COASTAL FLOOD RISK

Detailed analyses of the coastal flood hazards and associated vulnerability and risk were performed. The results are presented in **Attachment 2** and **Attachment 4**.

COASTAL FLOOD HAZARDS

Coastal flood hazards include:

- tides;
- extreme water levels and resulting flood inundation due to storm surge;
- waves; and
- coincident high wind and precipitation.

These coastal hazards are typically described (by FEMA and other flood planners and engineers) in terms of their likelihood of occurrence. Specifically, coastal floods, waves, precipitation and wind intensity are characterized by their "annual exceedance probability [AEP]" and, similarly, their "recurrence interval". The AEP defines the probability that a certain condition (say, flood water level) will be encountered or exceeded at least once in any given year. The FEMA base flood elevation (shown on FEMA Flood Insurance Rate Maps [FIRMs]) represents the predicted 1% AEP (aka 100-year recurrence interval) flood. This flood water level has a 1 in 100 chance of being met or exceeded in any given year. Since it is important (for Town planners as well as homeowners) to consider all coastal flood risks, conditions associated with other occurrence probabilities are also important. Due to their importance for public safety, Essential Facilities (police, emergency responders) conservatively consider lower probability floods (i.e., the 500-year recurrence interval flood). At the other end of the spectrum, although less intense, high probability floods (such as the 2-year and 10-year recurrence interval floods) are important because they are predicted to occur frequently.

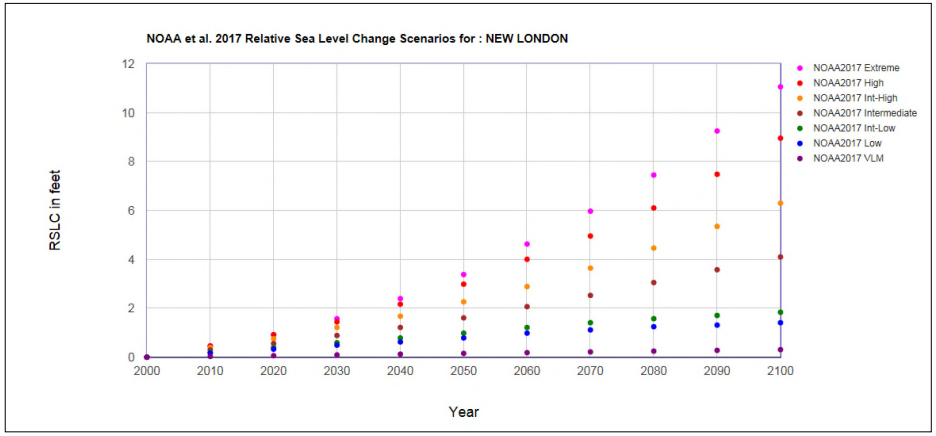
The recurrence interval (for example the 100-year recurrence interval flood) does not mean that it will only occur every 100 years - rather it is a statistical probability that reflects the chance of that flood (or a greater flood) occurring in any year. However, over a specific length of time (30-year mortgage, 100-year design life of a bridge) the chance of experiencing that flood (or greater flood) at least once is greater than the annual probability. For example, the 100-year recurrence interval flood has about a 25% chance (1 in 4) of occurring at least once in a 30-year period. **Attachment 1** and **Attachment 2** provides additional explanation.

There are a number of sources of information predicting the probability of coastal flooding in the vicinity of Old Saybrook. These include: 1) FEMA Flood Insurance Studies; 2) statistical analyses of NOAA tide station water level data (+/- 80 year record); and 3) the USACE North Atlantic Coast Comprehensive Study (NACCS). **Attachment 2** discusses each of these in detail.

Sea Level Rise

Sea level rise complicates the characterization of Old Saybrook's future coastal flood risk. Overall, sea level rise increases the flood risk. For a given flood water level, it increases the probability of experiencing that same flood in the future relative to today. Conversely, for a given occurrence probability it increases the associated flood water level. This means that tides will get higher, storms like Hurricane Sandy will be both more frequent and worse, and catastrophic storms will be more likely.

