EVALUATION OF CRITICAL INFRASTRUCTURE IN MATTAPOISETT, MA

Presentation to NEWEA - Resiliency Planning Specialty Conference

Tuesday, September 26, 2017 1:30 PM

Presentation Agenda

- **Introductions - Project Team**
- **Project Description and Discussion**
- **Review Project Efforts Completed**
  - **RPS Efforts for Modelling**
    - ***Storm Surge/Sea Level Rise***
    - ***Beach Migration***
    - ***Beach Stability Assessment***

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Meeting Agenda

- **Review Project Scope (Continued)**
  - **Engineering Evaluation**
    - ***Review Modelling Results***
      - **Inundation of Sites**
      - **Beach Migration**
      - **Beach Stability Assessment**
    - ***Look at Site Vulnerabilities***
    - ***Review Potential Adaptation Measures***
      - **Sketches for Potential Solutions**
    - ***Develop Budgetary Opinions of Construction Cost***
  - **Questions and Discussion**

Project Team

Project Team

- Project Lead Consultant
  - FUSS & O'NEILL, INC.
  - KEVIN FLOOD - PROJECT MANAGER
  - DOUGLAS BRISEE - PROJECT ENGINEER

- Project Subconsultant - Modeling
  - RPS
  - LISA MCSTAY - PROJECT MANAGER
  - NATHAN VINHATEIRO, PhD - MODELING

- Project Subconsultant - Survey
  - BAXTER NYE ENGINEERING & SURVEYING
  - MATTHEW EDDY - PROJECT MANAGER

- Mattapoisett Water & Sewer Department
  - HENRI RENAULD - SUPERINTENDENT

Background and History

Background and History

- **Increasing storm intensity and flooding caused by Sea Level Rise**
  - Mattapoisett's potable water and wastewater infrastructure at risk
- **Mattapoisett - situated along the coast of Buzzards Bay**
  - Particularly vulnerable to impacts of hurricanes
- **Prelim. analysis of vulnerability to storm surge projected:**
  - Expansion of the 1-percent annual chance storm floodplain resulting from SLR
  - Expanded floodplain extended north of I-195 to inland areas (historically did not experience flooding)
- **Clearly demonstrated the need to:**
  - Further quantify climate change impacts
  - Implement adaptation efforts to help ensure resilience
- **Project was funded through Massachusetts Coastal Zone Management (MACZM) Coastal Community Resilience Grant Program.**

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Background and History

- Use storm surge model (SLOSH), wave actions model (WHAFIS), and a shoreline change assessment (DSAS) as well as SBEACH
  - assess and visualize the risk to 5 infrastructure components
- Quantify Risk
- Develop recommended adaptation actions for 5 critical infrastructure components:
  - Eel Pond Sewer Pump Station
  - Eel Pond Sewer Crossing
  - Wellhouse No. 2 Facility
  - Wellhouse No. 3 Facility
  - Water Main Crossing From Pease's Point to Point Connett

Modeling Efforts

Modeling – Storm Surge Inundation

- **Dynamically model water levels resulting from the combination of hurricanes and sea level rise for project area**
- **RPS ASA completed this modelling in the region**
- **Used:**
  - **NOAA's SLOSH Model (used operationally to predict storm surge)**
    - ***Accounts for atmospheric wind field and pressure differential***
  - **Matrix of Hurricane Parameters**
    - ***Antecedent water level (Tide +SLR)***
    - ***Delta-P***
    - ***Radius of Maximum Winds***
    - ***Landfall Location***
    - ***Forward Speed***
    - ***Track Direction***
    - ***Model Grid***

Parameter	Values	# Variations
Landfall Location	Evenly spaced along the shoreline	12
Pressure Difference (ΔP)	20, 40, 60, 80, 90 mb	5
Radius of Maximum Winds (R)	20, 30, 40, 45, 50, 55 NM	6
Forward Speed (T)	20, 30, 40, 50, 60, 70 mph	6
Track Direction (Θ)	N, NNE, NNW, NW, NtW, NWtW, NtE	7
Matrix Total Cases		**15,120 per water level** **60,480 total**

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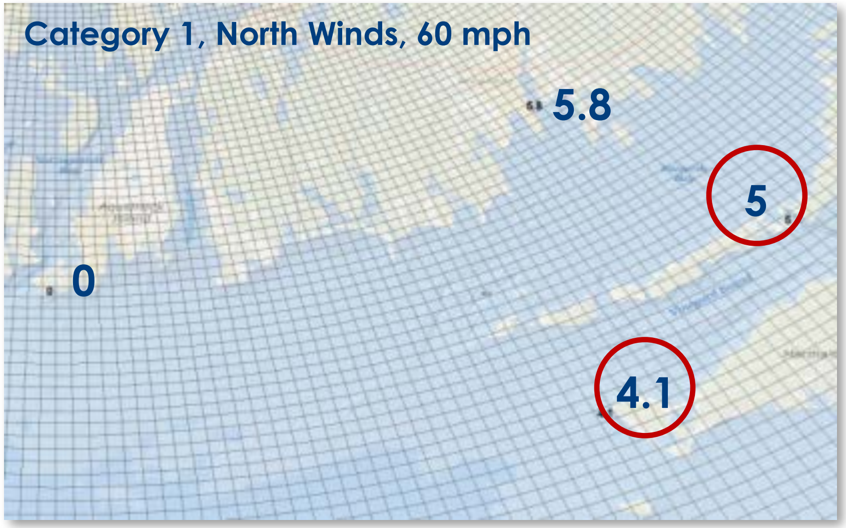
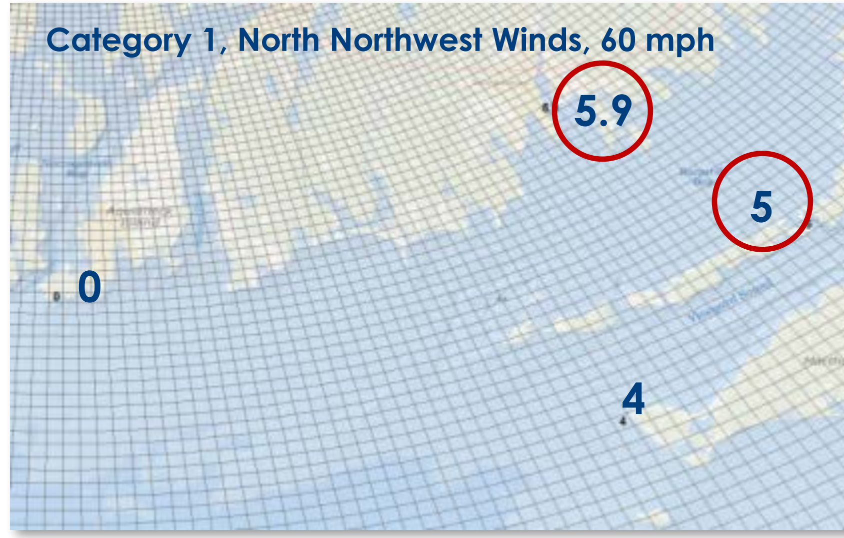
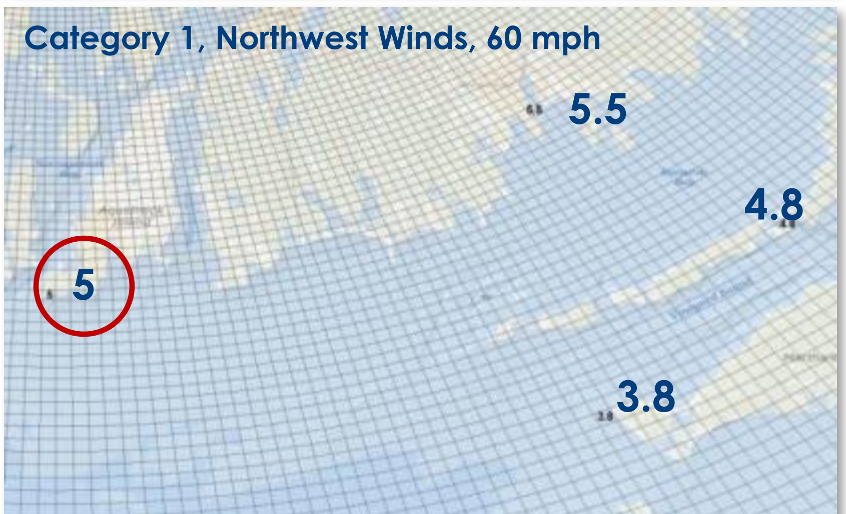
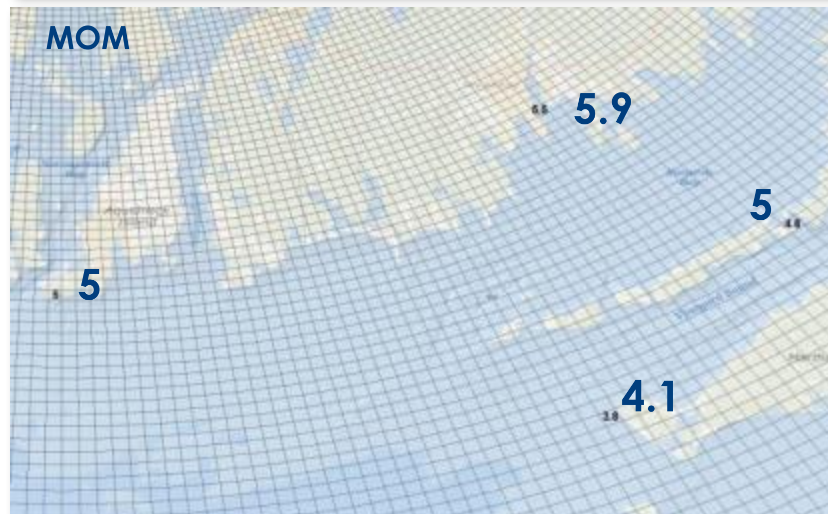
Modeling – Storm Surge Inundation









- Output –Worst case snapshot for a particular storm category

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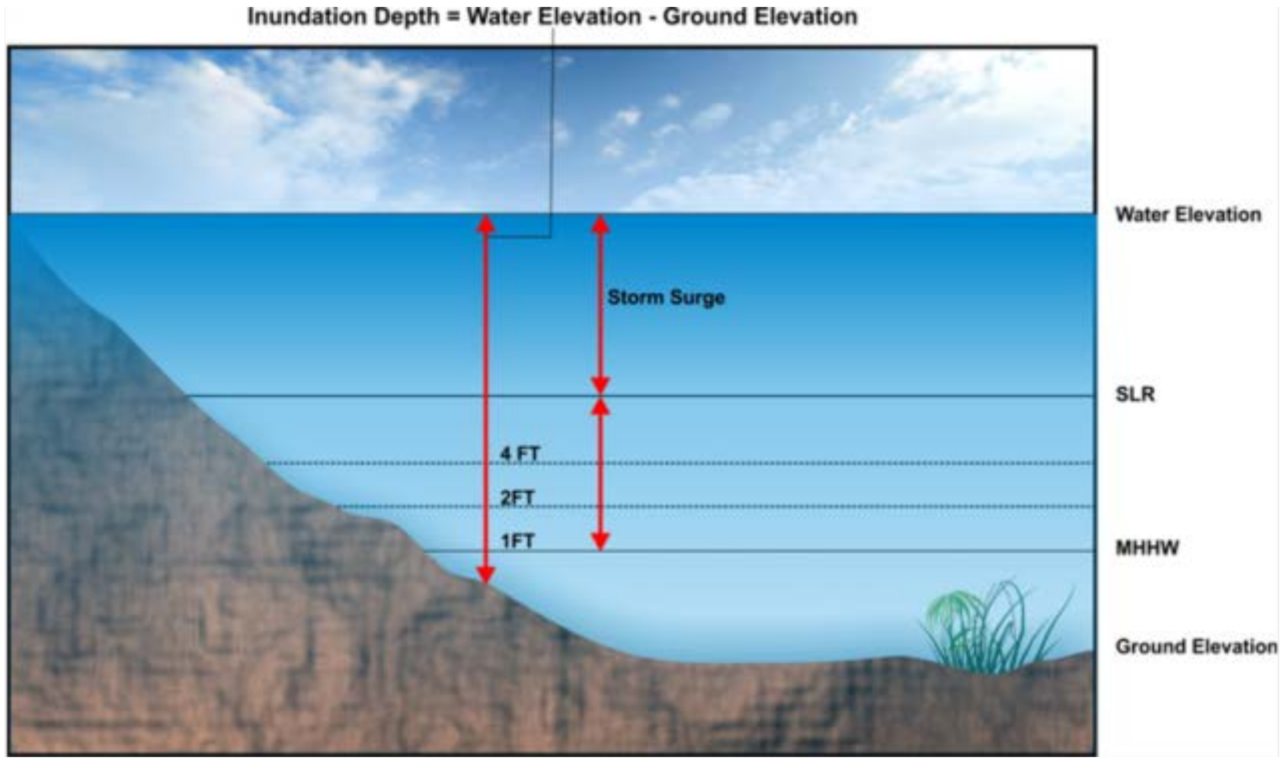
Modeling – Storm Surge Inundation



Converted and downscaled all water surface elevations to inundation depths - the depth of water above the ground elevations

Modeling – Storm Surge Inundation

Storm Surge:

- Inundation increased with increasing storm intensity.

- Inundation is substantial in all scenarios modeled
  - low-lying elevation
  - proximity to the water

- Category 3+ storms with any sea level rise
  - inundation depths exceeding 20 ft in the region.

- Factors that lead to the highest water levels:
  - Landfall in either Eastern Connecticut or Rhode Island,
  - An angle of approach between 168 and 180° from North (storms headed towards the NW to N directions),
  - A radius of Maximum Winds of 40 to 50 NM, and
  - A high forward speed (60 or 70 mph).

