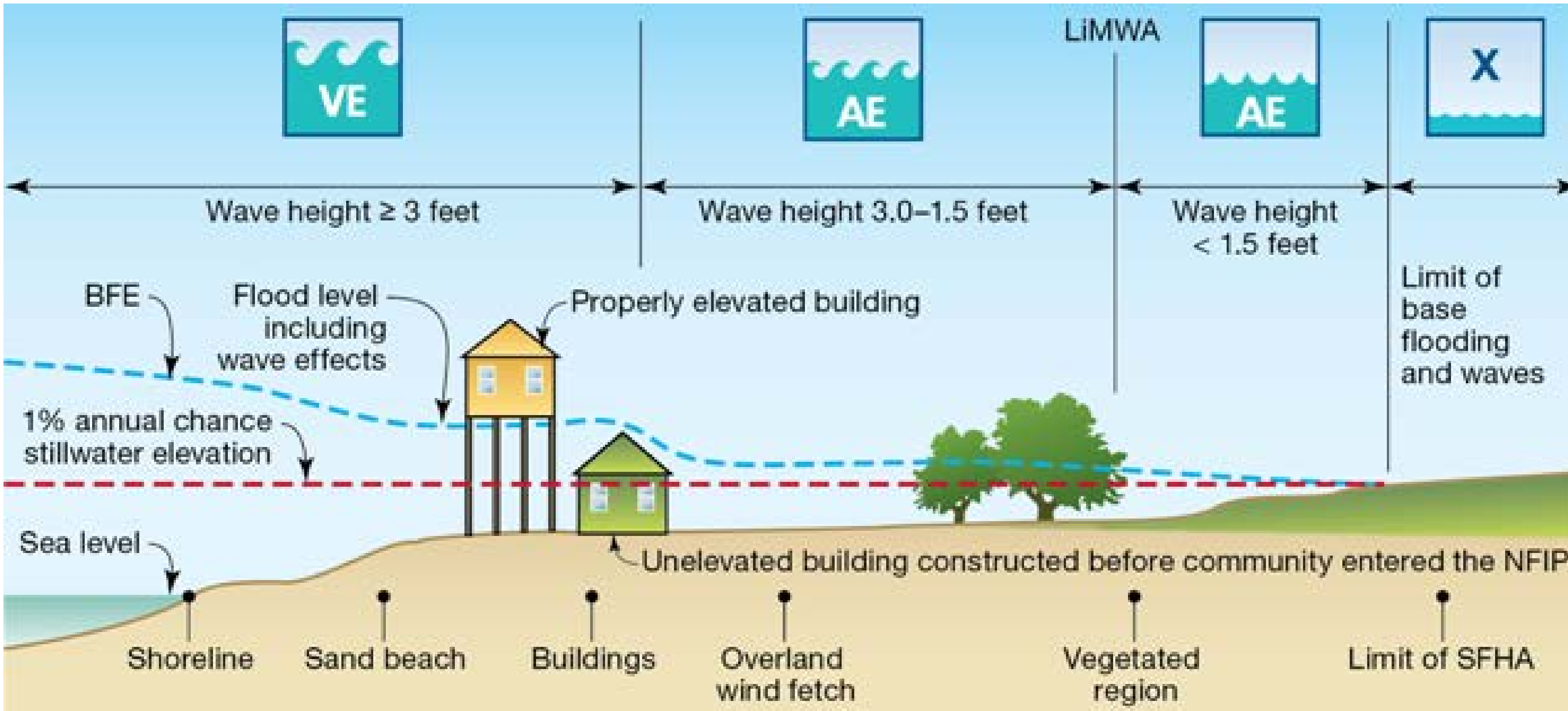
CHAMP - Coastal Hazard Analysis Modeling Program

WHAFIS - Wave Height Analysis for Flood Insurance Studies

Using WHAFIS, which is inside the CHAMP program, transects (shown right) are analyzed to determine the flood zones along them. This allows for a recreation of the FIRM map.



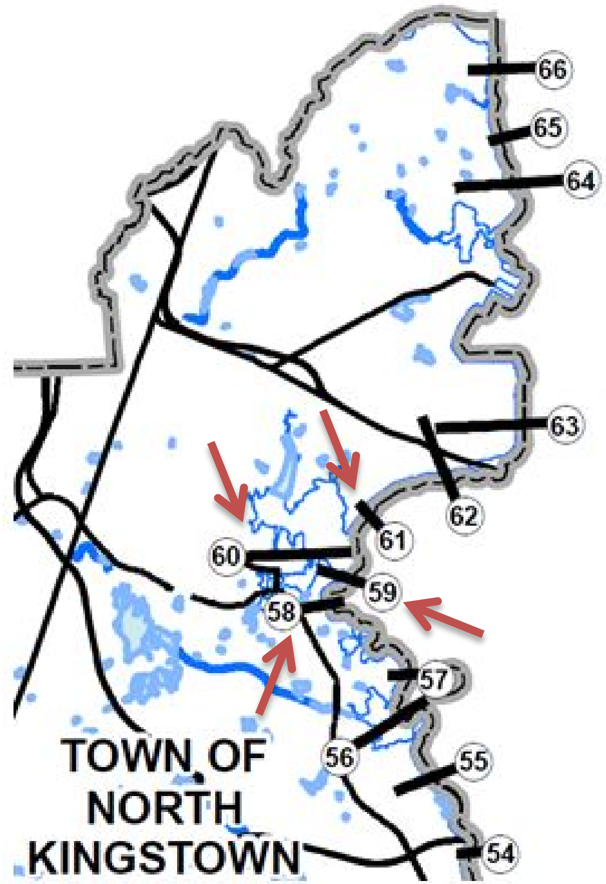
Transect



http://www.r3coastal.com/home/coastal-hazard-analysis-mapping/coastal-flood-hazard-mapping