On average, over the last +/- 80 years the observed mean rate of sea level rise at New London has been about 2.6 millimeters per year (about 0.1 inch/year or about 10 inches in 100 years). However, the rate of sea level rise has been observed to be increasing and is predicted to substantially increase during the next 25 to 100 years. As of the date of this report, the most current industry-accepted sea level rise projections for Old Saybrook are those published by NOAA in 2017. The figure shown below presents NOAA 2017 sea level rise projections (relative to the year 2000) for New London. Several projections are indicated, representing different probabilities. The projections are fairly closely grouped in the near-term (+/- 2040) but become quite varied toward the end of the century, reflecting the significant uncertainty associated with predicting long-term sea level rise. For planning studies , it can be assumed that the Interrnediate -Low projection shown below has a high likelihood of occurrence (50% to near 100%) and the Intermediate projection is a reasonable planning upper bound. This means that (relative to the year 2000), sea levels will rise by 1 to 1.6 feet by the year 2050 and 1.8 to 4.1 feet by the year 2100. It could be higher or lower, but at this time these are reasonable projections for planning purposes. The Intermediate projections are in-line with projections currently recommended by the State. Extreme projections (currently predicted to have very low probability) have sea levels rising at Old Saybrook on the order of 3.4 feet and 11.1 feet (2050 and 2100, respectively).



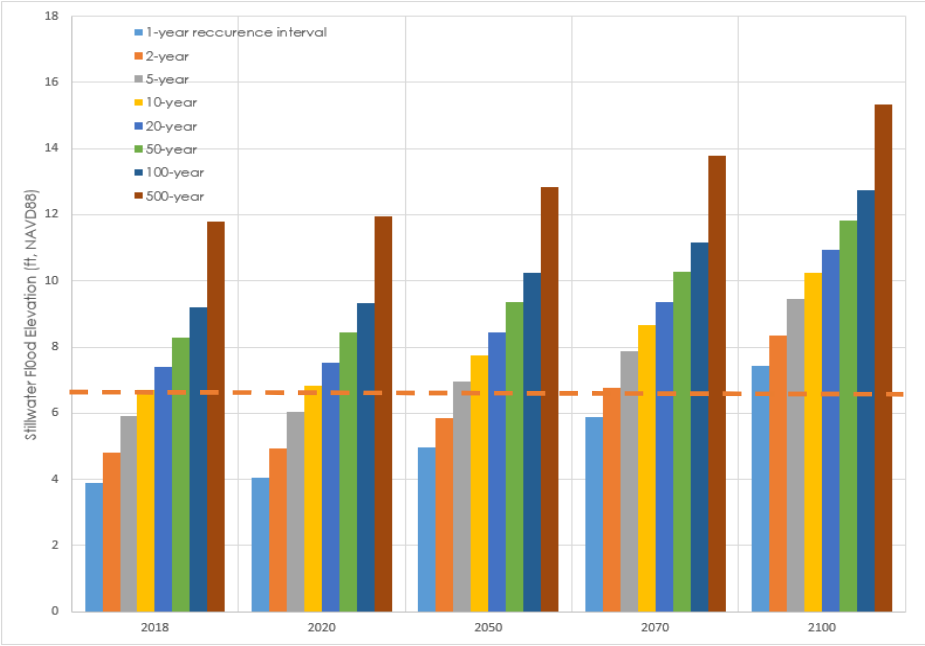
NOAA 2017 Relative Sea Level Rise Projections at New London