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Modeling – Storm Surge Inundation

Storm Category	Depth of Inundation (ft.)																			
	No SLR					1 ft. SLR					2 ft. SLR					4 ft. SLR				
	1	2	3	4	4+	1	2	3	4	4+	1	2	3	4	4+	1	2	3	4	4+
Eel Pond Sewer Pump Station		<1	6	10	13		1	7	11	14		2	7	12	15		4	9	14	17
No. 2 Pump Station			4	11	13			5	12	14		1	7	12	15		3	9	14	16
No. 3 Pump Station			2	7	10			3	9	11			4	9	12		<1	6	11	13

Modeling - Wave Modeling

- Calculate overland wave heights along transects at Various Locations
  - One-dimensional, transect based model part of FEMA's CHAMP package (Coastal Hazard Analysis Modeling Program).
  - Used in Flood Insurance studies since the 1980s to incorporate the effects of wave action on FIRMS for coastal communities.

- Inputs to the Model:
  - A specified SWEL (Still Water Elevation)
  - The computed wave setup
  - The starting wave conditions as input.
  - Transects with defined land use.

- Output from the Model:
  - Combined SWEL and wave height
  - Updated Inundation Depths including wave effects
  - Controlling wave height
  - Represents the highest 1 percent of waves during modelled conditions

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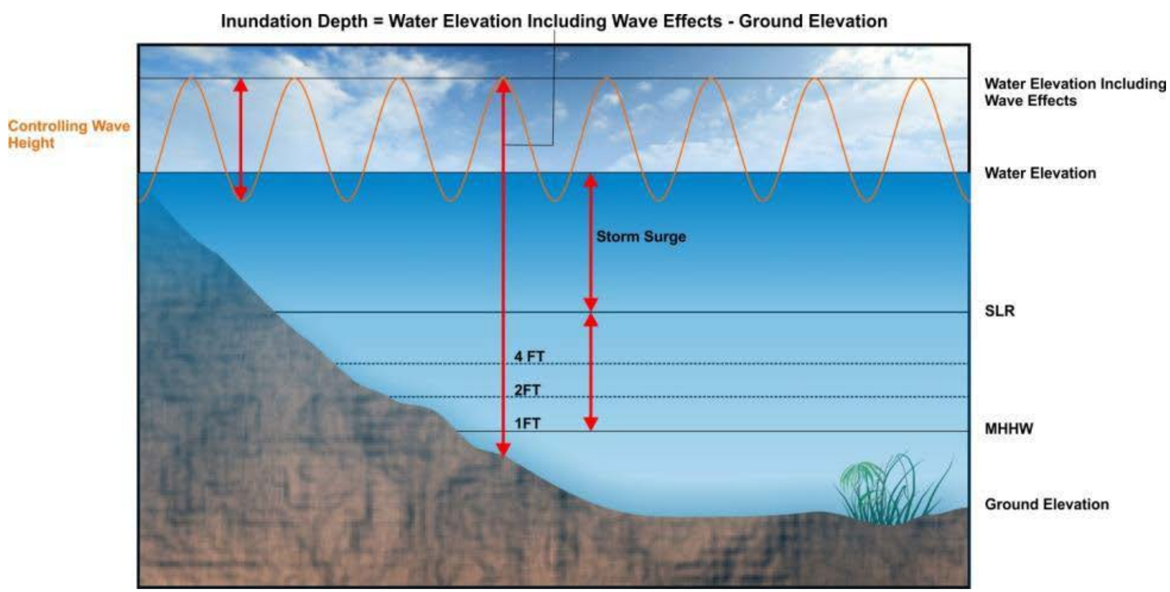
Modeling - Wave Modeling

Storm Category	No SLR					1 ft. SLR					2 ft. SLR					4 ft. SLR				
	1	2	3	4	4+	1	2	3	4	4+	1	2	3	4	4+	1	2	3	4	4+
Inundation Depth (no wave effects)		<1	6	10	13		1	7	11	14		2	7	12	15		4	9	14	17
Controlling Wave Height (ft.)		2	7	11	14		3	8	12	15		4	8	13	15		5	10	14	17
Inundation Depth*		4	14	22	28		5	15	24	29		7	16	25	31		11	19	29	34

Controlling Wave Heights and Corresponding Inundation Depths (ft.) at the Eel Pond Sewer Pump Station

*Includes wave effects – 70% of the controlling wave height is superimposed on top of the existing inundation depths plus wave setup.

Inundation Depth w/o wave effects + Wave Setup + 70 % of Controlling Wave Height = Inundation Depth



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Modeling - Beach Migration

- Digital Shoreline Analysis System (DSAS) calculates erosion rates based on historic data at time horizons of 25, 50, and 100 years into the future.

- Methodology

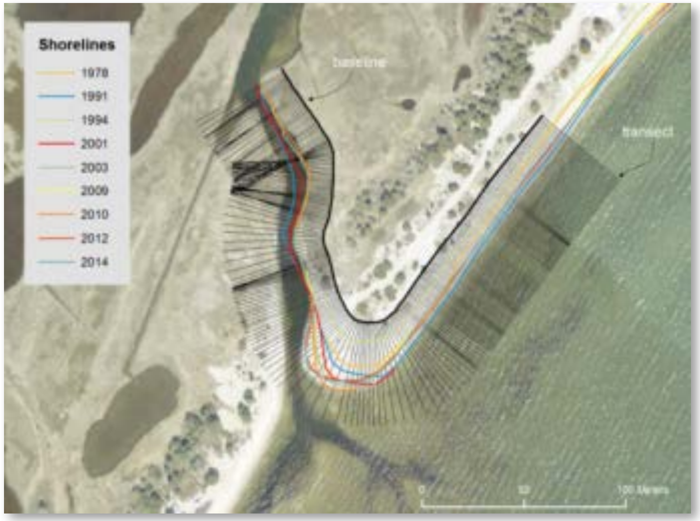
  – Historic shorelines were imported to ArcGIS.

    – Shorelines digitized from imagery in 1978 - 2014 were included in the analysis.

  – Vector shorelines merged into a single feature class and attributed with a date and uncertainty field.

    – Datasets without documented uncertainties were assigned a value of 5.5 m [average uncertainty in the position of the high water line derived from air photos]

  – DSAS used to generate orthogonal transects at 1 m spacing alongshore.



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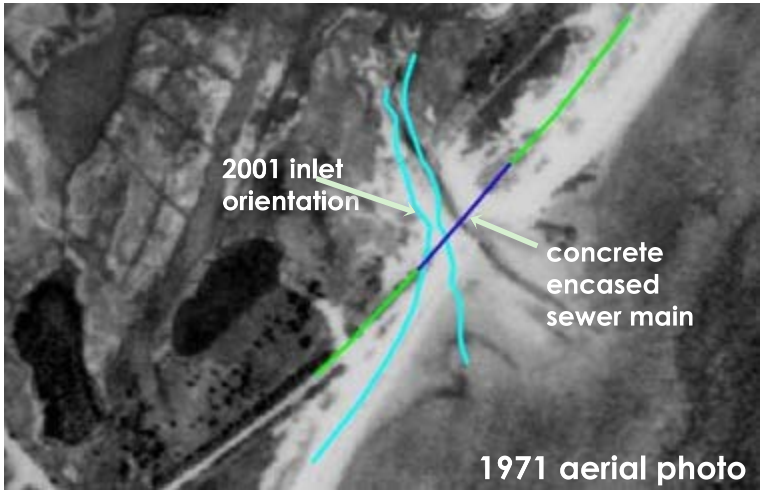
Modeling - Beach Migration

- Rates of erosion/accretion at each transect were calculated using DSAS. Rates of shoreline change were calculated using
  - the end point rate
  - linear regression
  - weighted linear regression



- Future shoreline positions were forecast at each transect at 25,50,100 yrs. from 2015 based on the various rates.
  - Distance weighting function was used for
  - shoreline positions between vertices.
  - New polyline features were developed for each:

time horizon (3) + rate method (3) = 9 total layers

- Polygons representing a total envelope of change produced for each time horizon
  - Based on the range of calculated rates (EPR, LRR, WLR) at each transect

Modeling - Beach Migration

- Inlet Migration Assessment - only first order estimates of future erosion and accretion.
- Configuration of the future shoreline may differ due to:
  - storm activity,
  - wave climate,
  - the rate of SLR
  - sediment supply, and
  - presence of coastal structures.
- Potential changes from a short-term, catastrophic event: NOT fully captured in this assessment for Eel Pond Sewer Crossing
  - (i) few major storms have impacted the site during the period of observation, and
  - (ii) the full beach morphology is not considered
- Beach and frontal dunes - exceedingly low volume
  - sand reservoir is likely to become depleted by wave action (or overwash completely) during a moderate to severe storm, exposing a much longer section of the sewer line.

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Modeling - Beach Migration

- **Imagery (1978 - 2014)**
  - General drift in the position the West Channel toward the southwest (eroding on the southern bank and accreting on the northern bank).
- **Rates of shoreline change in the area are highest at the inlet mouth.**
- **Results indicate shoreline movement**
  - Approximate rate of +0.5 m/yr (north bank) and -0.3 m/yr (south bank) in the vicinity of the pipe.
- **North bank of the West Channel**
  - Projected to migrate over the armored section of the sewer main within 50 years from 2015.

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Modeling - Beach Migration using SBEACH

- Use Storm-induced Beach Change model (**SBEACH**) to evaluate the storm-induced erosion on the water main crossing using cross-shore transects
  - Transect-based beach morphology model part of USACE CEDAS program
  - Simulates 2D (onshore/offshore) beach profile changes due to high water level events
  - Predicts formation and movement of morphologic features

- SBEACH was applied multiple transects to capture different orientations of the beach with respect to incoming waves

- Multiple scenarios were run at the site to consider erosion from:
  - low probability storm event (e.g., 100-yr return period flooding)
  - high probability storm events (e.g., 10-yr flooding)

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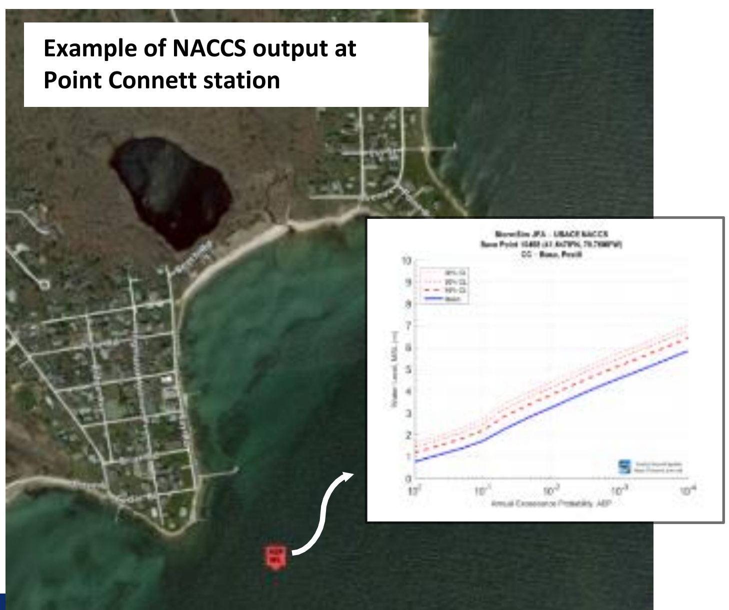
Modeling – Beach Stability Assessment

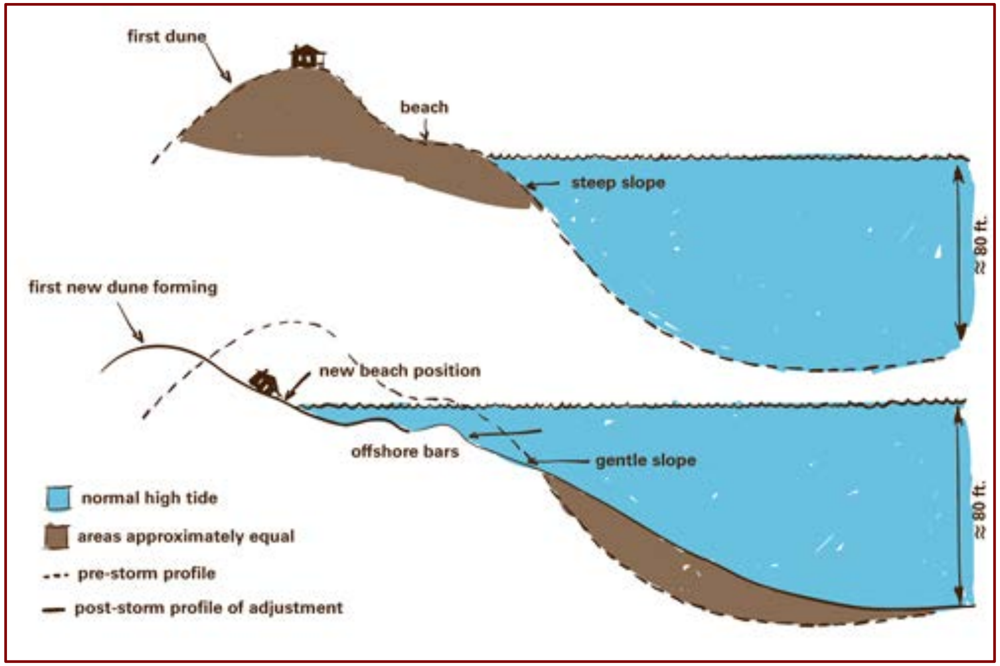
SBEACH Model Inputs

- initial beach profile
- median grain size (representative of surf zone)
- water level time series
- wave height/period time series (static for this application)
- shoreward boundary (e.g. seawalls)

SBEACH Model Output

- final calculated beach profile
- volume/area change
- elevation change
- change of shoreline