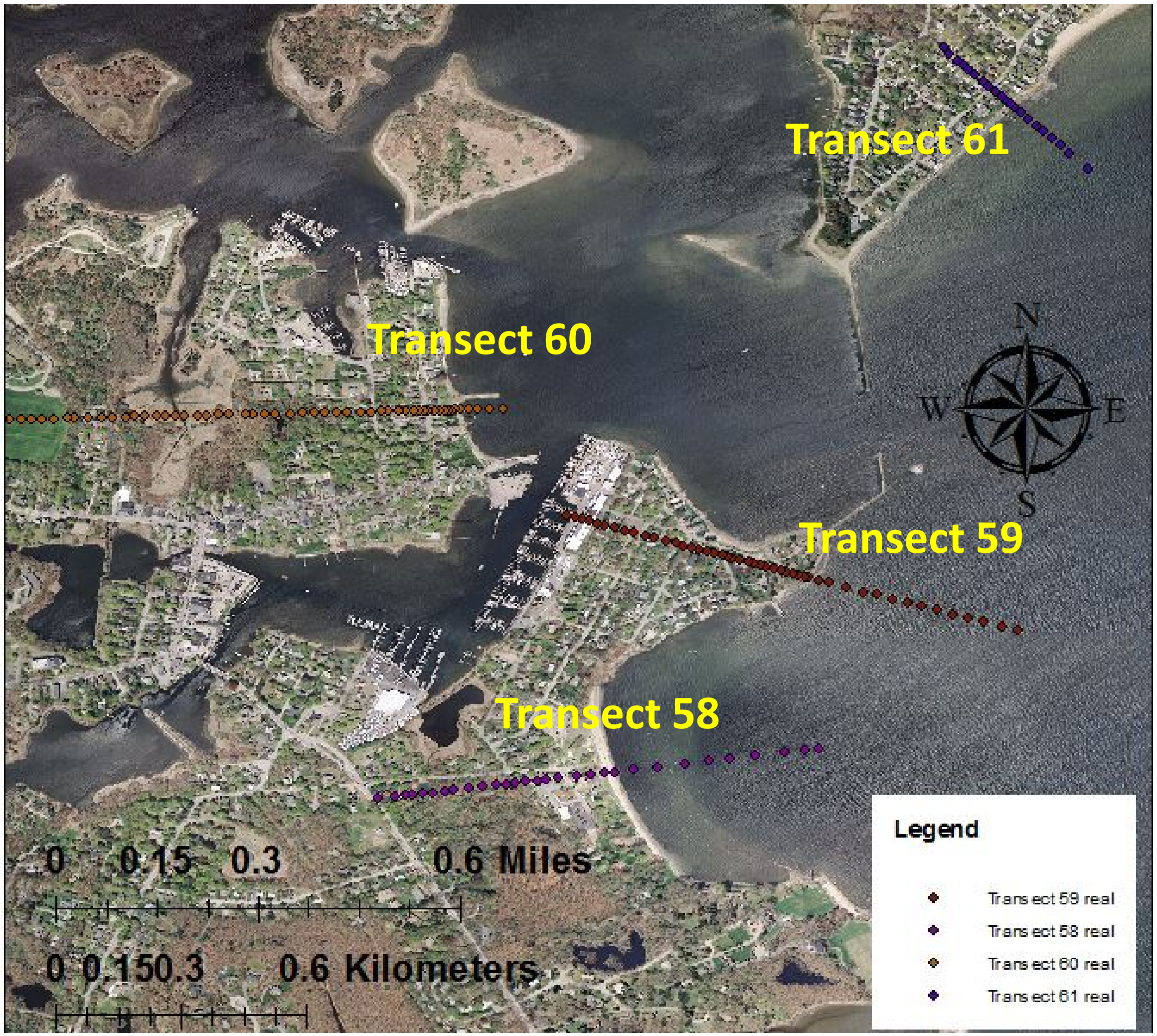
Defining the Coastline

- Transects are located perpendicular to a shoreline.
- Represent an average coastline along the shore.
- Allow an estimation of coastal flooding for a linear region.
- More transects are used at more complex topographies to better represent the coasts morphology
- FEMA coastal guidelines suggests transects every few hundred feet for a complicated coastline



FIS 2012

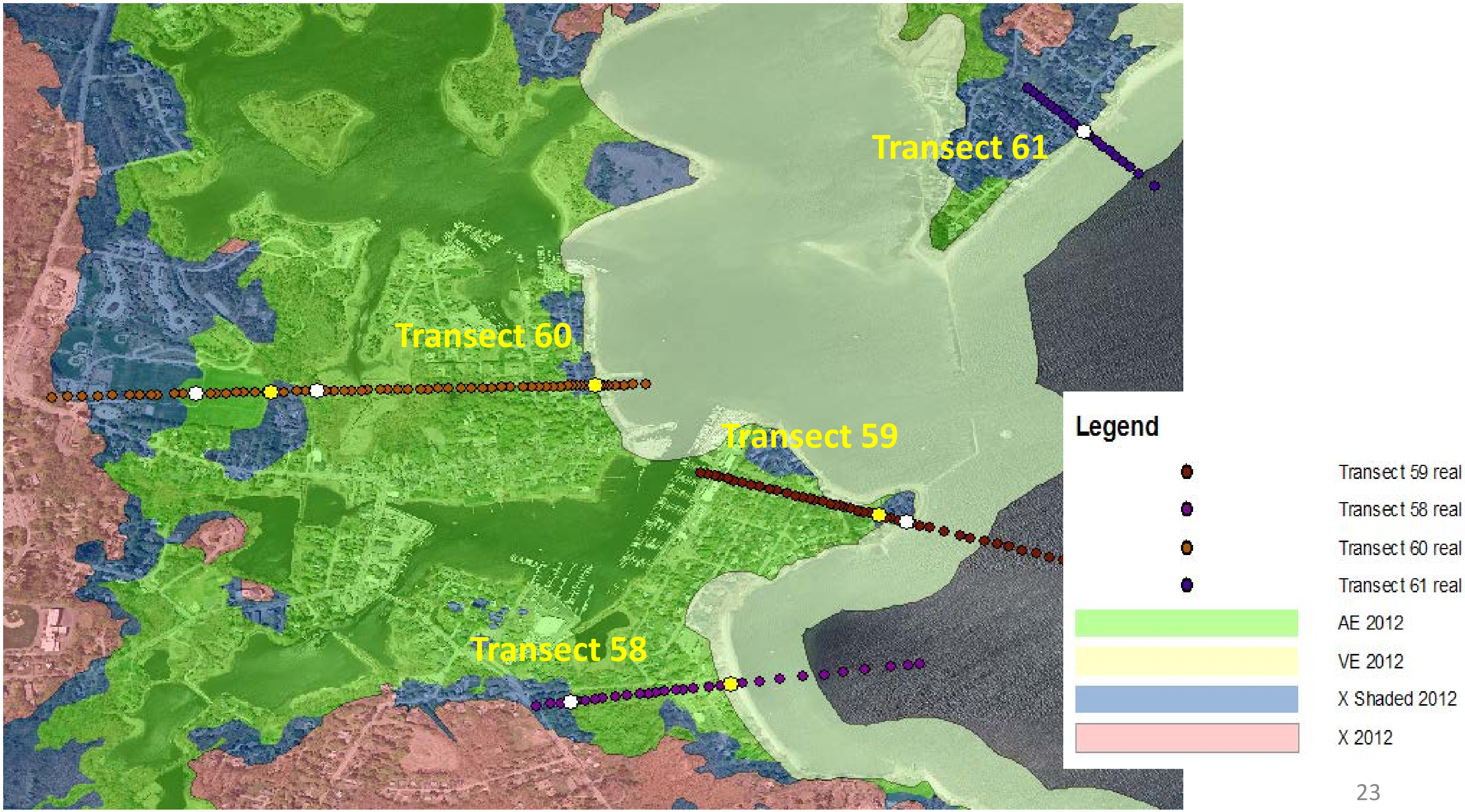
Transects Created



Transects 58, 59, 60, and 61 were created in ArcGIS. These values were inputted into CHAMP to model a 100 year storm to recreate the 2012 FIRM.