COASTAL FLOOD HAZARDS

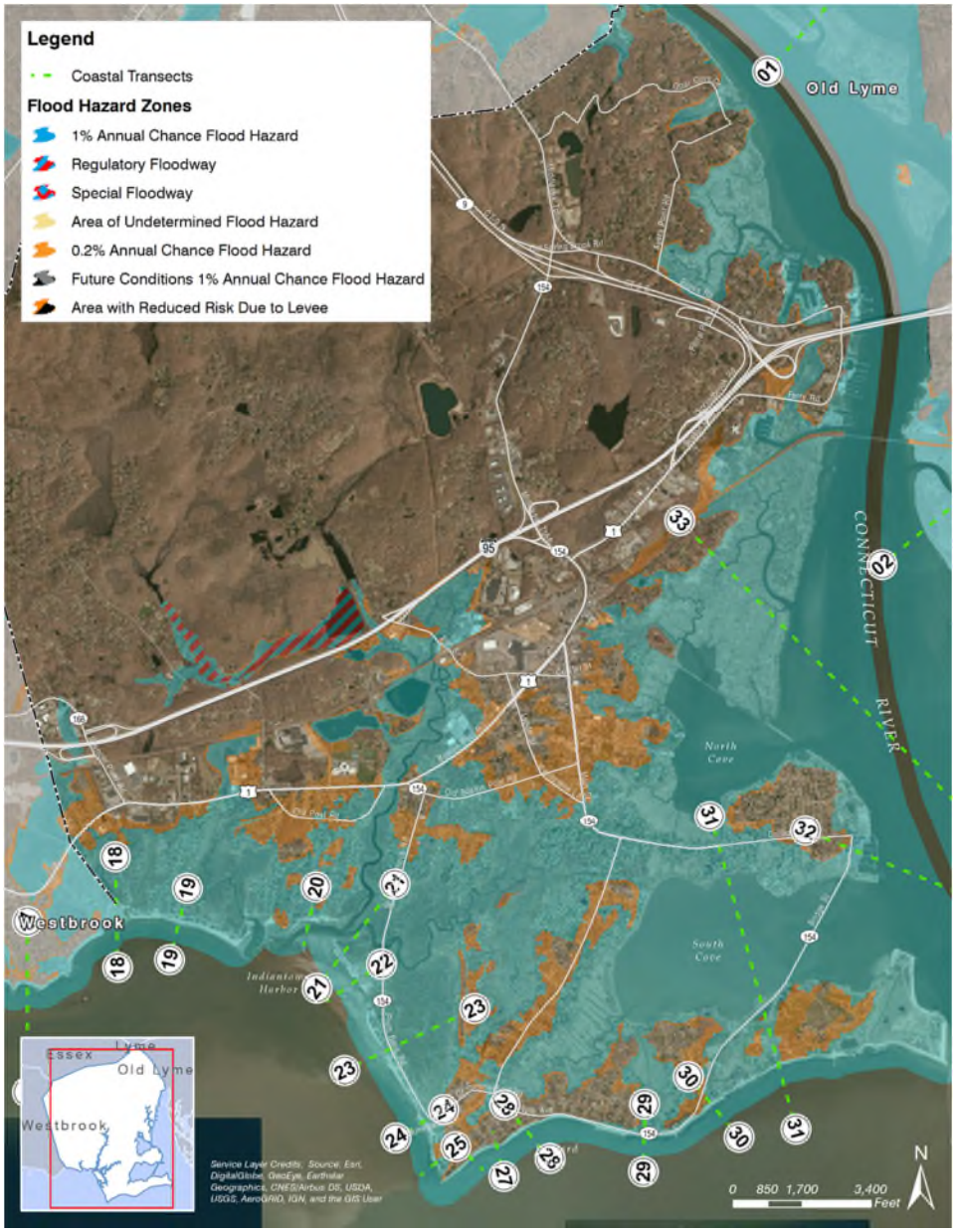
As detailed in **Attachment 2**, the extent and elevation of different probability flood events at Old Saybrook were evaluated using available sources (including FEMA, NOAA and NACCS). GZA supplemented these by performing numerical computer storm surge and wave simulations.

The figure (across) presents the special flood hazard areas as currently defined by FEMA. (note that FEMA does not consider sea level rise for hazard mapping). As shown on the this figure, essentially all of the land area located below Interstate 95 and the Amtrak rail line is flooded during the 100-year recurrence interval coastal flood. So, obviously, the coastal flood risk of Old Saybrook is high. The figures on the following pages present the flood limits associated with higher probability floods. As presented in these figures, even the high probability coastal floods inundate large areas of Town, including extensive stretches of Town roads.