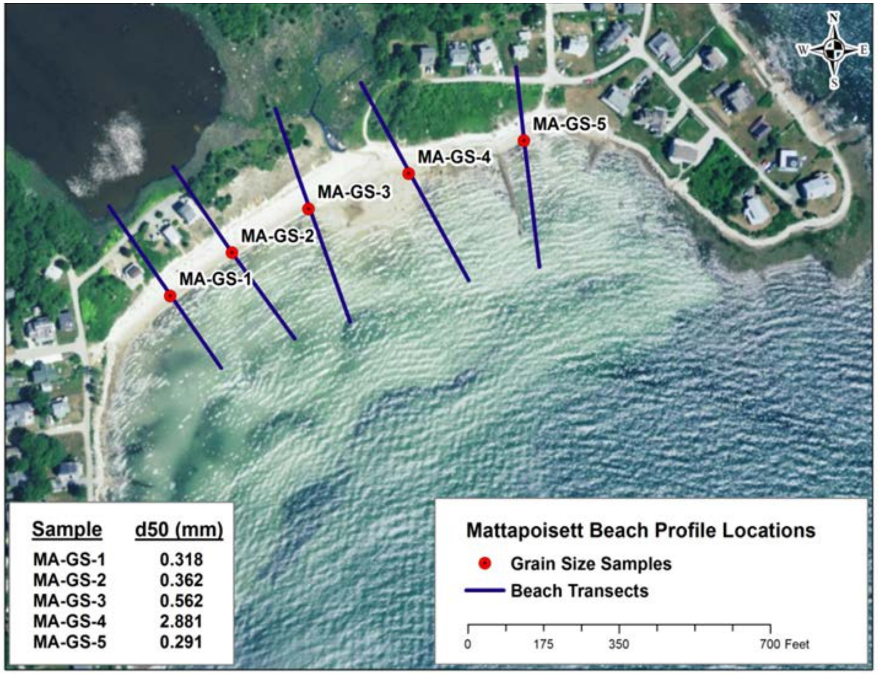

Example of NACCS output at Point Connett station

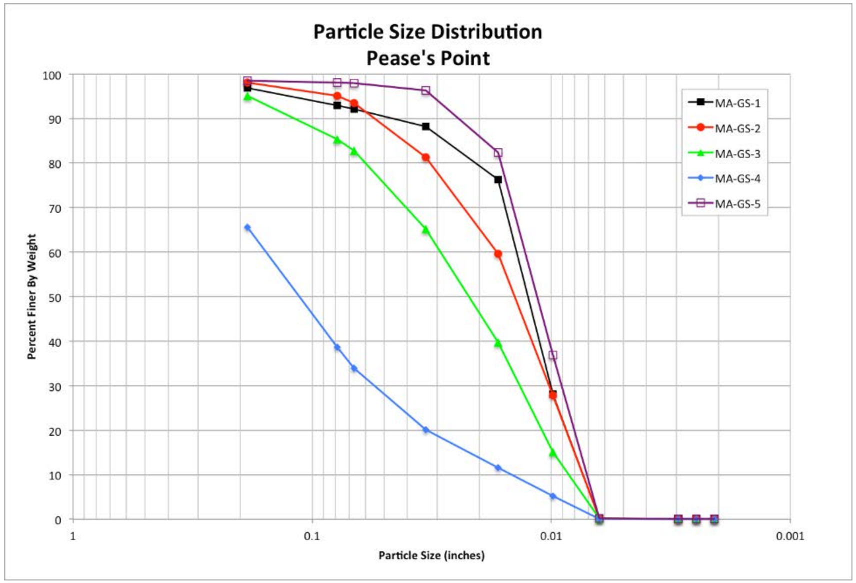


Modeling – Beach Stability Assessment

Model Inputs – Beach Transects

- Field survey of the existing beach conditions (Dec. 2016)
- Offshore bathymetry – USGS and MACZM
- Sediment samples collected at five location





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Modeling – Beach Stability Assessment

Model Inputs – Storm Events

- Two different types of storm events selected:
  - low probability (100-year) storm event
  - high probability (10-year) storm event
- Additional simulations to evaluate
  - 2 events in succession (10-year events), and
  - future beach profile under SLR
- Storm Parameters obtained from North Atlantic Coast Comprehensive Study (NACCS - Point Connett Station):
  - water level
  - wave height
  - wave period

Storm Event Category	Storm Event Return Period	Maximum Water level	Significant Wave Height	Peak Period (s)
Low Probability	100-year	10.9 ft (3.32 m)	8.37 ft (2.55 m)	15.5
High Probability	10-year	6.40 ft (1.95 m)	6.40 ft. (1.95 m)	15.5

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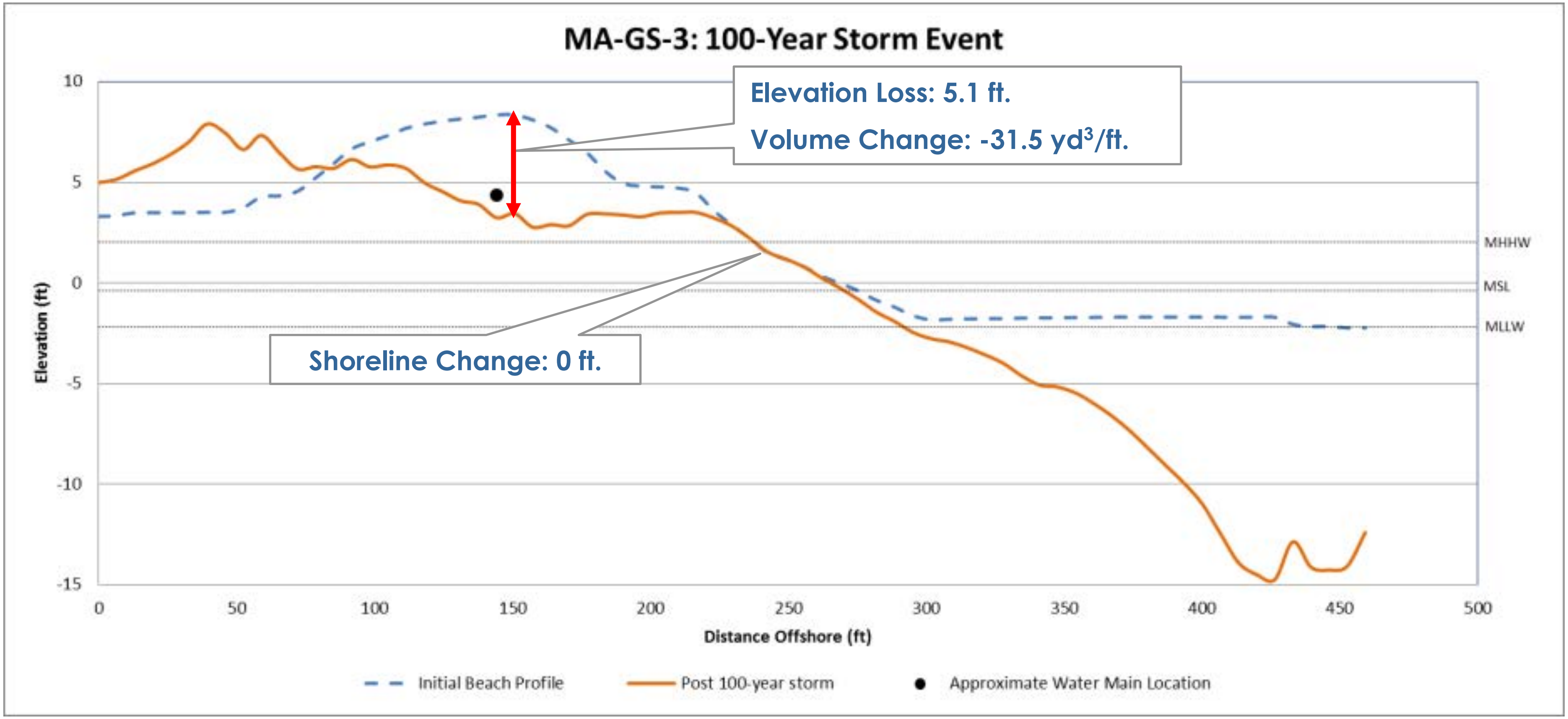
Modeling – Beach Stability Assessment

Example of SBEACH Model Results



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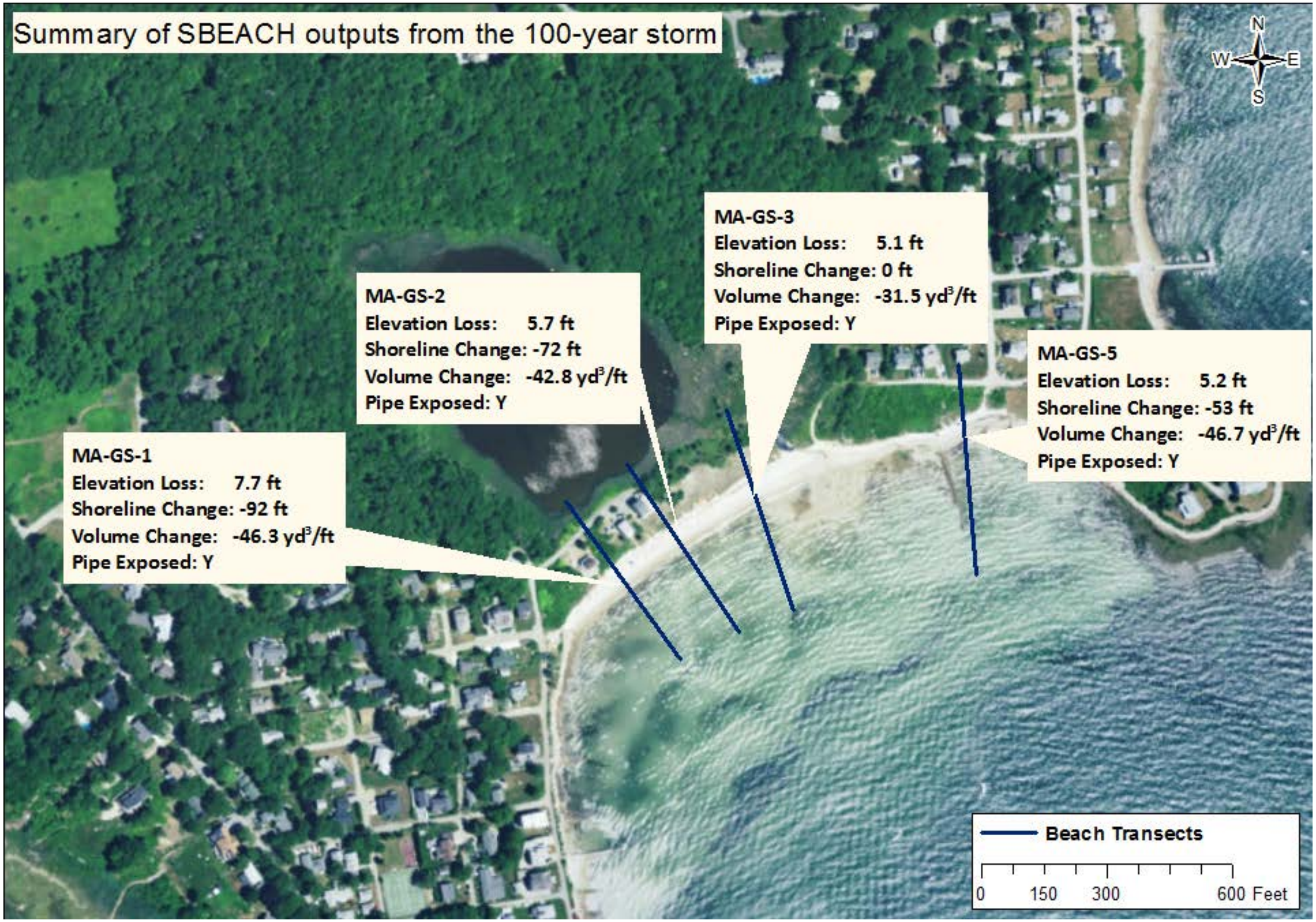
Modeling - Beach Stability Assessment



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Engineering Evaluation

Engineering Evaluation

- **Review Facilities Evaluated**

- **List Vulnerabilities Found**

- **Review Inundation Results**

  - **Facilities Evaluated for Category 2 and Category 3 Storms with 2 feet of Sea Level Rise - Most Severe Storms of Record**

- **Discuss Order of Magnitude Costs for Adaptation Measures**

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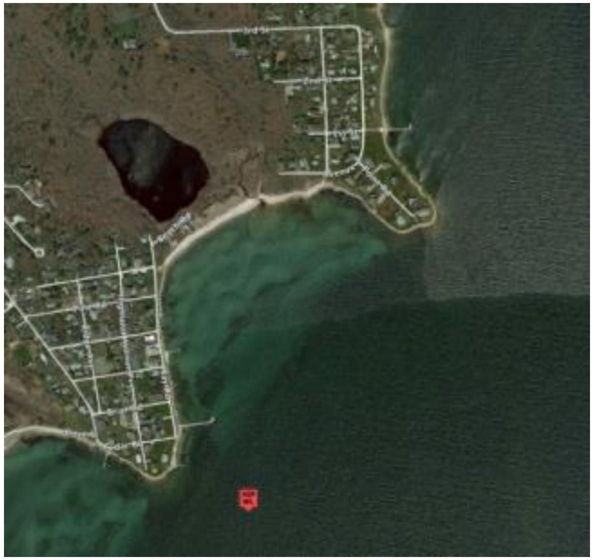
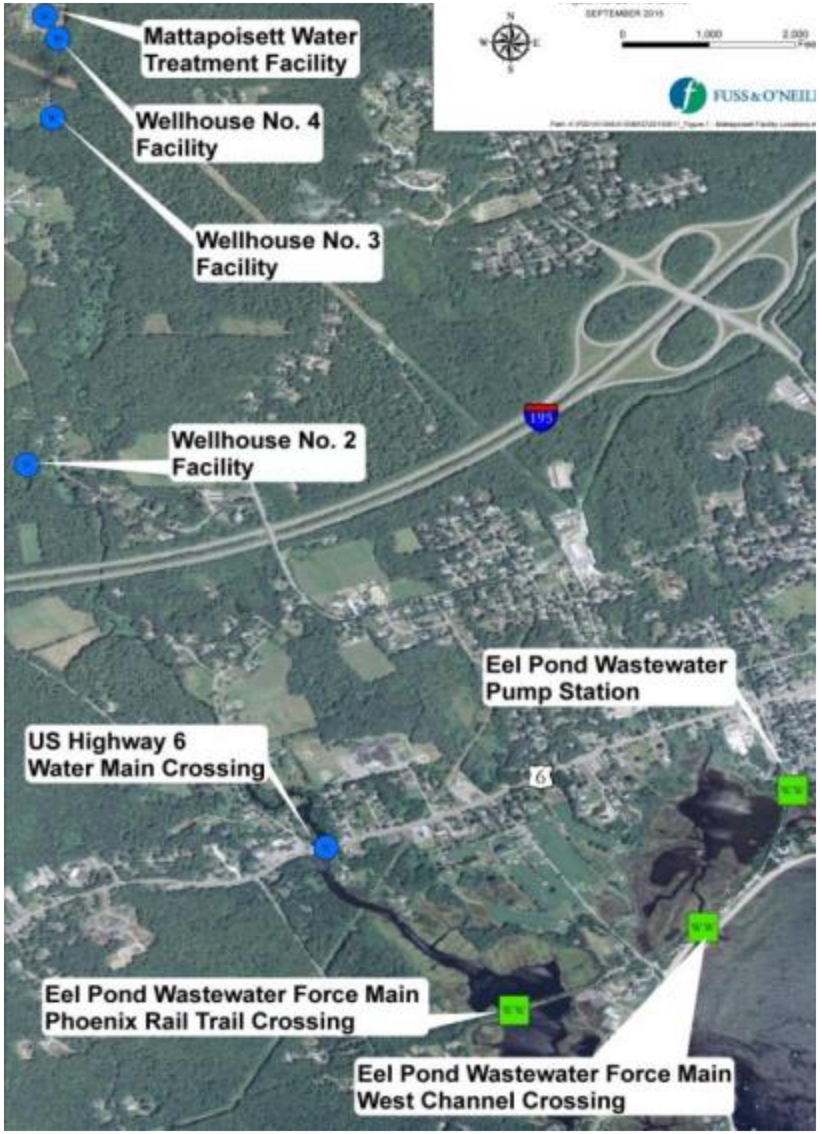
Engineering Evaluation - Locations