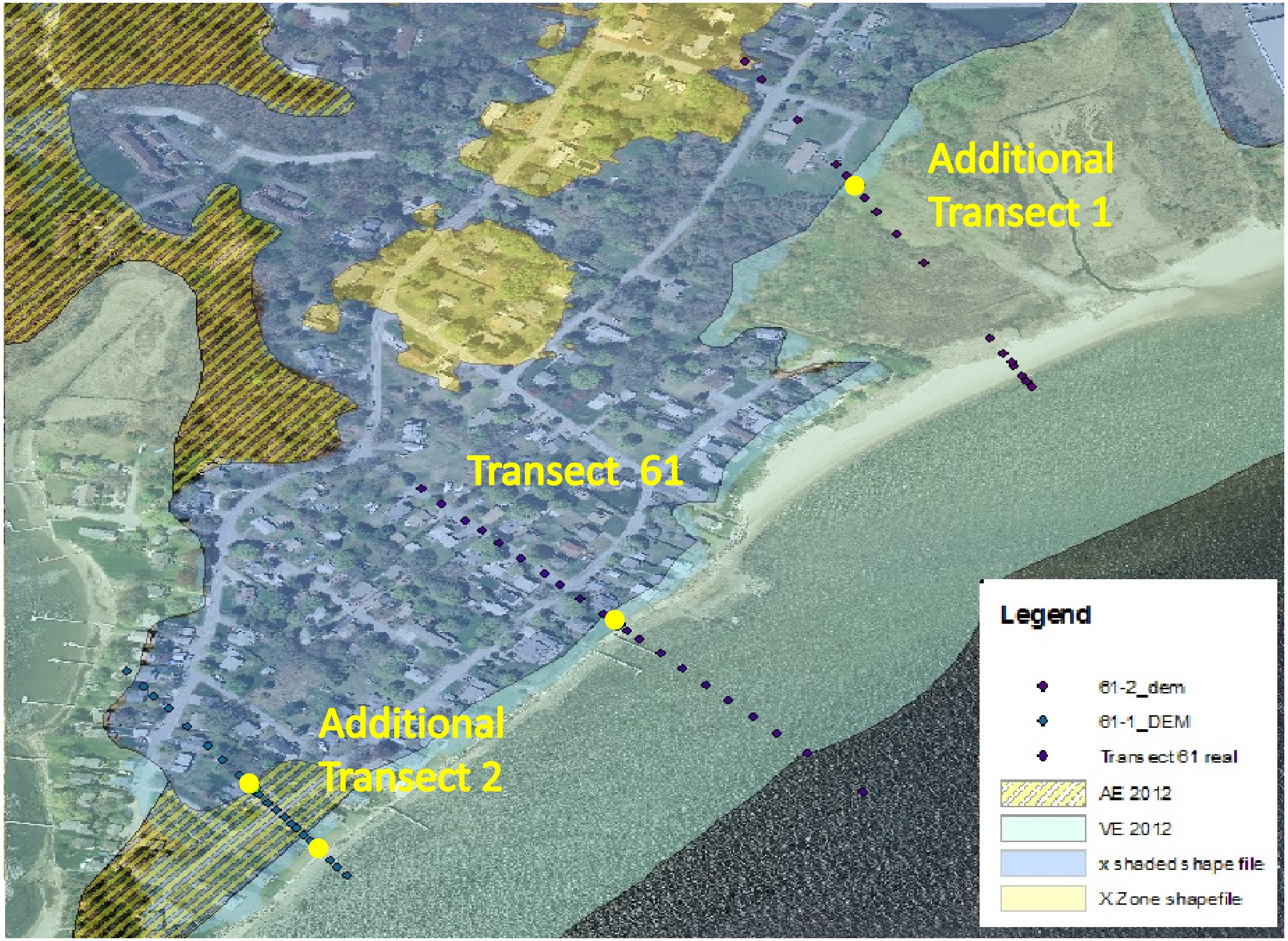
2012 FIRM Recreation

The yellow dots denote the change to AE zones and the white dots denote the change to X zones. These values were found using WHAFIS.



Transect Sensitivity Study

Two additional transects were created on either side of transect 61 to see if we could recreate the FIRM.