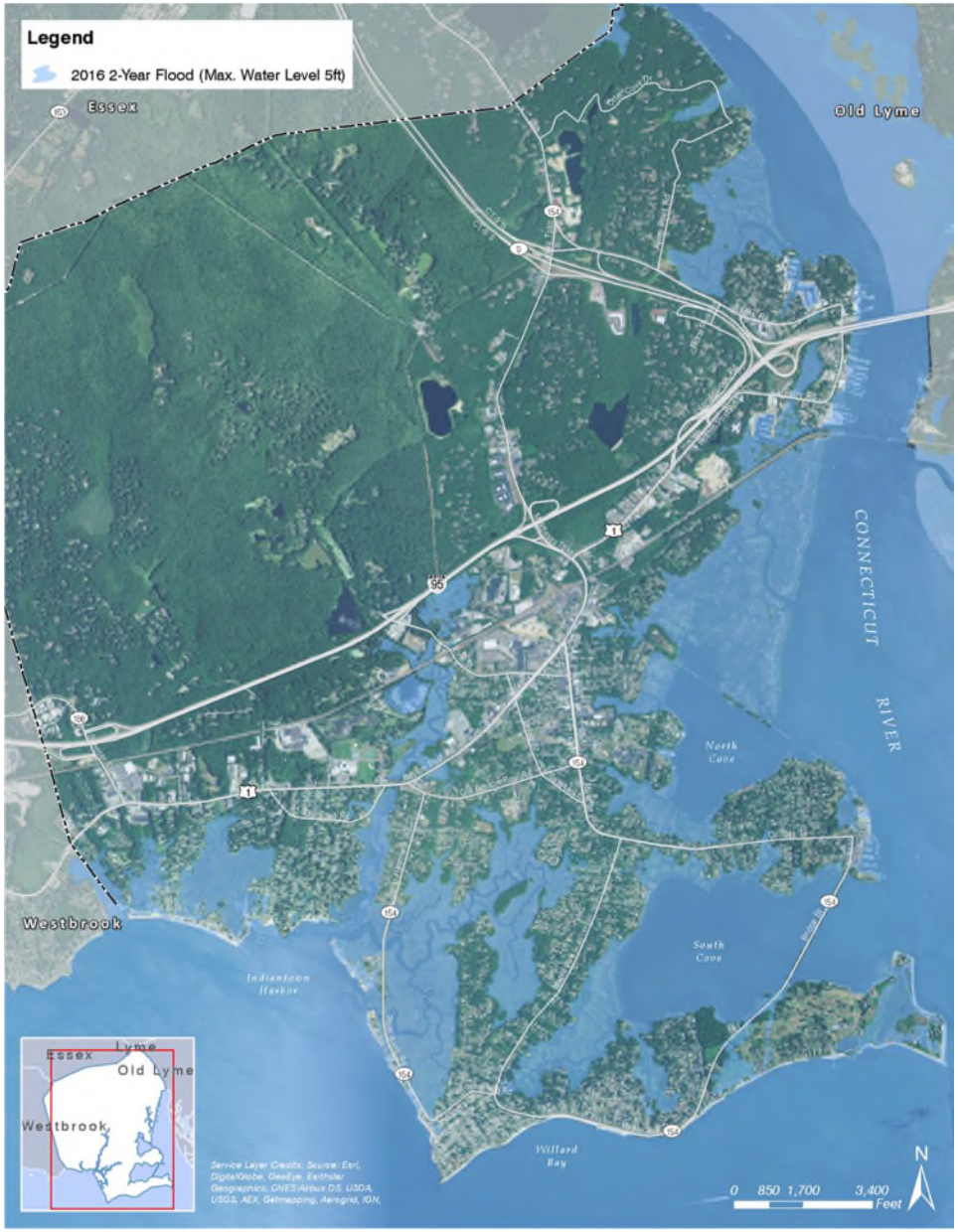
The following chart shows the effect of sea level rise on water levels associated with different probability floods. The NOAA 2017 Intermediate projection is assumed. The horizontal orange line is the typical elevation of low-lying Town areas. To get a perspective on the implications of the flood elevations presented in this chart, refer to the ground elevations shown in **Attachment 2, Figure 2-3**.



Effect of sea level rise on different probability floods. NOAA 2017 Intermediate sea level rise



Current FEMA Special Flood Hazard Areas. The 100-year recurrence interval flood shown. in green and the 500-year recurrence interval flood shown in brown,