Evaluation of Critical Facilities

- Eel Pond WW Pumping Station
- Eel Pond Sewer Crossing
- Wellhouse No. 2 Facility
- Wellhouse No. 3 Facility
- Water Main Crossing between Pease's Point and Point Connett





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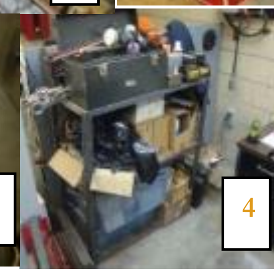
Eel Pond Wastewater Pump Station

Vulnerabilities

- Files, Materials and Supplies (1, 2, 4)
- Electrical switchgear
- Storage shed (7)
- Bioxide storage (9)
- Ventilation and heating duct work (8)
- Emergency generator
- Three Flygt pumps w/ exposed cable (6)
- Flow sampler (3)
- Wet well - Franklin Miller comminutor
- Exterior Fuel Tank



Eel Pond Wastewater Pump Station

SLOSH Modeling Results

Depth of Inundation (ft.)																				
Storm Category	No SLR					1 ft. SLR					2 ft. SLR					4 ft. SLR				
	1	2	3	4	4+	1	2	3	4	4+	1	2	3	4	4+	1	2	3	4	4+
Eel Pond Sewer Pump Station		<1	6	10	13		1	7	11	14		2	7	12	15		4	9	14	17

Critical Items Compare Base & Inundation Elevations

Category 2 Storm with 2 Ft. SLR

Critical Infrastructure	Elev. (ft.)	Water Surface Elevation (ft.)	Inundation above Item (ft.)	Proposed Remedial Action
Ground Elevation	13.48	[2.2 ft. inundation]		
Door Threshold	13.92	15.68	1.76	Floodproof Doors
Electrical Switchgear Buckets	13.92	15.68	1.76	Floodproof Doors
Generator	14.91	15.68	0.77	Floodproof Doors
Fuel System for Gen Set	15.50	15.68	0.18	Floodproof Doors
Pump Control Panels	14.02	15.68	1.66	Floodproof Doors

Category 3 Storm with No SLR

Critical Infrastructure	Elev. (ft.)	Water Surface Elevation (ft.)	Inundation above Item (ft.)	Proposed Remedial Action
Ground Elevation	13.48	[5.83 ft. inundation]		
Door Threshold	13.92	19.31	5.39	Barrier Wall
Electrical Switchgear Buckets	13.92	19.31	5.39	Barrier Wall
Generator	14.91	19.31	4.40	Barrier Wall
Fuel System for Gen Set	15.50	19.31	3.81	Barrier Wall

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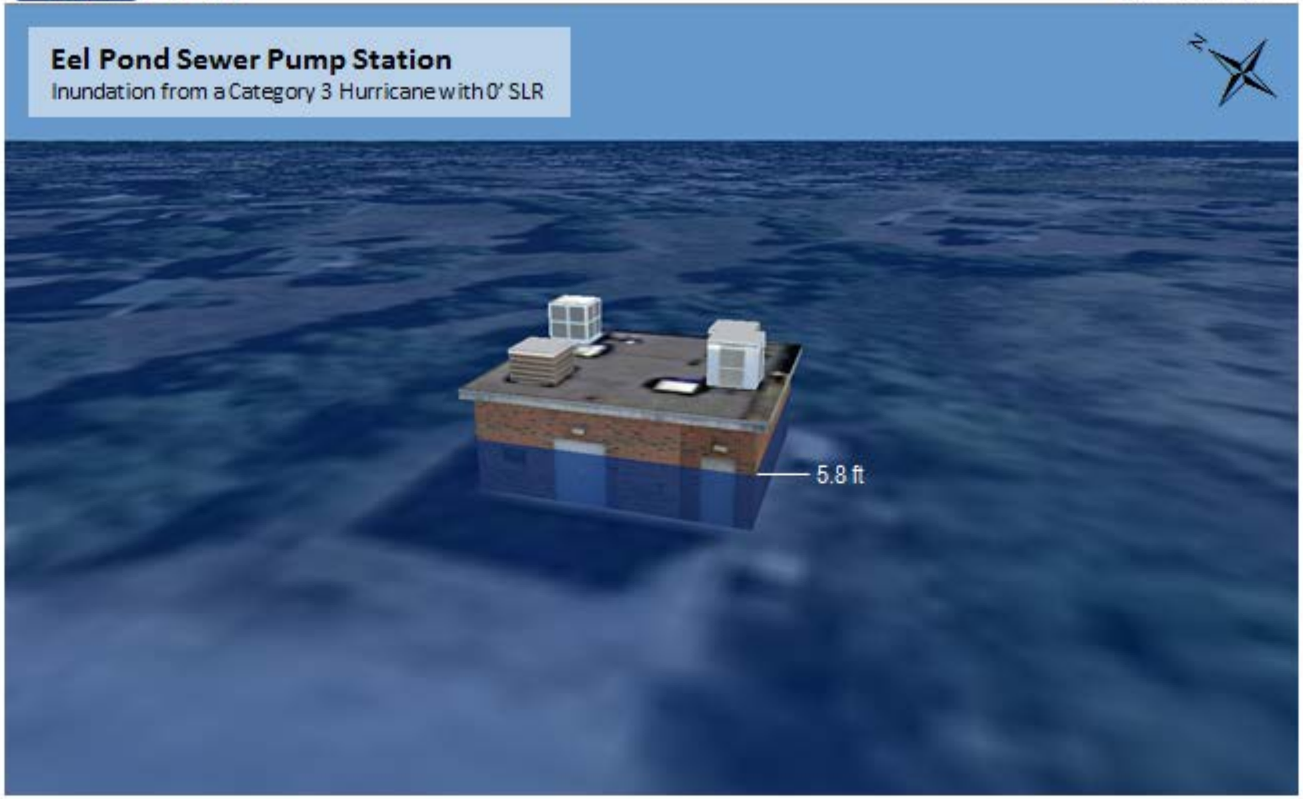
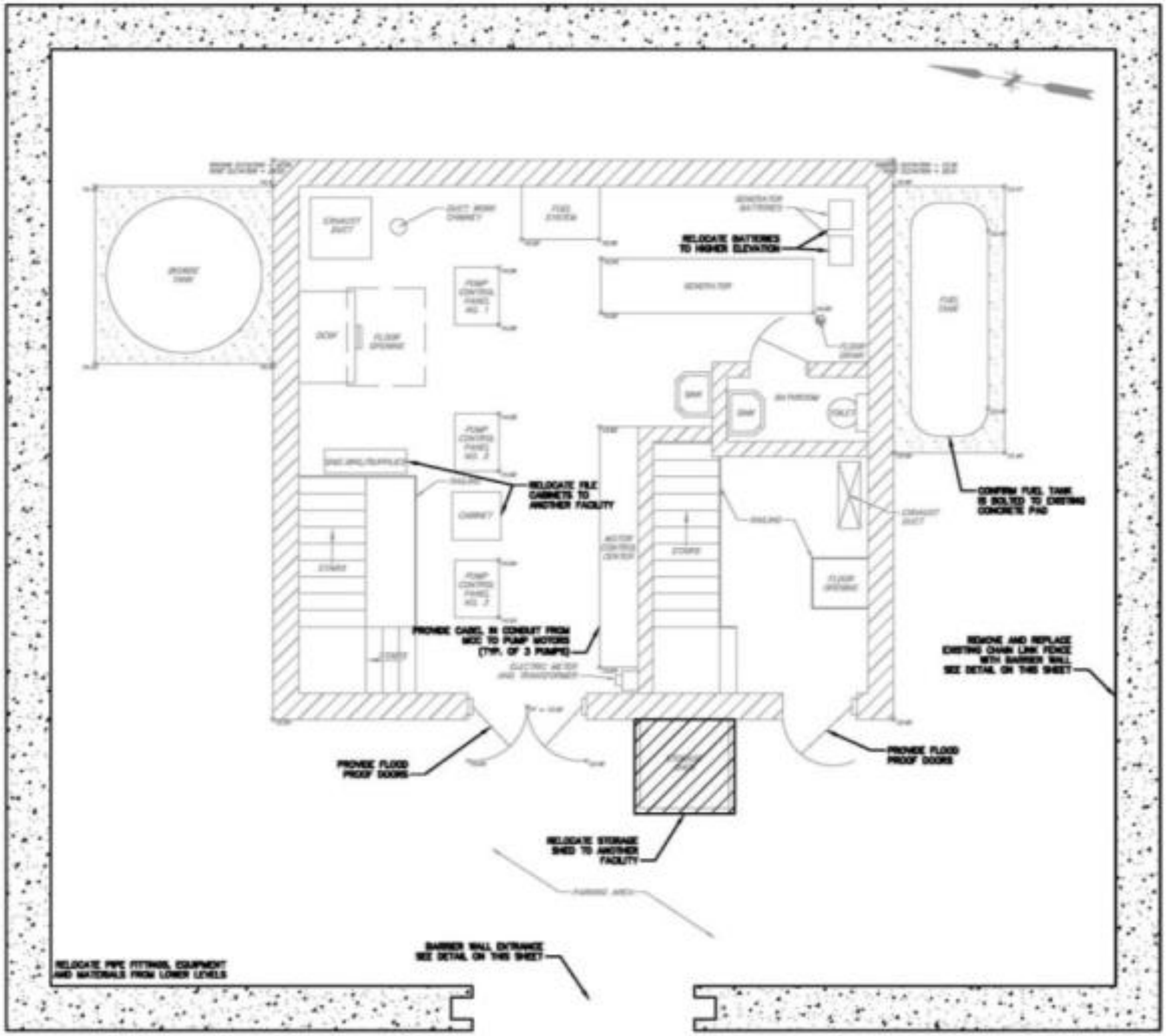
Eel Pond Wastewater Pump Station

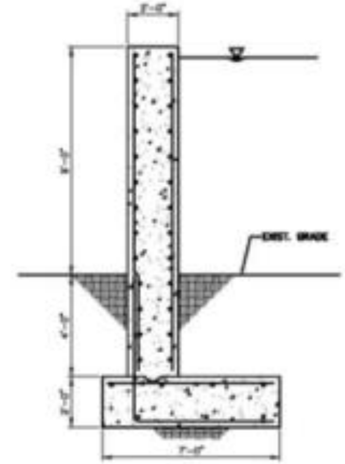
SLOSH Modeling Results - 3D Visualization



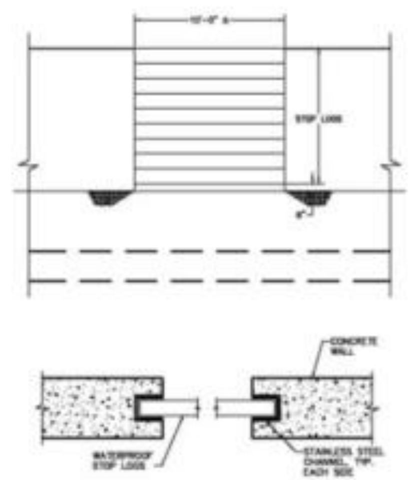
Labels represent flood water depths from a category measured from the foundation at ground level (ft). Completed July 2015.