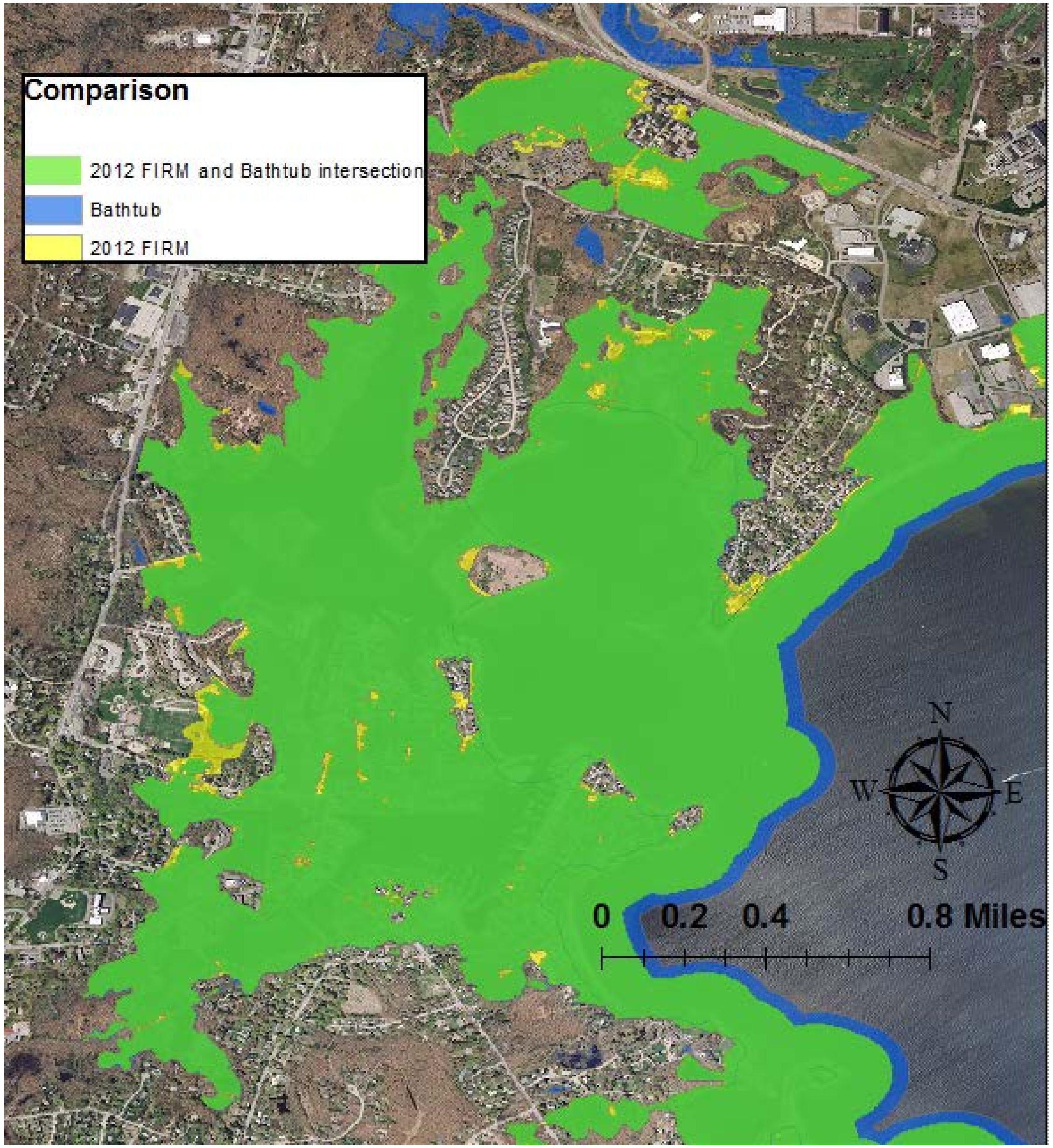


First Order Flooding Estimation

Bathtub of an AE Zone

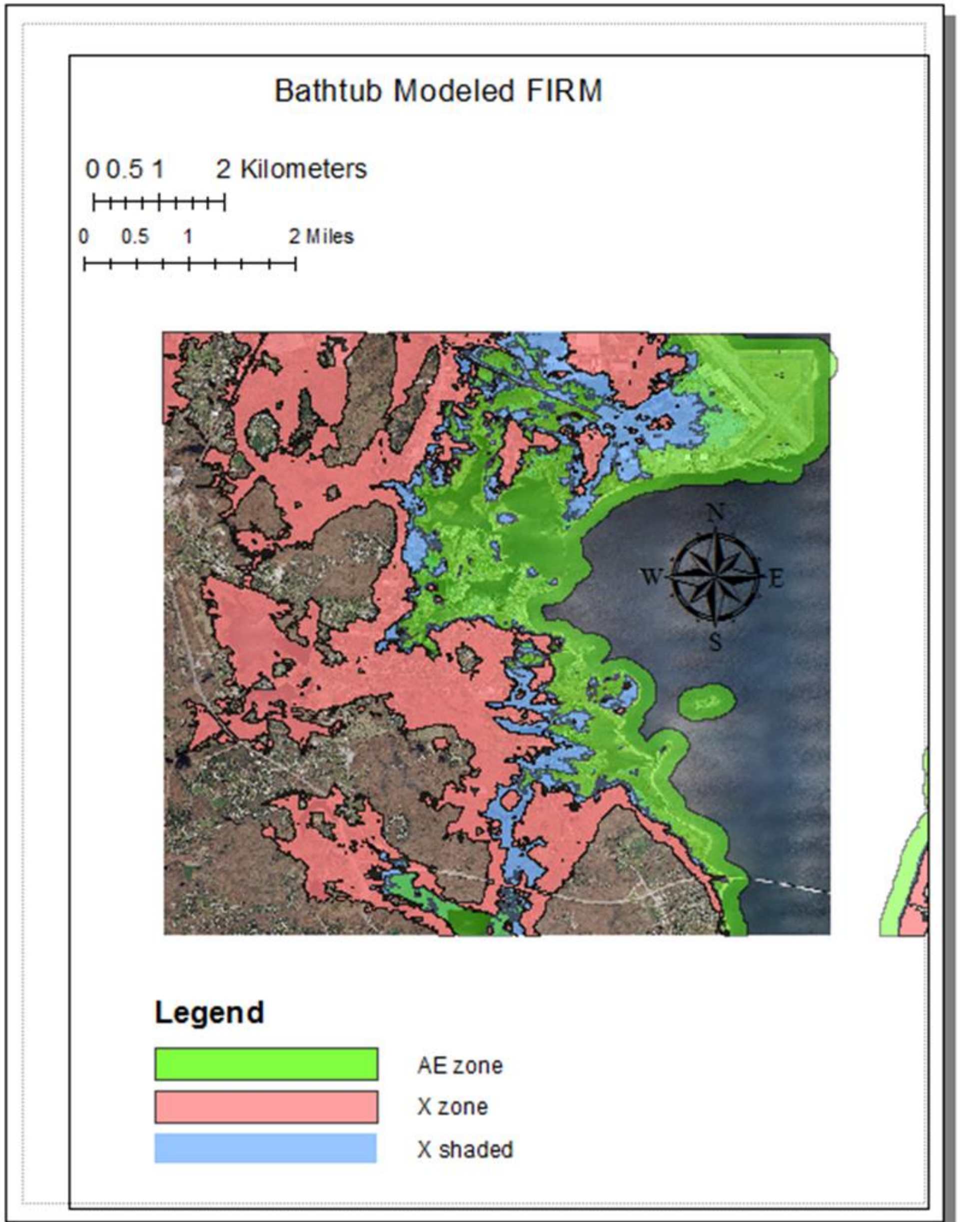
FEMA 2012 FIRM AE and VE Zones

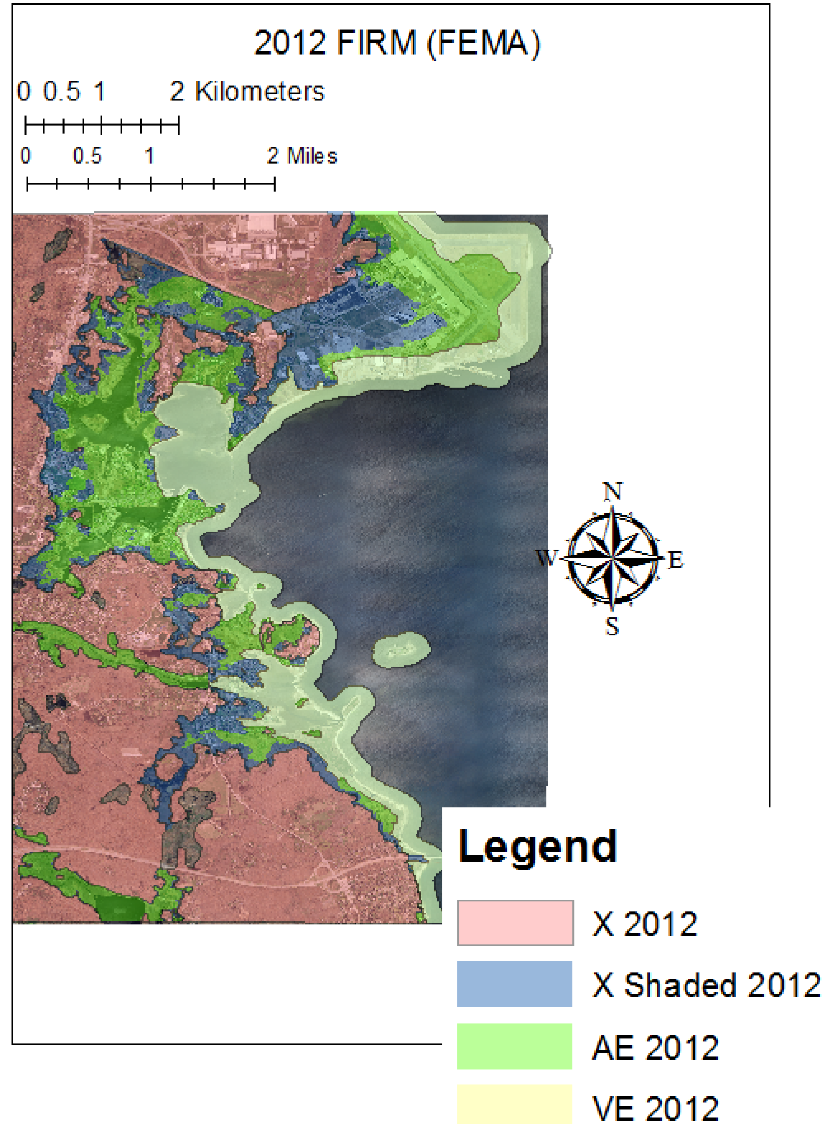
First Order Flooding Estimation



This is a direct comparison of the figures shown before

The VE zone for 2012 FIRM includes Wave Height Analysis for Flood Insurance Studies (WHAFIS)