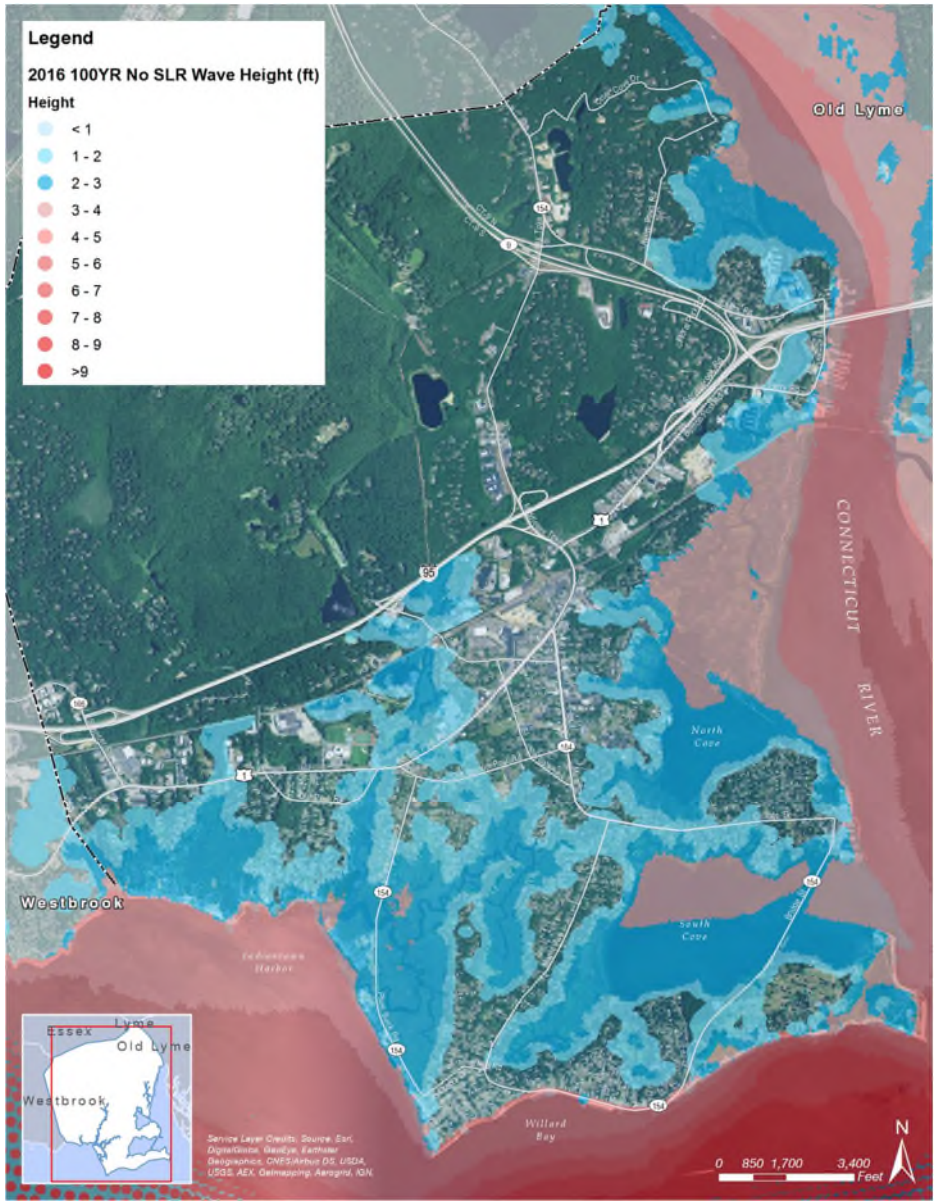


Current 2-year recurrence interval flood,

Current 10-year recurrence interval flood,

Current 50-year recurrence interval flood.

Coastal flood risks include waves. The modeled current 100-year recurrence interval waves are shown below. Waves over 1.5 feet in height can cause significant wave damage.



Current 100-year recurrence interval wave heights.

COASTAL FLOOD RISKS

A detailed analysis of the Town's vulnerability to coastal flooding was completed and is presented in **Attachment 4.** Consistent with FEMA, coastal flood vulnerability is characterized as follows:

- property and residents located within the limits of the 100-year recurrence interval flood are considered to be in a high flood hazard zone;
- property and residents located in the area between the 100 and 500-year recurrence interval floods are considered to be in a low to moderate flood hazard zone;
- property and residents located outside the limits of the 500-year recurrence interval flood are considered to be in a low flood hazard zone.

Although not evaluated by FEMA for the National Flood Insurance program (NFIP), structures, businesses, property and residents located within flood inundation areas with recurrence intervals less than 100-years (i.e., more frequent flooding) are considered to be in areas with a very high flood vulnerability.

The evaluation of coastal flood risk also considered the type of structure and its importance to public safety and loss potential. ASCE/SEI 24-14 "Flood Resistant Design and Construction" categorizes buildings and structures into one of four Flood Design Classes based on use and occupancy. The Flood Design Class dictates the level of acceptable risk and appropriate level of flood protection. The Flood Design Class was used to assess vulnerability in this study.

The presence of waves, along with flood inundation, can significantly increase flood risk since waves are the primary cause of structural building damage and beach erosion. High flood hazard areas exposed to waves greater than 3 feet in height are located in a "high velocity" zone (i.e., large wave and hydrodynamic forces). Waves of 3 feet and greater height result in significant building damage. Areas exposed to waves greater than 1.5 feet but less than 3 feet (Limit of Moderate Wave Action) can also experience building damage, in particular to timber-framed structures such as typical houses.

The extent and depth of flooding, as well as the effects of waves, are predicted to get worse in the future, principally due to sea level rise. The current flood risk will increase (including the future limits of flood hazard areas defined by FEMA and the NFIP).

The term "chronic flood inundation" is used to characterize areas with very high frequency flooding. Specifically, this term describes coastal flooding that occurs on average 26 times per year over 10% of a communities developed land area. These represent areas where people and business begin to leave permanently, with impact to property values and tax revenue. **Attachment 2** and **Attachment 4** identify areas that are predicted to meet this criteria in the future.