Eel Pond Wastewater Pump Station – Adaptation Measures





2 BARRIER WALL DETAIL
SCALE: N.T.S.



3 BARRIER WALL ENTRANCE DETAIL
SCALE: N.T.S.

Eel Pond Wastewater Pump Station

Summary of Costs for Category 2 Storm - 2 Ft. SLR

Item	Budgetary Opinion of Cost
Clean Materials Stored in PS and Relocate	$5,000
Furnish /Install Flood Proof Door	$18,000
Furnish /Install Flood Proof Door	$38,000
Relocate Storage Shed	$5,000
Place Electrical Wiring in Conduit for Pumps	$5,000
Subtotal	$71,000
Division 1 Costs (21%)	$15,017
TOTAL Construction Costs	$86,017
Engineering Legal and Administration (15%)	$12,902
Contingency (25%)	$21,504
TOTAL COST (Rounded to nearest 1000)	$120,000

Budgetary Opinions of Cost Includes Gen. Requirements, Engineering (15%), Contingency (25%)

Summary of Costs for Category 3 Storm - No SLR

Item	Budgetary Opinion of Cost
Furnish/Install Flood Barrier Wall	$300,000
Clean Materials Stored in PS and Relocate	$5,000
Relocate Storage Shed	$5,000
Place Electrical Wiring in Conduit for Pumps	$5,000
Subtotal	$315,000
Division 1 Costs (21%)	$66,623
TOTAL Construction Costs	$381,623
Engineering Legal and Administration (15%)	$57,243
Contingency (25%)	$95,406
TOTAL COST (Rounded to nearest 1000)	$534,000.00

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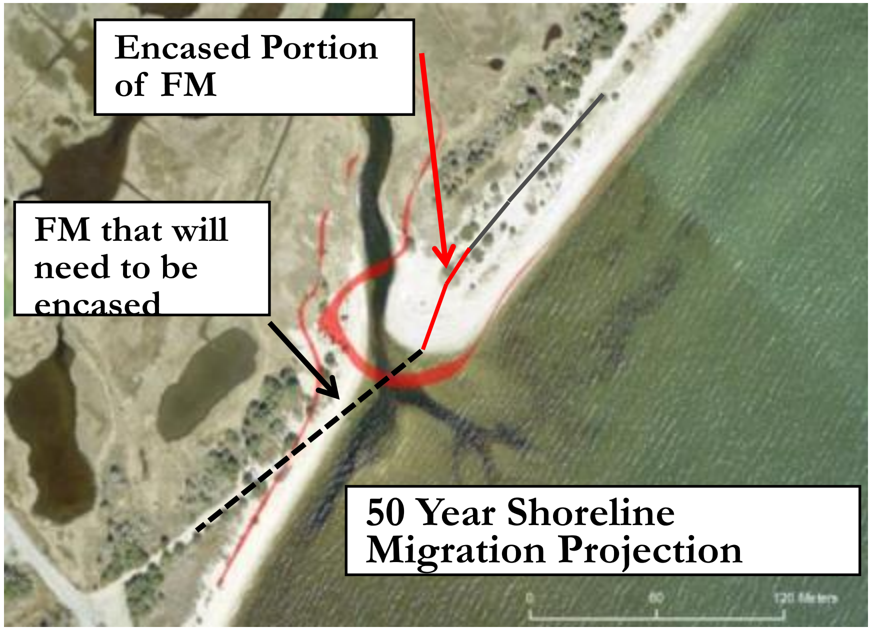
Eel Pond Sewer Crossing

Depth of Inundation (ft.)																				
Storm Category	No SLR					1 ft. SLR					2 ft. SLR					4 ft. SLR				
	1	2	3	4	4+	1	2	3	4	4+	1	2	3	4	4+	1	2	3	4	4+
Sewer Force Main	9	14	19	29	27	12	15	20	25	28	12	16	21	26	28	13	18	22	27	30

- SLOSH Model completed
- Model shows 5 different Categories and 4 different Sea Level Rise (SLR) values
- Inundation ranges from 9 feet above ground elevation (10.5 ft.) to just over 30 feet of inundation
- FM location is taken from Town mapping provided. The portion of the main shown by the red line is encased in concrete
- With Flooding - Shoreline will move - FM vulnerable
- Needs to be further encased (black dashed line) to protect against Tidal Influences



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Eel Pond Sewer Crossing

- Modeling completed is taken from a period when there were no Significant Storms
- More Severe Storm could exacerbate the migration and require further protection of the main than shown here
- Another option - Directional Drilling of New Force Main - Many of the same costs as encasing, but more main would need to be replaced further increasing overall cost. Also, bypass pumping would be necessary.
- A Third option - Utilizing a Different Route from pump station.

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Eel Pond Sewer Crossing

Budgetary Opinions of Cost
Includes Gen. Requirements, Engineering (15%), Contingency (25%)

Item	Budgetary Opinion of Cost
Cofferdamming for Ocean and Inlet Area	$150,000
Excavation to Expose FM Piping, Deepen Piping	$125,000
Sheeting, Shoring, Dewatering, Protection around work	$150,000
Furnish /Install Concrete Encasement	$300,000
Backfill and Compaction	$90,000
Restoration	$50,000
Subtotal	$865,000
Division 1 Costs (21%)	$182,948
TOTAL Construction Costs	$1047,948
Engineering Legal and Administration (15%)	$157,192
Contingency (25%)	261,987
TOTAL COST (Rounded to nearest 1000)	$1,467,000

- **Directional Drilling Option Mentioned above - Budgetary Opinion of Cost – $2.5 to $3 Million Dollars.**

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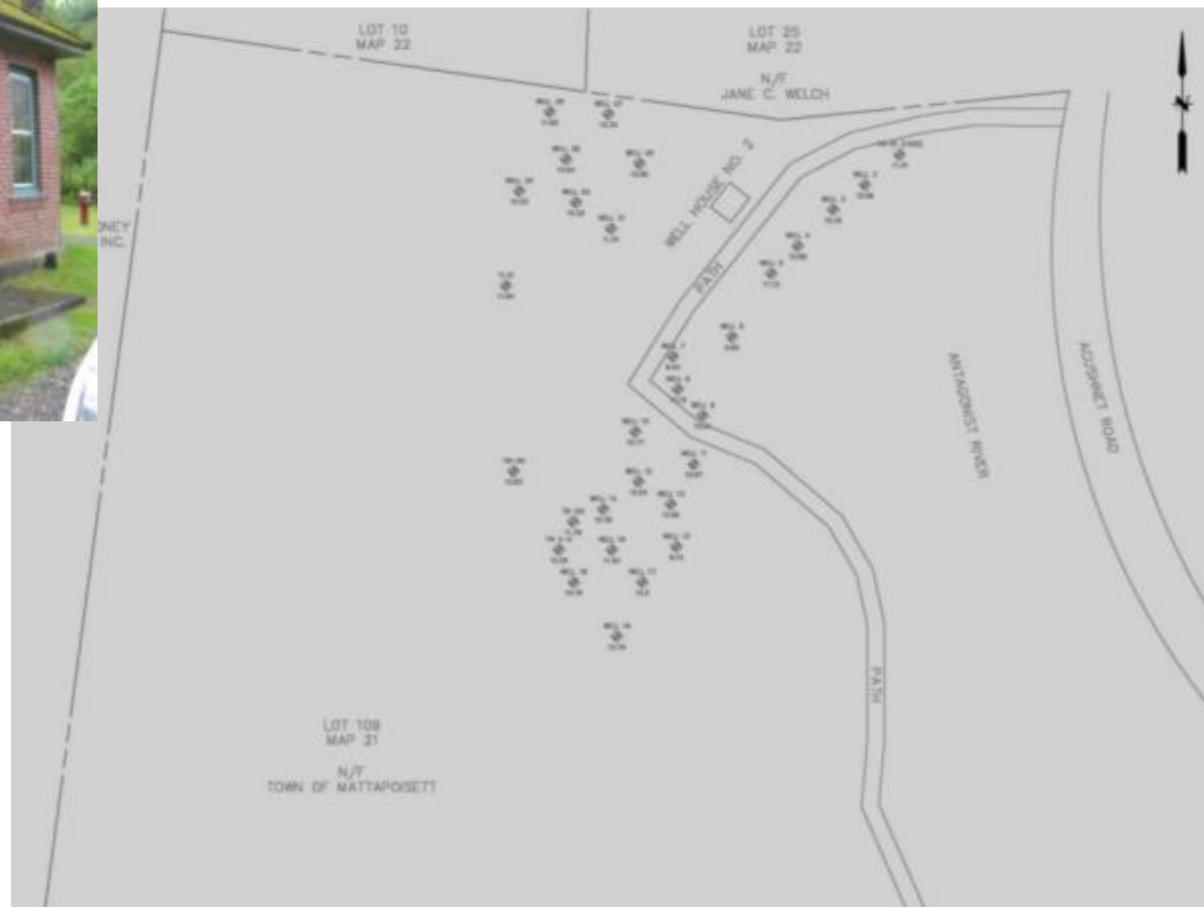
Wellhouse No. 2 Facility and Wellfield



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Wellhouse No. 2 Facility and Wellfield

Vulnerabilities

- Air compressor (1)
- Electrical conduit
- Facility unit heater (2)
- Desk and file cabinets (2)
- Electrical service cabinet (4)
- Sulzer booster pump.
- Alarm service wires (8)
- Four (4) vents located outside (3)
- 8 windows (3)
- Propane tanks (5)
- Floor penetrations to lower level
- Valves are inoperable (6)
- Tubular Wells (7)

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Wellhouse No. 2 Facility and Wellfield

SLOSH Modeling Results

Depth of Inundation (ft.)																				
Storm Category	No SLR					1 ft. SLR					2 ft. SLR					4 ft. SLR				
	1	2	3	4	4+	1	2	3	4	4+	1	2	3	4	4+	1	2	3	4	4+
No. 2 Pump Station			4	11	13			5	12	14		1	7	12	15		3	9	14	16

Critical Items - Compare Base & Inundation Elevations

Category 2 Storm with 2 Ft. SLR

Critical Infrastructure	Elev. (ft.)	Water Surface Elevation (ft.)	Inundation above Item (ft.)	Proposed Remedial Action
Ground Elevation	13.12	[1.36 ft. inundation]		--
Door Threshold	14.37	14.48	0.11	Floodproof Doors
Electrical Switchgear	14.54	14.48	--	Floodproof Doors
Compressor	14.54	14.48	--	Floodproof Doors
Unit Heater	14.50	14.48	--	Floodproof Doors
Vents for Clearwell	13.70	14.48	0.78	Extend Vents and Cap
Floor Penetrations to Lower Level	14.50	14.48	--	Floodproof Hatch
Tubular Wells	varies	14.50	varies	Extend Well Caps
Propane Tanks	12.85	14.48	1.63	Place on Pad

Wellhouse No. 2 Facility and Wellfield

SLOSH Modeling Results

Depth of Inundation (ft.)																				
Storm Category	**No SLR**					**1 ft. SLR**					**2 ft. SLR**					**4 ft. SLR**				
	1	**2**	**3**	**4**	**4+**	**1**	**2**	**3**	**4**	**4+**	**1**	**2**	**3**	**4**	**4+**	**1**	**2**	**3**	**4**	**4+**
No. 2 Pump Station			4	11	13			5	12	14		1	7	12	15		3	9	14	16

Critical Items - Compare Base & Inundation Elevations

Critical Infrastructure	Elev. (ft.)	Water Surface Elevation (ft.)	Inundation above Item (ft.)	Proposed Remedial Action
Base Elevation	13.12	[6.70 ft. inundation]		--
Door Threshold	14.37	19.82	5.45	Barrier Wall
Electrical Switchgear	14.54	19.82	5.28	Barrier Wall
Compressor	14.54	19.82	5.28	Barrier Wall
Unit Heater	14.50	19.82	5.32	Barrier Wall
Vents for Clearwell	13.70	19.82	6.12	Extend Vents and Cap
Facility Windows	16.12	19.82	3.70	Floodproof Windows
Floor Penetrations to Lower level	14.50	19.82	5.32	Floodproof Hatch, Concrete repairs
Tubular Wells	varies	19.82	Varies	Extend Well Caps
Propane Tanks	12.85	19.82	6.97	Bury Tanks

Category 3 Storm with 2 Ft. SLR

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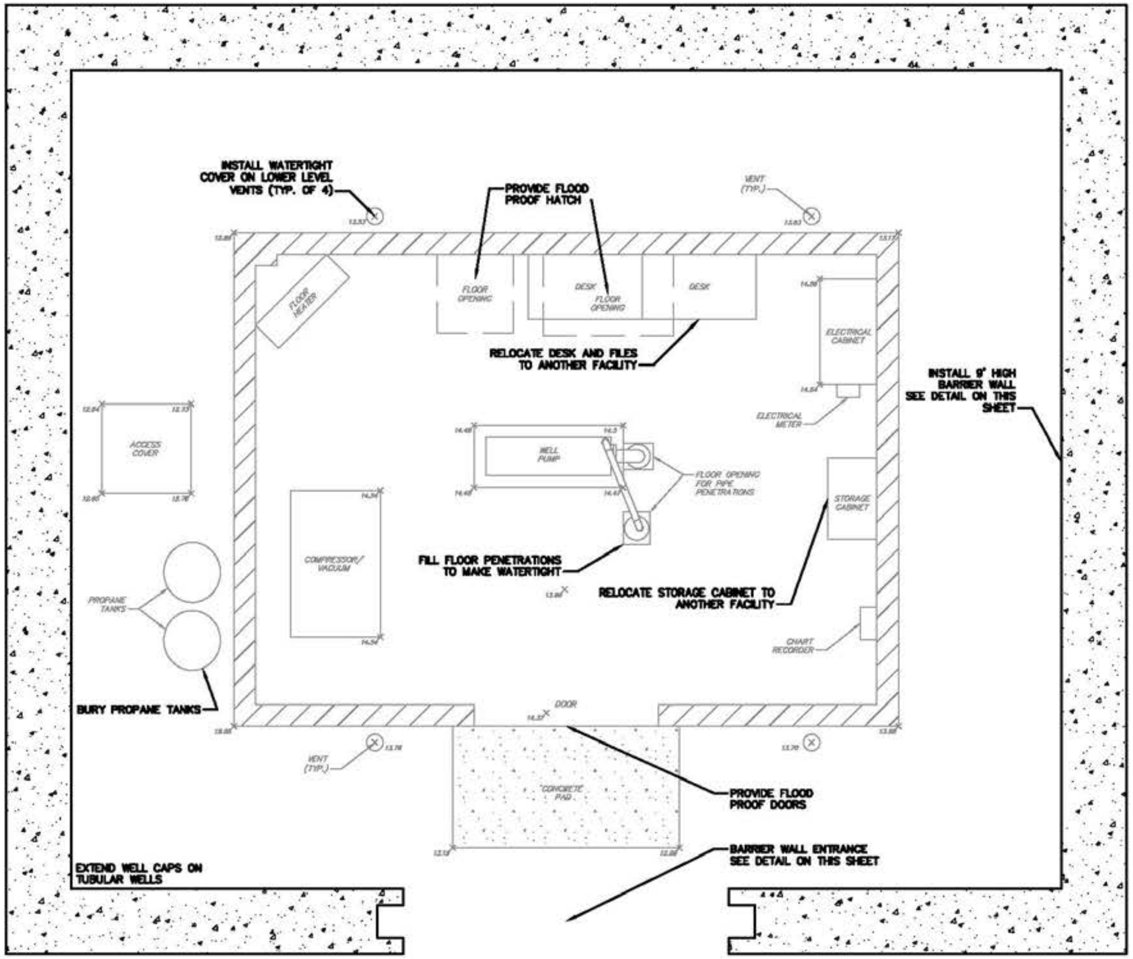
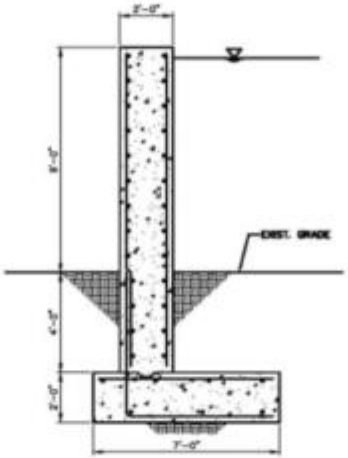
Wellhouse No. 2 Facility and Wellfield
SLOSH Modeling Results -3D Visualization

Labels represent flood water depths from a category measured from the foundation at ground level (ft). Completed July 2015.