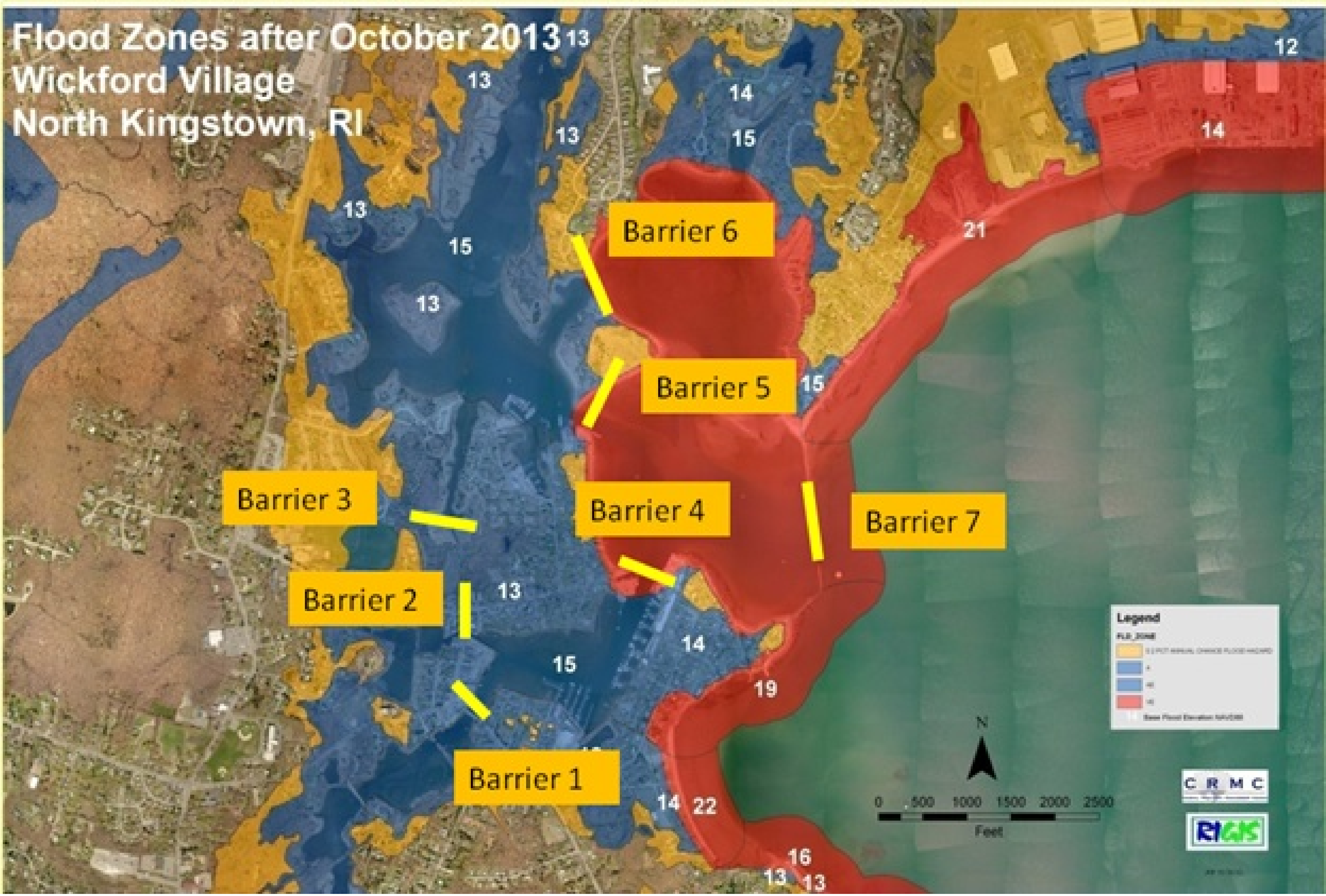

Bathtub Modeled FIRM
0 0.5 1 2 Kilometers
0 0.5 1 2 Miles
N
W
E
S
Legend
AE zone
X zone
X shaded


2012 FIRM (FEMA)
0 0.5 1 2 Kilometers
0 0.5 1 2 Miles
N
W
E
S
Legend
X 2012
X Shaded 2012
AE 2012
VE 2012

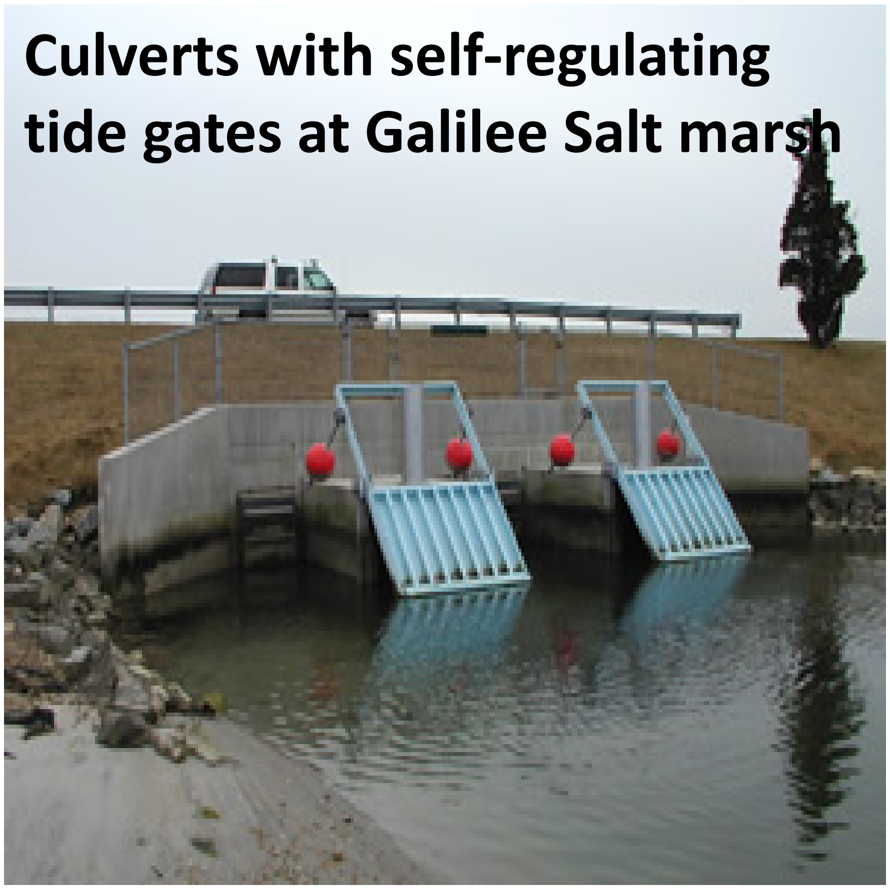
Mitigation

- Help to reduce the damage caused by flooding during storms.
  - Tide gates, sea walls, dune creation, and breakwaters
- Target barrier locations to maximize reduction of surge inundation.