Fire damage to beach home on Saye Street in Old Saybrook after Sandy (Image from http://www.theday.com/article/20121030/NWS01/121039993)

The following pages summarize the coastal flood risk of the Town's key assets including:

- Economic Risk
- Commercial and Industrial Districts
- Essential Facilities
- Lifeline Facilities
- High Potential Loss Facilities
- Shelter and Evacuation Requirements
- Historic Districts
- Transportation Infrastructure
- Natural Resources: Marshes

  Natural Resources: Beaches

See **Attachment 4** for the complete, comprehensive vulnerability and risk evaluation.

ECONOMIC RISK FOR PROPERTY OWNERS, THE TOWN AND TAXPAYERS

The following summarizes economic risk in terms of: 1) estimated loss potential; and 2) property owner participation in the National Flood Insurance Program (NFIP). The loss potential analysis was performed using the FEMA Hazus program and simulating multiple coastal flood hazard risk scenarios. The NFIP analysis was based on information provided by the Town relative to properties located within FEMA special flood hazard areas (SFHAs). The predicted economic loss potential is characterized in terms of the Average Annualized Loss (AAL). The AAL is the expected loss per year if averaged over many years. The AAL predicted by FEMA for Middlesex County is $77.4M. The current Old Saybrook AAL is $16M. On a per capita basis, the predicted $16M AAL for Old Saybrook is about $1,500 per person compared to about $500 per person for the County, reflecting the high risk associated with Old Saybrook's coastal location. The Town has been proactive with improving the NFIP compliance by property owners. However, the analysis indicates that, while continuing to improve, property value overall within the Town is underinsured for coastal flooding. The analysis also indicates that paid claims are disproportionately weighted toward certain properties and overall risk is weighted towards properties located within VE zones.

ECONOMIC LOSS POTENTIAL

- Current Town Asset Value is about $2.3B:
    i. Number of structures: +/- 5,900
    ii. Residential: 70% to 80% ($1.5B to $2B)
    iii. Commercial: 10% to 20% ($250M to $400M)
    iv. Industrial: 1% to 5% ($22M to $90M)
- Predicted Average Annualized Loss (AAL) due to coastal flooding is $16M

The "Averaged Annualized Loss" (AAL) is the expected loss per year if averaged over many years. The current predicted AAL is $16 million. Assuming a Town population of about 10,200 people (based on 2010 Census data), this translates to a per capita AAL of about $1,569. For comparison, FEMA (FEMA's HAZUS Average Annualized Loss Viewer, 2016) has estimated the total AAL for Middlesex County to be $77.4M, which represents a per capita average AAL within Middlesex County of $467. Damage to residential buildings accounts for a majority of the total loss, with privately-owned commercial and industrial buildings accounting for about 35% of the loss. The economic risk applies to property owners, taxpayers and the Town Budget and indicates the potential for increased property damage, Town costs for public works and public safety, decrease in property tax revenue and increase in the borrowing rate for municipal bonds. See figures on following page for the appraised property value and the predicted distribution of loss.