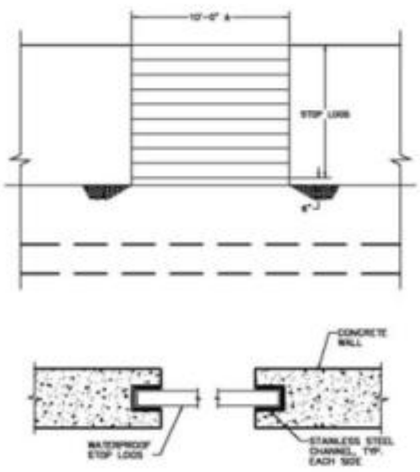
Wellhouse No. 2 Facility and Wellfield - Adaptation Measures



1 FLOOR PLAN
SCALE: 1/4" = 1'



2 BARRIER WALL DETAIL
SCALE: N.T.S.



3 BARRIER WALL ENTRANCE DETAIL
SCALE: N.T.S.

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Wellhouse No. 2 Facility and Wellfield

Summary of Costs for Category 2 Storm - 2 Ft. SLR

Item	Budgetary Opinion of Cost
Clean Materials Stored in PS and Relocate	$5,000
Furnish/Install Floodproof Door	$38,000
Extend Well caps for Tubular Wells	$5,200
Hatches - Floor penetration to Lower Level	$30,000
Minor Concrete Floor Repairs	$25,000
Bury Propane Tanks	$10,000
Subtotal	$113,200
Division 1 Costs (21%)	$23,942
TOTAL Construction Costs	$137,142
Engineering Legal and Administration (15%)	$20,571
Contingency (25%)	$34,285
TOTAL COST (Rounded to nearest 1000)	$192,000

Budgetary Opinions of Cost Includes Gen. Requirements, Engineering (15%), Contingency (25%)

Summary of Costs for Category 3 Storm - 2 Ft. SLR

Item	Budgetary Opinion of Cost
Furnish/Install Flood Barrier Wall	$360,000
Furnish/Install Floodproof Windows	$32,000
Hatches - Floor penetration to Lower level	$30,000
Extend Well caps for Tubular Wells	$5,200
Minor Concrete Floor Repairs	$25,000
Bury Propane Tanks	$10,000
Subtotal	$462,200
Division 1 Costs (21%)	$97,755
TOTAL Construction Costs	$559,955
Engineering Legal and Administration (15%)	$83,993
Contingency (25%)	$139,989
TOTAL COST (Rounded to nearest 1000)	$784,000

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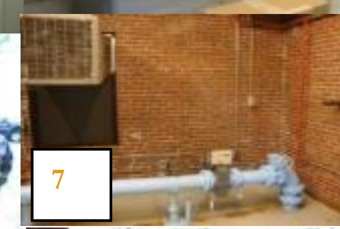
Wellhouse No. 3 Facility

Vulnerabilities

- Vertical turbine pump (1)
- Force main piping (2)
- Storage units and cabinet files (3)
- Switchgear (4)
- Chrysler motor (5)
- Propane tank (8)
- Electrical feed
- Conduit and Receptacles(7)
- Variable Frequency Drive (6)



Wellhouse No. 3 Facility

SLOSH Modeling Results

Depth of Inundation (ft.)																				
Storm Category	No SLR					1 ft. SLR					2 ft. SLR					4 ft. SLR				
	1	2	3	4	4+	1	2	3	4	4+	1	2	3	4	4+	1	2	3	4	4+
No. 3 Pump Station			2	7	10			3	9	11			4	9	12		<1	6	11	13

Critical Items - Compare Base and Inundation Elevations

Category 2 Storm with 2 Ft. SLR

Critical Infrastructure	Elev. (ft.)	Water Surface Elevation (ft.)	Inundation above Item (ft.)	Proposed Remedial Action
Base Elevation	17.90	**--**	**--**	**--**
Vertical Turbine Pump	18.53	--	--	--
Discharge Piping	19.00	--	--	--
Propane Tank Outside Wellhouse	--	--	--	--
Electrical Service Location	20.90	--	--	--
Conduit and Receptacle	19.00	--	--	--
Variable Frequency Drives	19.40	--	--	--

Category 3 Storm with 2 Ft. SLR

Critical Infrastructure	Elev. (ft.)	Water Surface Elevation (ft.)	Inundation above Item (ft.)	Proposed Remedial Action
Base Elevation	17.90	[3.80 ft. inundation]		--
Vertical Turbine Pump	18.53	21.70	3.17	Floodproof Doors
Discharge Piping	19.00	21.70	2.70	Floodproof Doors
Propane Tank Outside Wellhouse		21.70	--	Bury Tank
Electrical Service Location	20.90	21.70	0.80	Raise
Conduit and Receptacle	19.00	21.70	2.7	Raise
Variable Frequency Drives	19.40	21.70	2.30	Raise

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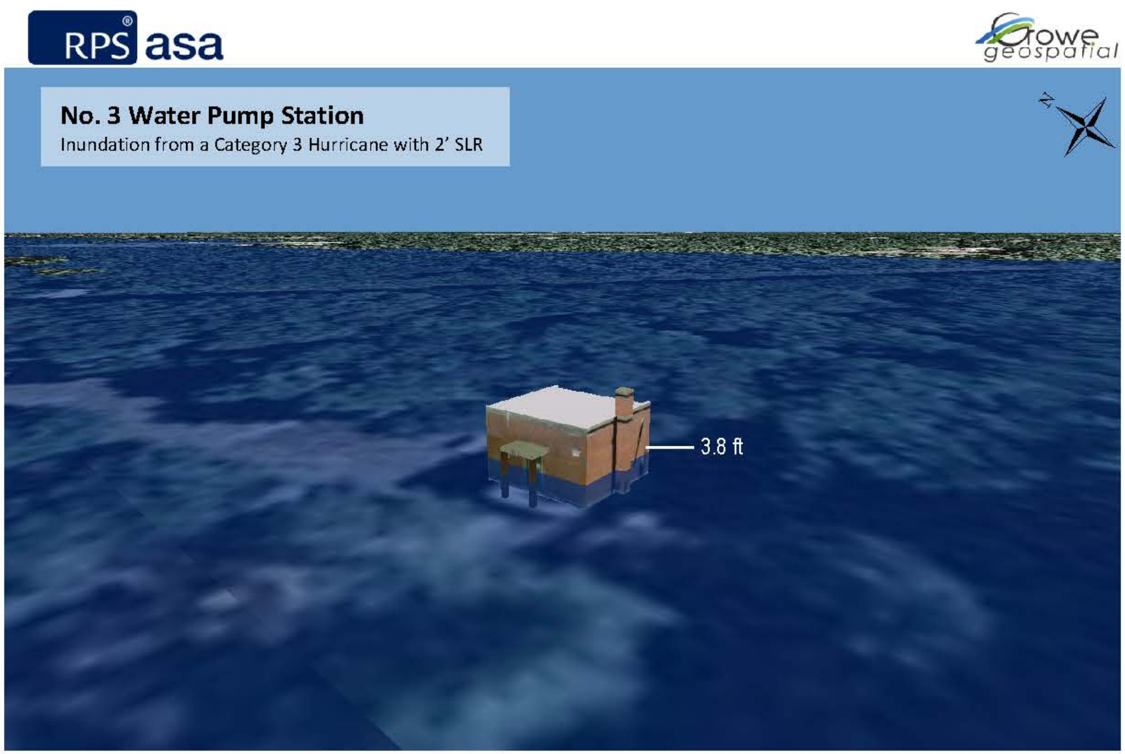
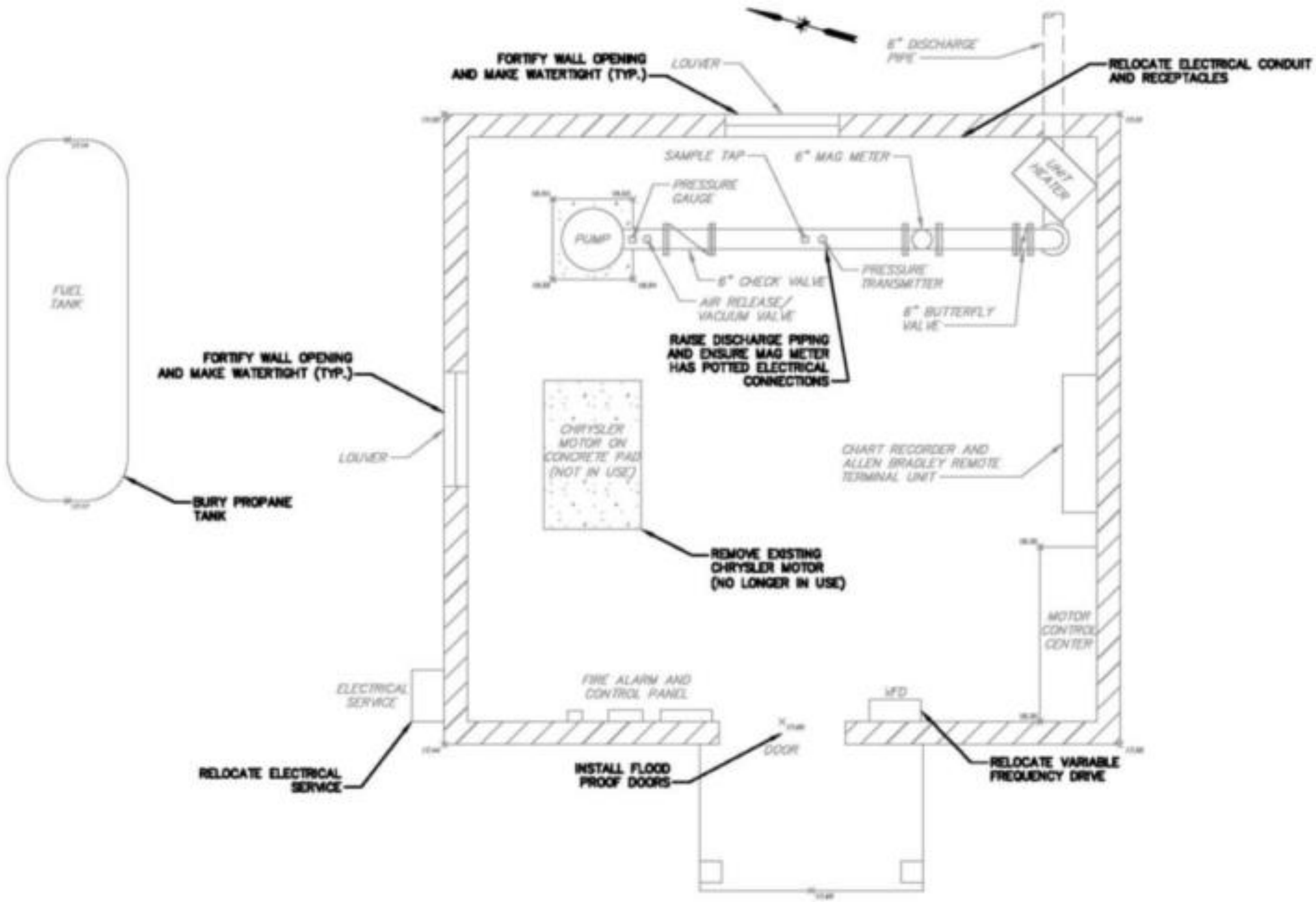
8 No. 3 Water Pump Station – 2 ft of SLR



Labels represent flood water depths from a category measured from the foundation at ground level (ft). Completed July 2015.