Structures and Features of Wickford Coastal Study Area


Flood Zones after October 2013
Wickford Village
North Kingstown, RI
Barrier 6
Barrier 5
Barrier 4
Barrier 3
Barrier 2
Barrier 1
Barrier 7
13
14
15
12
21
19
22
16
Legend
N
0
500
1000
1500
2000
2500
Feet
CRMC
RIGIS

Self Regulating Tide Gate (SRT)



Purpose:

- To restore tidal flushing of marshes without flooding property upland behind dikes and levees
- Reduces sheet flooding of the marsh
- Allows upland storm water runoff when the tide is low

http://www.edc.uri.edu/restoration/html/tech_sci/restsalt.htm

SRT (continued)

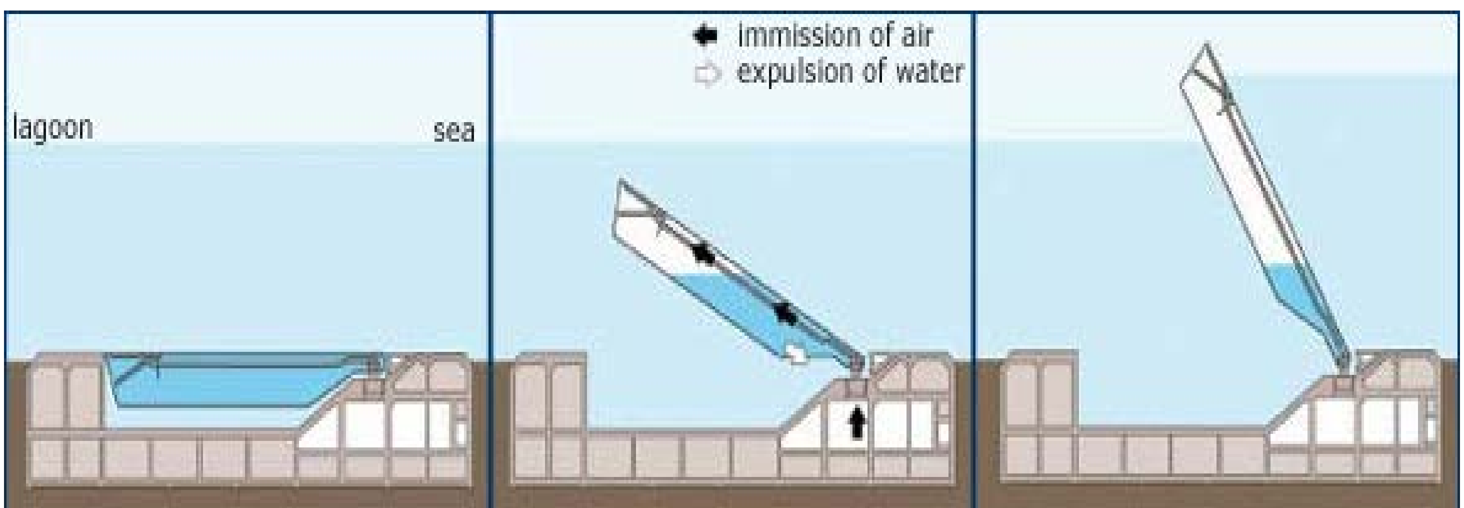
- The buoyant gate floats on the surface of the water until it is closed by counter floats behind the hinge point
- The position of the counter floats can be adjusted to meet the allowable water level at specific sites
- The gate could rise and close daily with tides or only close during significant flood events

Measures From the Netherlands

- The Oosterschelde Storm Surge Barrier is one of the biggest structures in the world with an overall length of three kilometers.
- This vertical lift gate barrier contains sixty-two openings, each forty meters wide.
- Only closes under heavy storm conditions with high water levels in order to maintain tidal flow and allow significant salt water to pass through.

MOSE Project

- Intended to protect the city of Venice, Italy and the Venetian Lagoon
- Rows of oscillating buoyant flap gates will separate the lagoon and sea during significant high tide events
- The gates remain in their housing structures, full of water, until a high tide is forecasted. Compressed air forces water out of the gates, raising the gates about their hinged axis until they emerge above water.



SWEL for various intensities of storms and sea level rise

Using the SWEL values that we calculated for Wickford of different storm events bath tub models were created for the harbor. These were determined to accurately represent the area for AE and VE zones in Wickford. Then SLRs of 1, 3 and 5 feet were added on to each. The result is the table below.

SWEL Values for sea level rise and storm surge				
Return Period (years)	SLR (feet sea level rise)			
	0	+1	+3	+5
0	0	1	3	5
1	3	4	6	8
10	6	7	9	11
25	7.5	8.5	10.5	12.5
50	9.5	10.5	12.5	14.5
100	11.5	12.5	14.5	16.5

Mitigation has some effect
Mitigation not effective

8.5 feet of SWEL was found to be the maximum value that mitigation can effect.

100 Year Storm with 5 feet of SLR

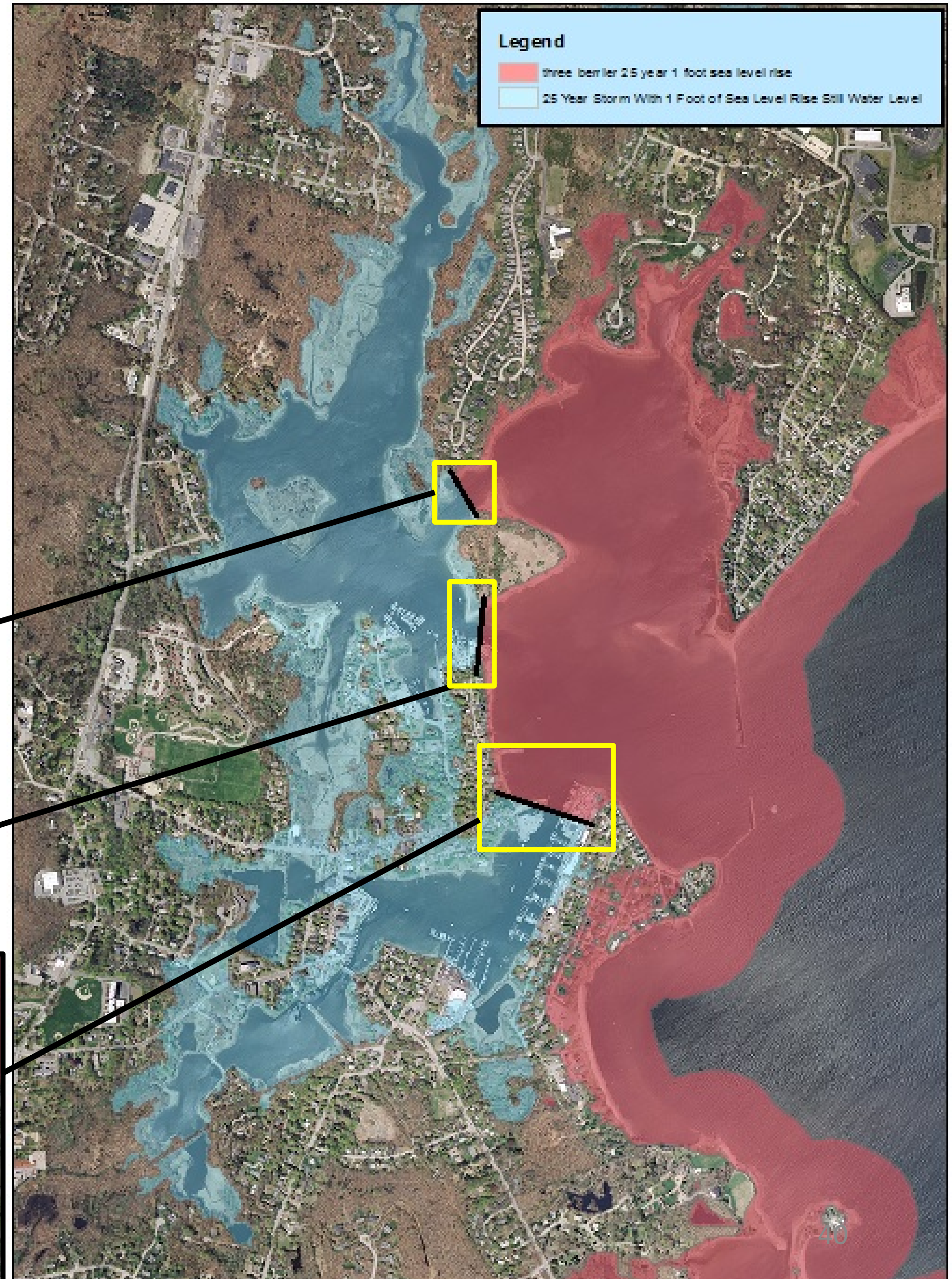
The area shown here, was selected as the limiting factor for mitigation. When the peninsula highlighted becomes inundated, it becomes very difficult to prevent flooding in Wickford due to low lying topography.