NATIONAL FLOOD INSURANCE PROGRAM

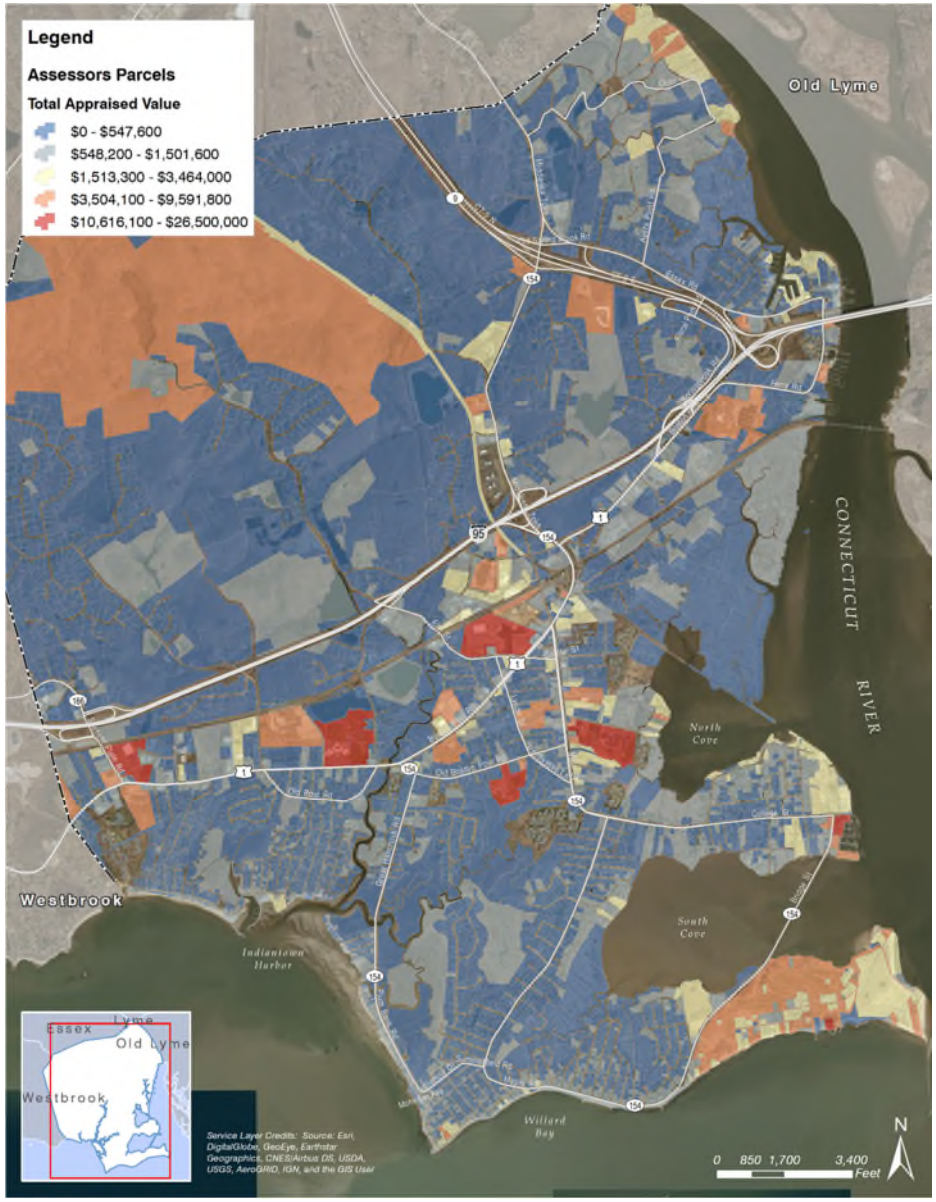
- 1,492 NFIP Insurance Policies in Force
    i. Residential: 97% of policies
    ii. Non-Residential: 3% of Policies
    iii. SFHA Properties: 62% of policies (61 in Zone V/VE)
- 628 claims paid since 1978
    i. $14.2M of Closed Paid Losses
    ii. SFHA properties: 92% of insured claims paid
    iii. Repetitive Loss properties: 28% of insured claims paid
- $385.5M of NFIP Insurance in force

The number of total NFIP policies includes 44% of the total number of buildings located within FEMA SFHAs (56% of buildings located within SFHAs are not covered by NFIP policies). 97% of NFIP policies are for residential structures. Damages to residential buildings located within SFHAs account for the majority of paid losses at 92%.