Wellhouse No. 3 Facility

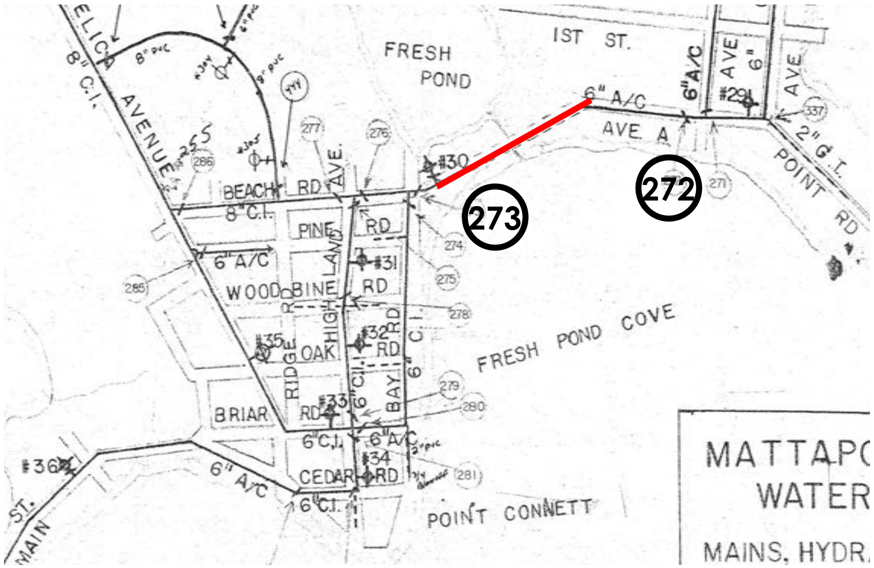


Budgetary Opinions of Cost
Includes Gen. Requirements, Engineering (15%), Contingency (25%)

Summary of Costs - Category 3 Storm - 2 Ft. SLR

Item	Budgetary Opinion of Cost
Clean Materials Stored in PS and Relocate	$5,000
Furnish/Install Floodproof Door	$38,000
Fortifying Wall Openings	$5,200
Raise Electrical Items	$25,000
Bury Propane Tank	$10,000
Subtotal	$83,200
Division 1 Costs (21%)	$17,597
TOTAL Construction Costs	$100,797
Engineering Legal and Administration (15%)	$15,120
Contingency (25%)	$25,199
TOTAL COST (Rounded to nearest 1000)	$141,000

Water Main Crossing b/w Pease's Point and Point Connett



- 6 -Inch Asbestos Cement
- 1,000 Linear Feet
- Starts at end of Avenue "A" - Pease's Point
- Crosses the beach behind 3 Homes on Beach Road; Connects to Water Main located at the intersection of Beach Road and Bay Road
- Water Main has valves for Isolation
  - Valve 272 on Pease's Point
  - Valve 273 on Point Connett
- Water Main has hydrant
  - Hydrant #30 on Point Connett

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Water Main Crossing b/w Pease's Point and Point Connett

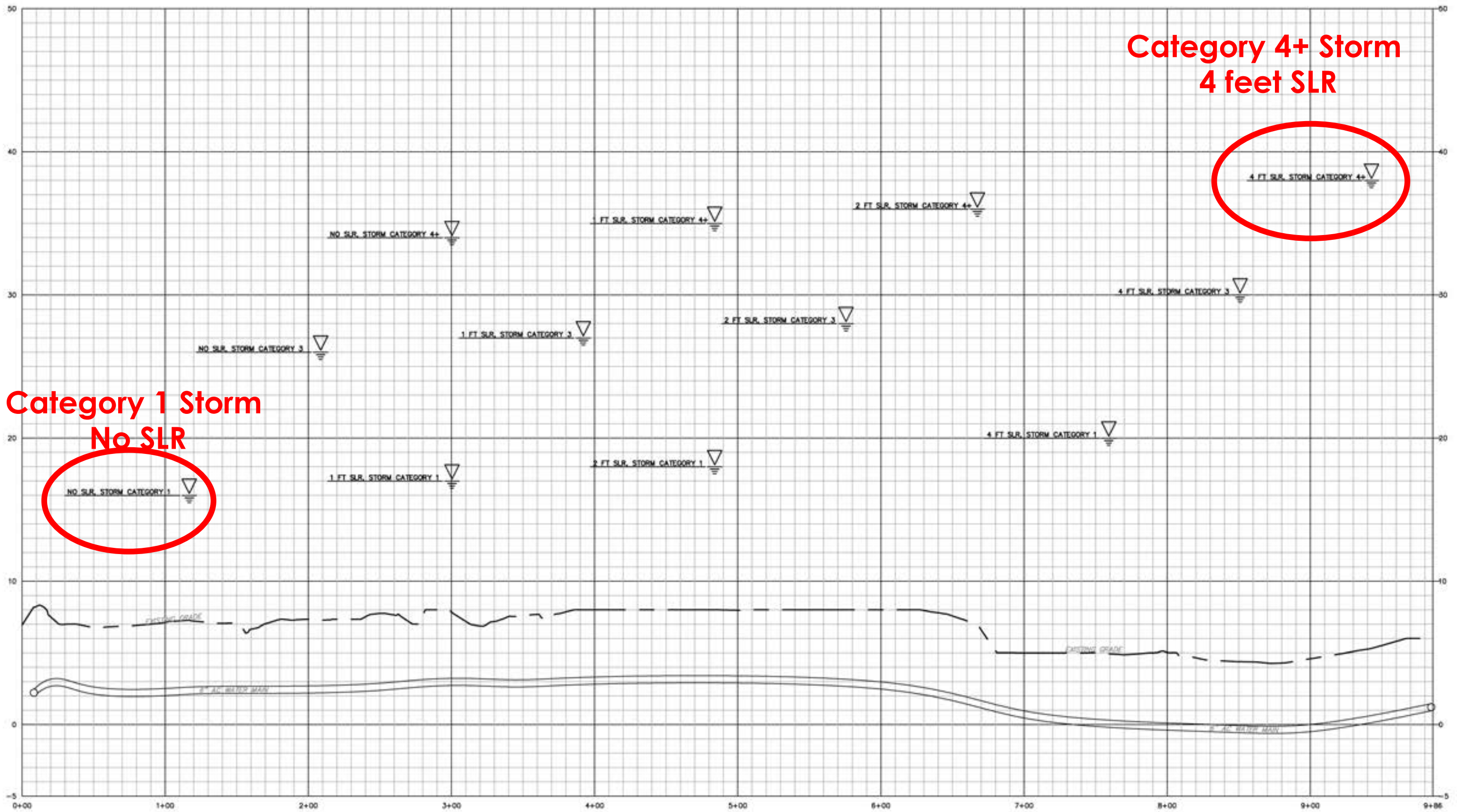
Exposure of Water Main and replacement of the Sand

Two Main Vulnerabilities

1. One of the Vulnerabilities is Exposure
   - Water Main exposed in 2013
     - *Tropical Storm Andrea*
   - Significant Beach Erosion in the Area where the Main crosses Fresh Pond Just North of Beach
   - Water Main was Isolated from Distribution system at Pease's Point and Point Connett
   - Received numerous complaints/call regarding pressure and quality
2. Second Vulnerability is Condition
   - Asbestos Cement pipe is brittle and with this environment could have frequent breaks

Water Main Crossing b/w Pease's Point and Point Connett

Minimum of 9 feet of Inundation for Cat. 1 Storm with no SLR to above 30 feet for Category 4+ Storm with 4 ft. of SLR



STATION
PROFILE STA 0+00 – 9+86
SCALE: H: 1"=40'
V: 1"=4'

NOTE:
1.) INUNDATION DEPTHS ARE APPROXIMATE AND DOES NOT INCLUDE WAVE ACTION.

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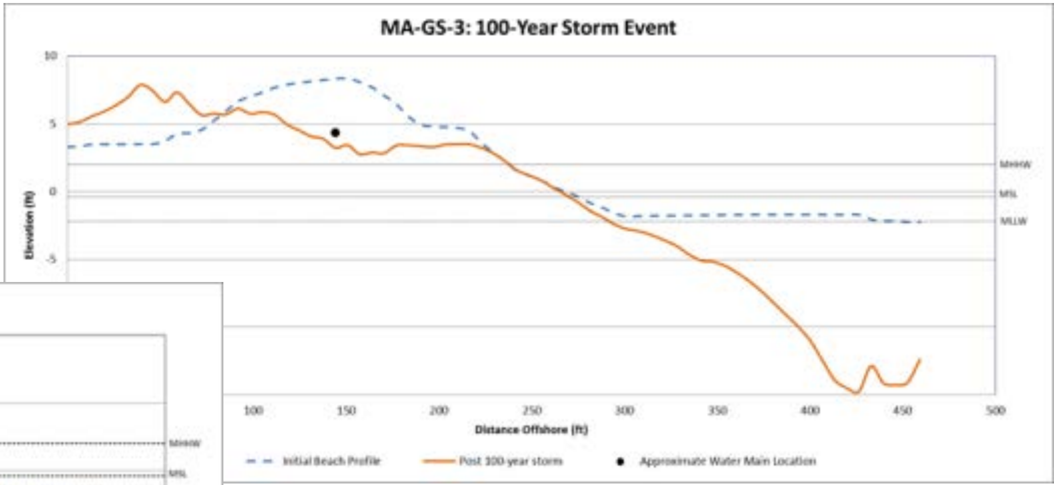
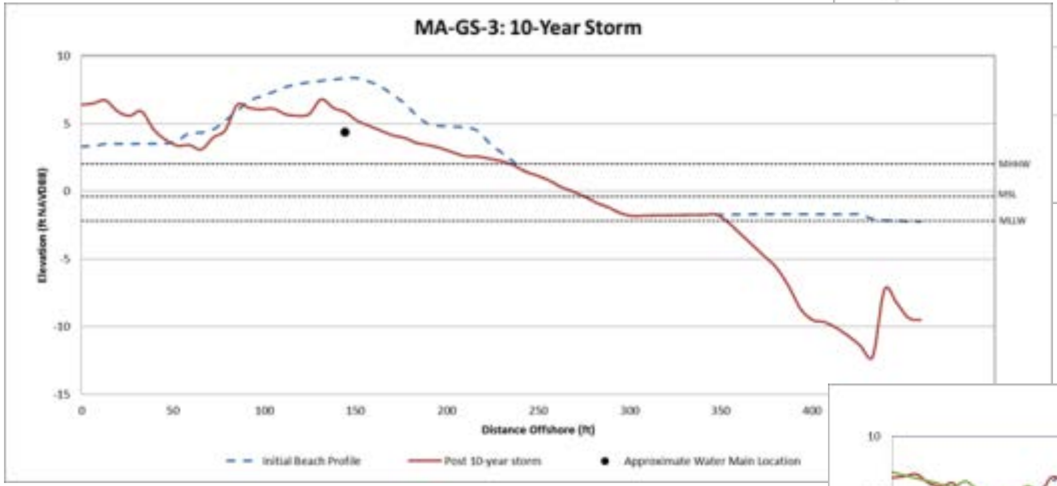
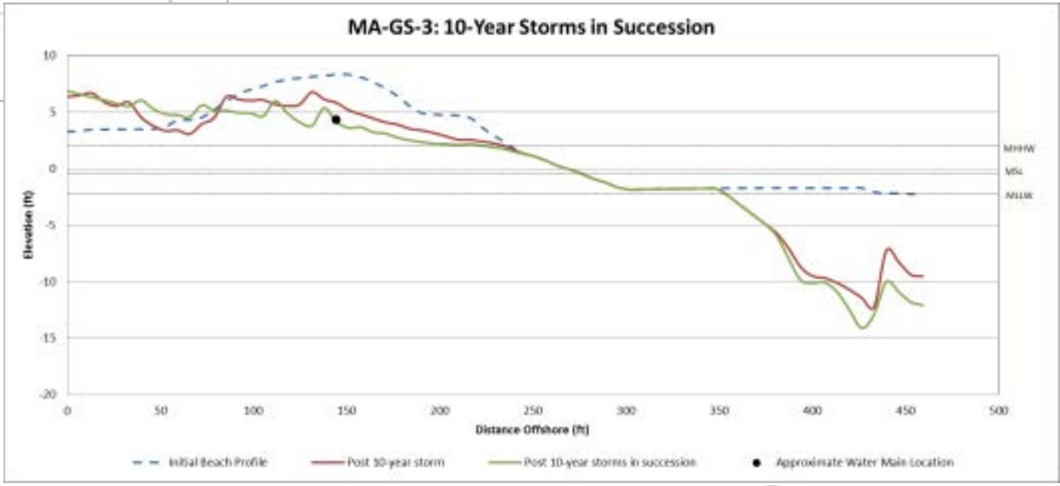
Beach Assessment Results

- Existing Main is Exposed after 100 Yr. Storm Event





- Existing Main is just barely covered after 10 Yr. Storm



- Existing Main is Exposed after 10 Yr. Storm Events in succession

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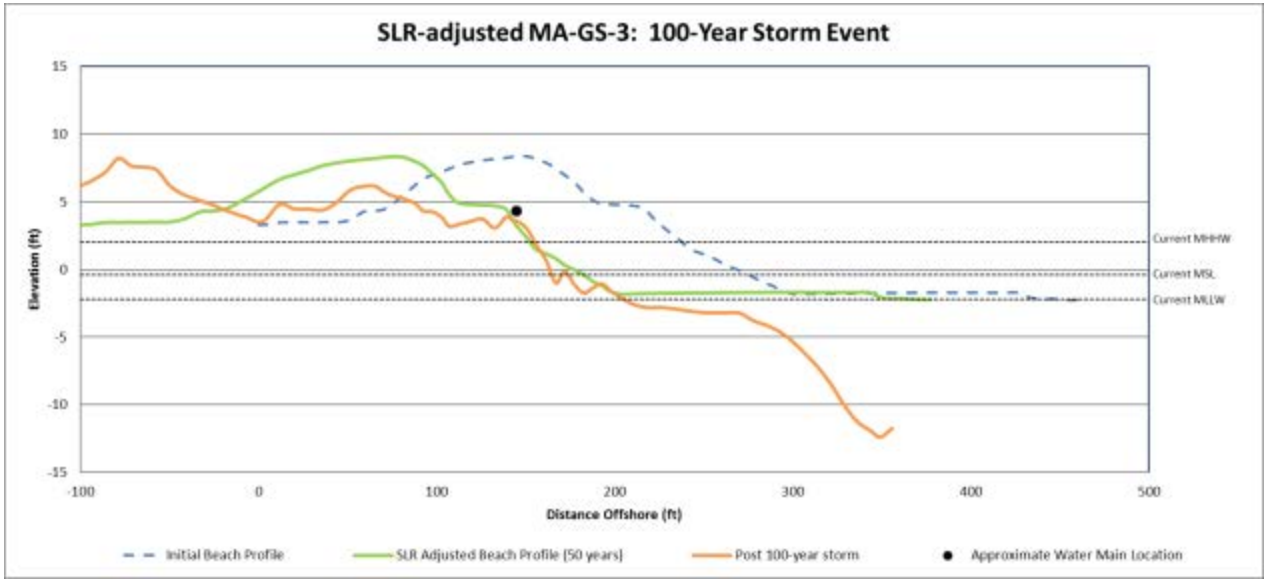
Beach Assessment Results