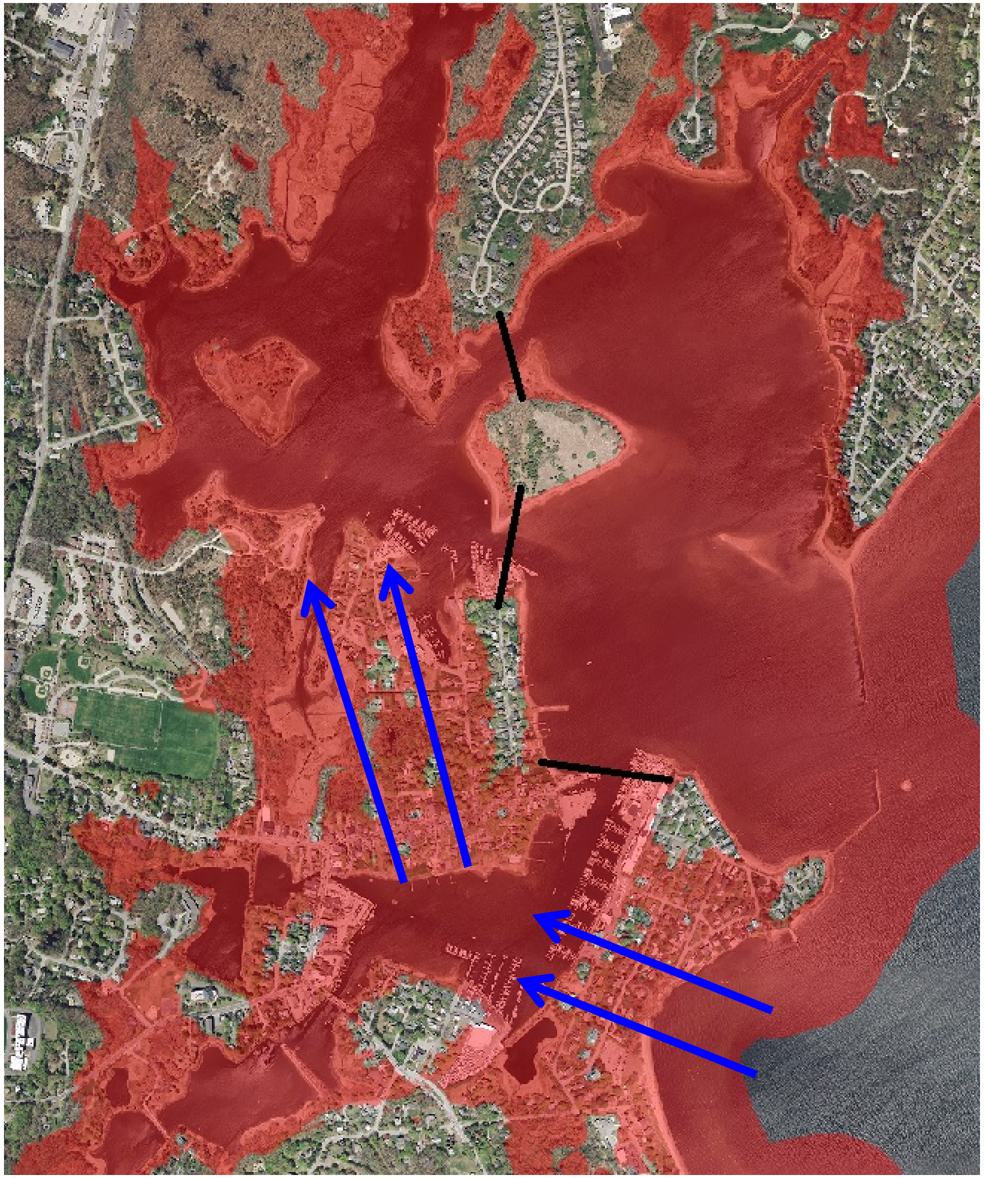
Storm Surge From 25 Year Storm 1' Sea Level Rise (8.5 feet of SWEL)

Under current conditions This is the worst case scenario that can be reasonably solved.

Three Barrier Solution

This is a possible mitigation strategy for the 25 year storm with 1 foot of SLR. The black lines are the areas where barriers could be constructed that allow boat traffic until a storm is approaching. The red is where the flooding will happen while the blue areas are where flooding would be prevented.