Results of Beach Migration with Sea Level Rise - 100 Year Storm



- Significant Movement of the Dune and Beach area inward
- Exposure of the existing water main

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Engineering Evaluation

- Work with Town Water & Sewer Dept. Staff to
  - Develop Two Alternatives;
  - Discuss advantages and disadvantages;
  - Develop Budgetary Opinions of Probable Cost

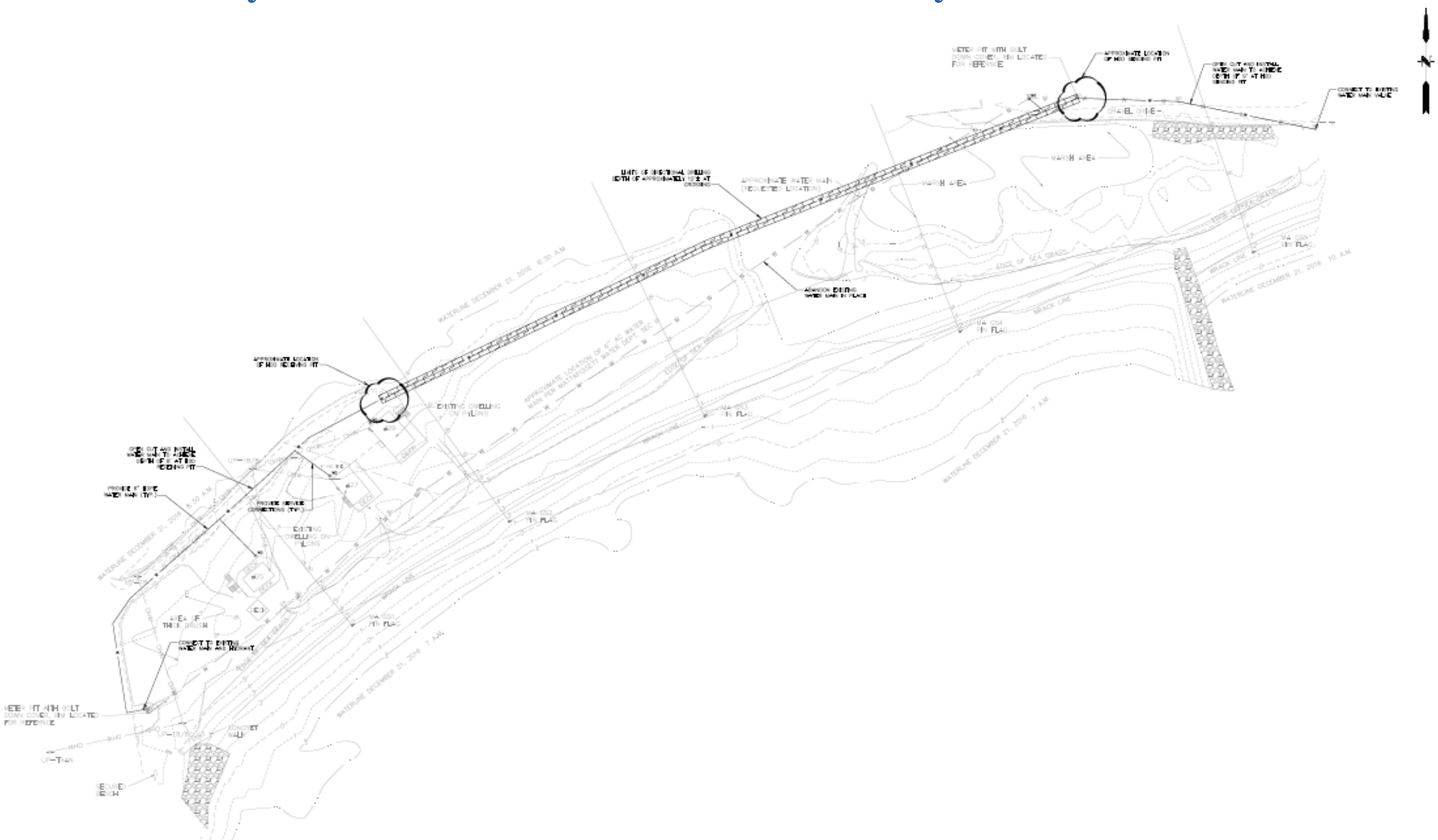
<u>**Two Alternatives for Water Main Relocation**</u>

- Directionally Drill Water Main and relocate away from Beach Area

- Install New Water Main North of Fresh Pond

Engineering Evaluation - Alternative No. 1

Directionally Drill Water Main and relocate away from Beach Area



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Engineering Evaluation - Alternative No. 1

Directionally Drill Water Main and relocate away from Beach Area

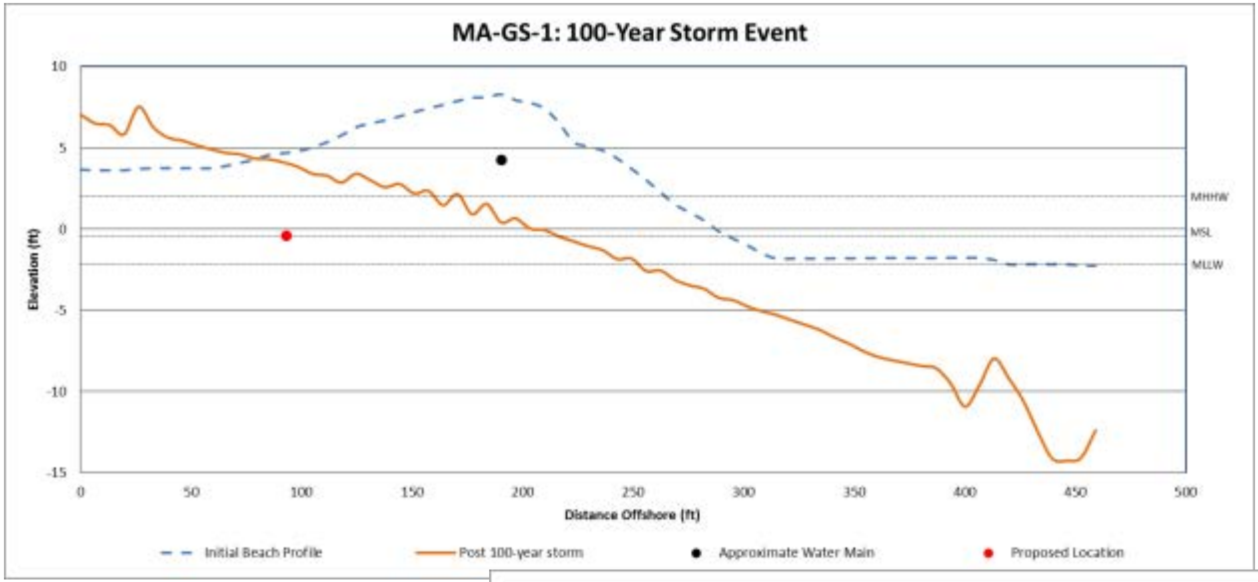
Advantages

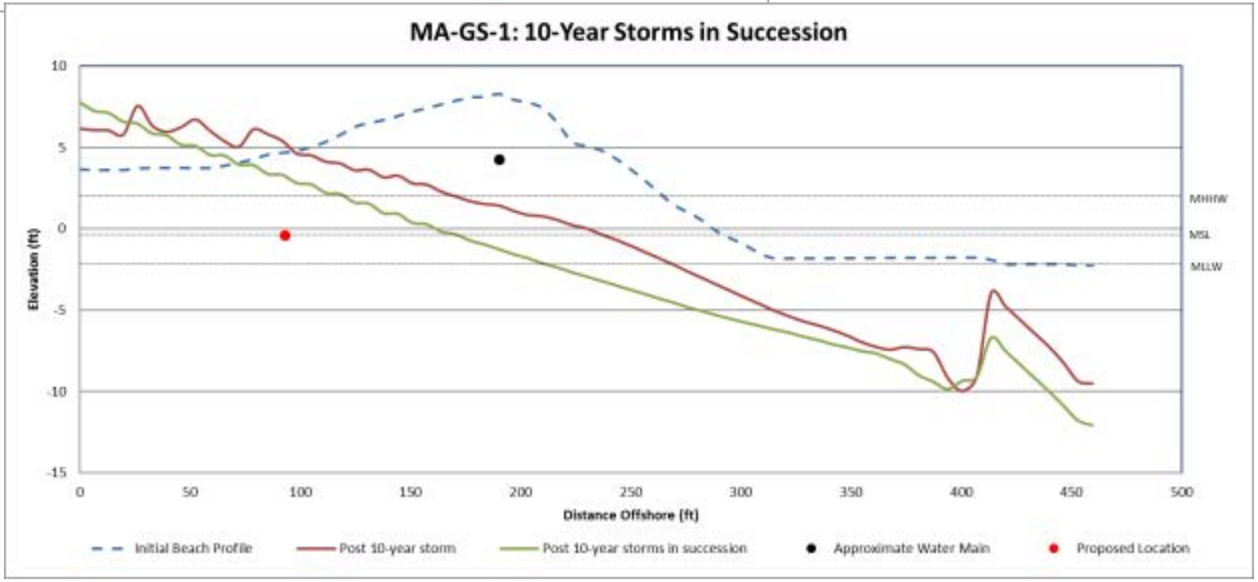
- Permitting phase would not be as difficult given there wouldn't be any open cut excavation occurring along the beach or in the vicinity of the pond.
- Restoration work would be limited because horizontal directional drilling is a trenchless technology.
- This alternative would preserve existing water system loop and not create additional water system dead ends that would require additional maintenance or result in Water quality/pressure issues.

Disadvantages

- Soil conditions in the area are unknown and could affect installation.
- Existing Piping on Beach Road and Avenue will need to be deepened and there may be slight disruption of service in this area.

Relocation in relation to Beach Assessment Results





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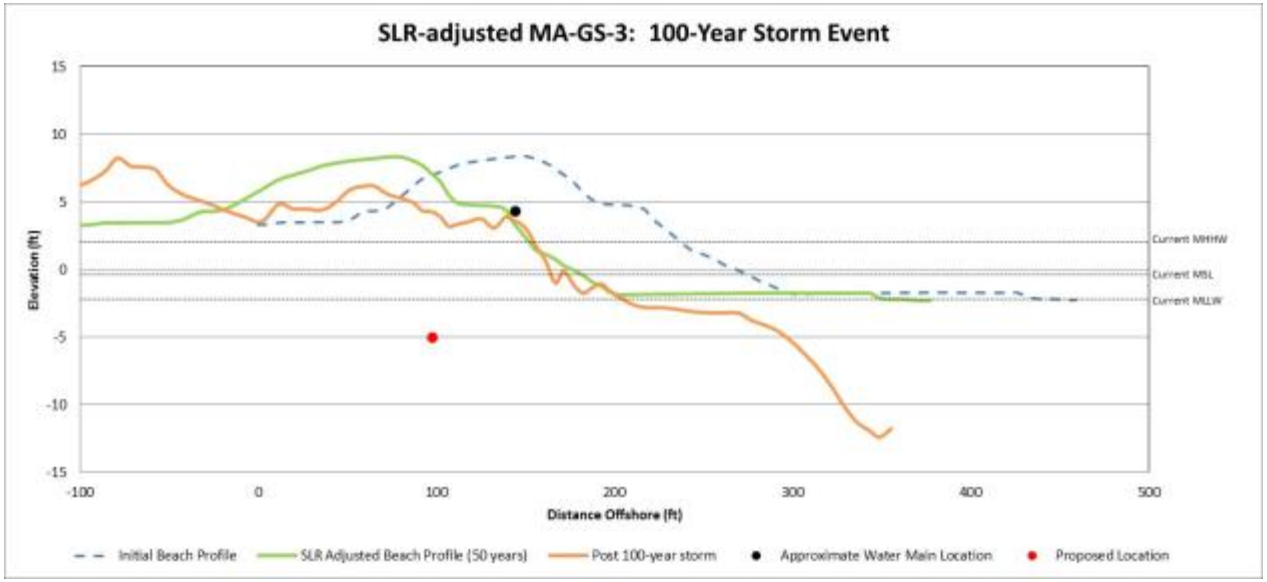
Relocation in relation to Beach Assessment Results



- When looking at the profile with the Sea Level Rise Adjustment made for storms such as the 100 Year Storm, the event will just barely expose the existing pipe at this transect but will expose for other transects.
- When looking at the proposed pipe locations (red dot above), it will remain buried and protected at each of the profiles.

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Engineering Evaluation

Budgetary Opinion of Cost for Alternatives Evaluated

Item	Alternative No. 1 HDD Water Main	Alternative No. 2 Cross Country Extension
Construction Cost	$259,700	$377,600
Division 1 Costs (20%)	$52,000	$76,000
Legal and Administrative (8%)	$25,000	$37,000
Engineering (15%)	$47,000	$69,000
Permitting	$60,000	$50,000
Contingency (25%)	$78,000	$114,000
Total Project Cost	$530,000	$730,000

Notes:
- **Refer to Appendix A of Report for breakdown of Construction Costs.**
- **Engineering, Legal, and Administrative cost are for design services only.**

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Recommendations

- **Replace Water Main as detailed for Alternate No. 1**
  - This alternative consists of abandoning the existing 6” AC water main in place and installing a new 6-inch water main just north and nearly parallel to the existing water main, but at a much greater depth by means of a horizontal directional drill rig.
  - Water mains on Avenue A and Beach Road will also be replaced and installed at deeper depths to fortify the distribution system closest to the beach
  - This alternative will protect the water main crossing from future erosion by installing it deeper and minimizing the possibility it would be exposed.

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Recommendations

- **Replace Water Main as detailed for Alternate No. 1**
  - **Before Design Begins - Work with Drilling Contractor to further define the soils in the area of directional drilling through the completion of soil borings.**
  - **Investigate water mains on Beach Road and Avenue "A" to confirm depth and operability of valves and hydrants.**
  - **Discuss the proposed approach with Mattapoisett's Agencies to better define permitting requirements**

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Any questions?

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