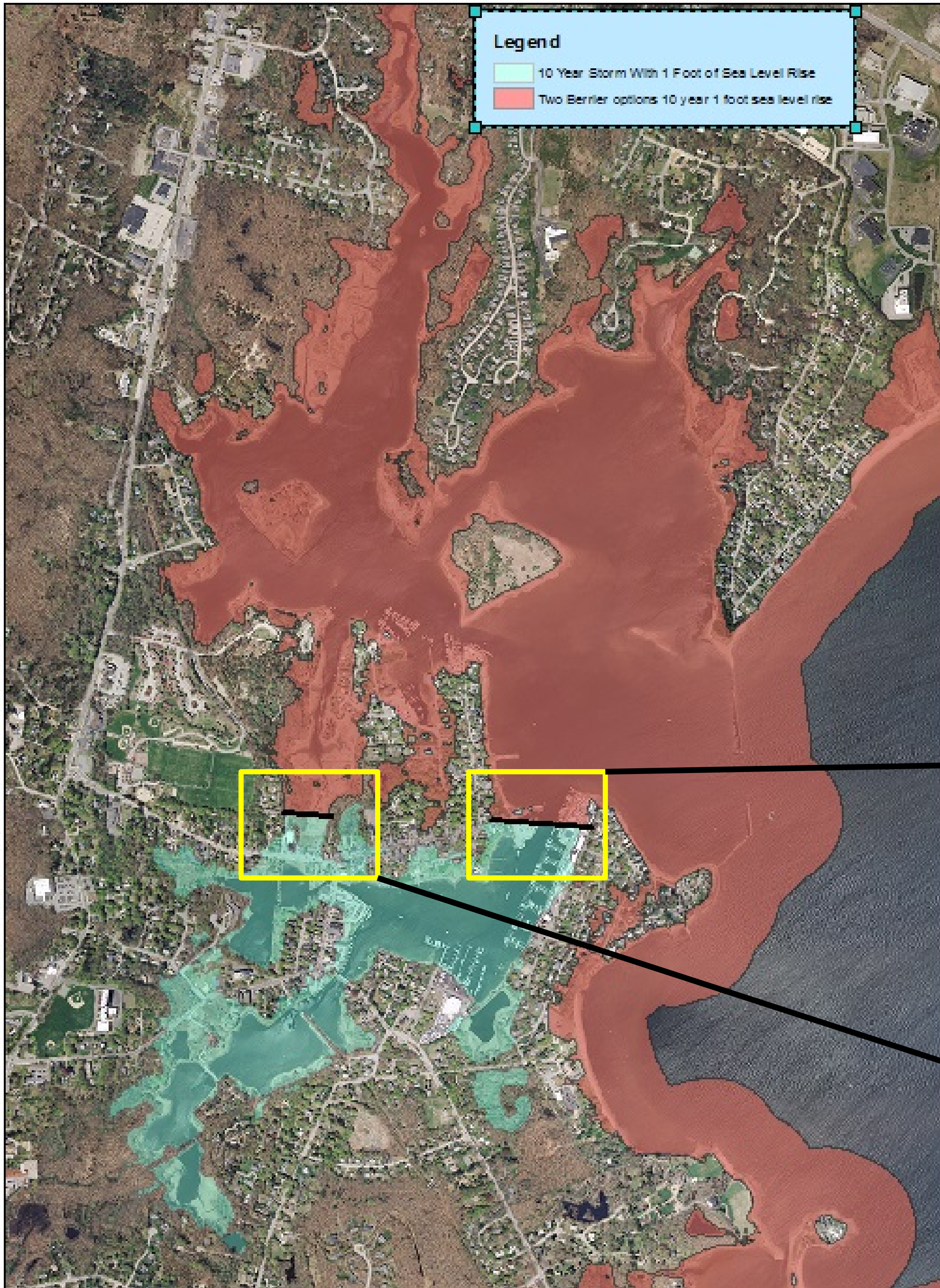


Three Barrier Option Failure

- This map shows the effects of the 25 year storm with 3 feet of sea level rise.

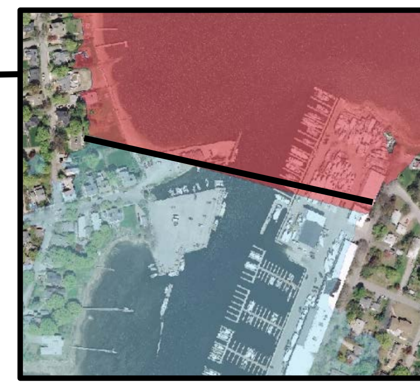
- Due to the over wash of the peninsula the water is free to flood following the blue arrows around the barriers.

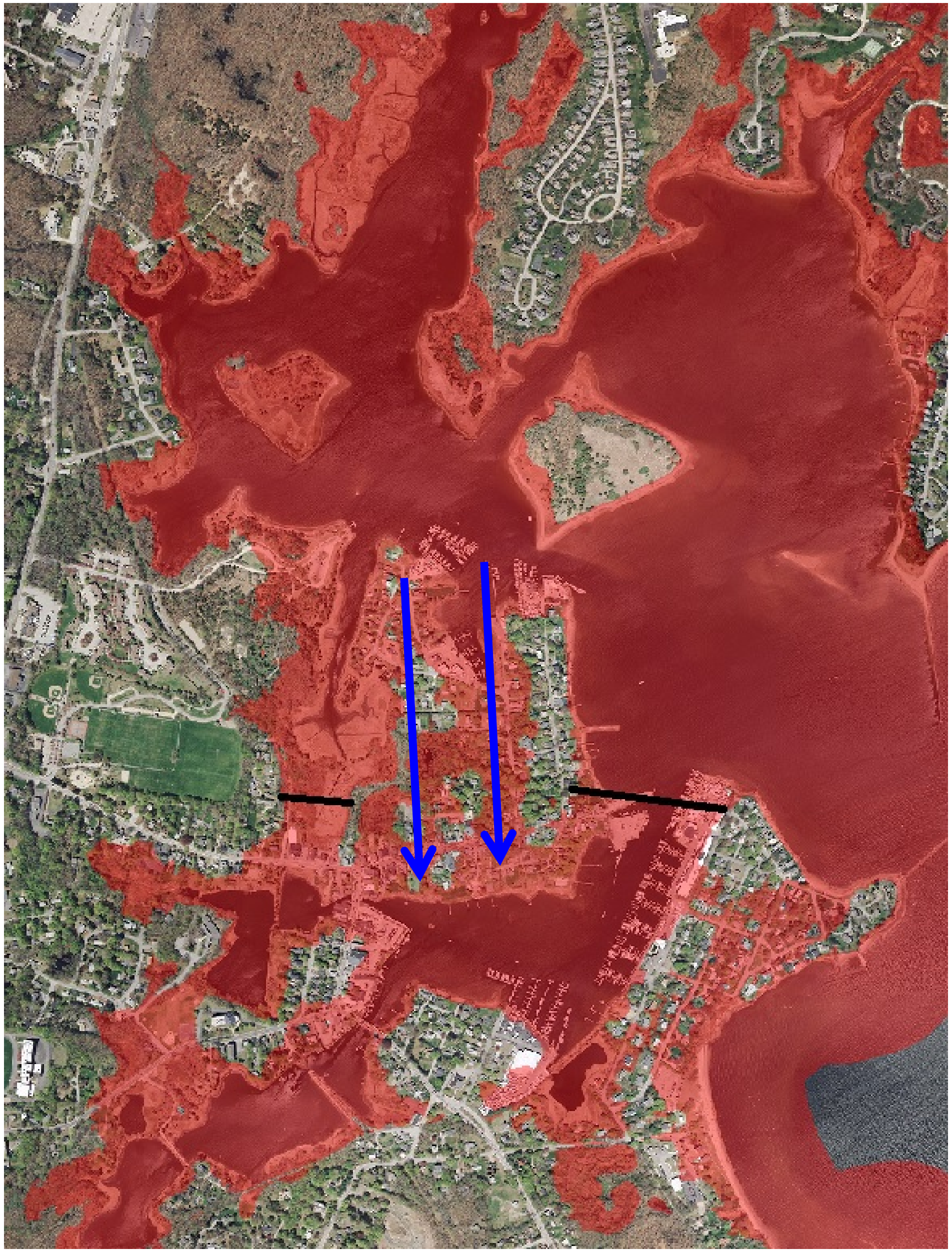
- Even if the barrier is infinitely high the water can still go around them.



Two Barrier Option

Looking at the area in the box as another area that could be a place for a barrier. This area is only feasible for a 10 year storm with one foot SLR. This option would protect the main escape road and the barrier in the box doesn't go through any property and could be a permanent structure





Two Barrier Option Failure

• This scenario is 8.5 ft of SWEL or 25 year storm with 1 ft of SLR

•Due to the height of the SWEL, in this scenario the water floods following the blue arrows in between the barriers.

•Even if the barrier is infinitely high the water can still go in between them.

Summary

- Amplification factors for Narragansett Bay were found to linearly increase up the bay .
- Using an extreme value distribution the SWEL value was found to be 3.5 meters, which was comparable with NOAA and FEMA's studies.
- Using CHAMP and WHAFIS the 2012 FIRM was recreated.
- Bathtub models were found to be a good first order estimate of inundation when compared to the FIRM's zones
- The two and three barrier strategies proposed provide protection to Wickford, RI for still water level values less than 8.5 feet.

Thank You