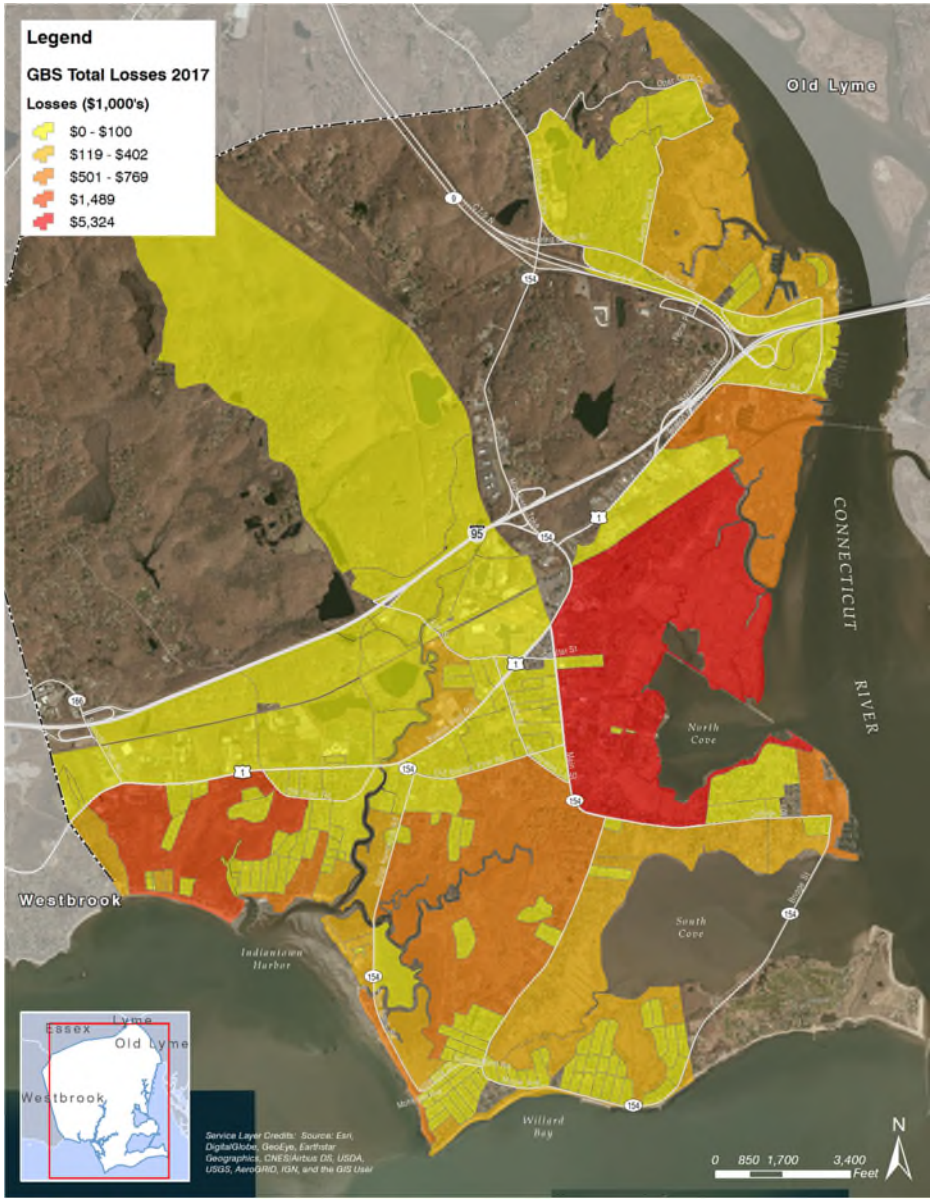
The number of NFIP policies for properties located within VE zones is less than 50% of the total number of buildings located within VE zones. Buildings located within VE/V zones accounted for 30% of the total Town claims, totaling close to $4.4M. 68 Repetitive Loss Properties accounted for about 29% of the total Town claims, at just over $4M.

Buildings located within AE/A zones have accounted for over 60% of the total Town claims, totaling over $8.7M.

Repetitive loss properties represent an economic risk to both property owners and Town insurance rates.



Property Appraisal Values throughout Old Saybrook



Predicted Distribution of Economic Loss (by AAL) due to Property and Content Damage

ESSENTIAL FACILITIES

	Current	2041	2066	2116
LOCATION				
Police Station at 36 Lynde Street	Low	Moderate	Moderate	Moderate
Fire Department at 310 Main Street	High	High	High	High
Emergency Management at 302 Main Street (Town Hall)	High	High	High	High
Ambulance Association at 316 Main Street	High	High	High	High
Emergency Shelter at 1111 Boston Post Road (Old Saybrook Senior High School)	Low	Moderate	High	High

Risk Profile of Old Saybrook Essential Facilities

Location of Fire, Police, Emergency Management rand Ambulance relative to FEMA special flood hazard areas

The vulnerability of Old Saybrook's Essential Facilities was evaluated relative to coastal flooding up to the 500-year recurrence interval flood (FEMA BFE). Essential facilities are classified as Flood Design Class 4 per ASCE/SEI 24-14. Flood Design Class 4 structures are evaluated for risk relative to the 100-year recurrence interval flood (plus a minimum freeboard) or the 500-year recurrence interval flood, whichever is higher.

The High Risk classification of the Fire and Emergency Management is due to portions of these structures being located within the 500-year floodplain. Flood protection of these structures can be readily provided using building scale permanent or deployable measures. A detailed building Flood Vulnerability Assessment and Flood Emergency Response Plan (FERP) is recommended for each of the high risk Essential Facilities. The ambulance facility is located within a FEMA AE zone and relocation of this facility should be planned for.

A significant, additional, risk is road flooding which will impact the capability of the Town to provide essential services (e.g., emergency response).

See **Attachment 4** for a detailed description of the flood risk of each of Old Saybrook's Essential Facilities.

LIFELINE FACILTIES

LOCATION	Current	2041	2066	2116
Electricity (Elm Street Substation only)	Moderate	Moderate	Moderate	Moderate
Natural Gas	Low	Low	Low	Low
Water	Low	Low	Low	Low
Sewer	High	High	High	High
Communication	Low	Low	Low	Low

Risk Profile of Old Saybrook Lifeline Facilities

The vulnerability of Old Saybrook's Lifeline Facilities was evaluated relative to coastal flooding, up to the 500-year recurrence interval flood (FEMA BFE). Essential facilities are classified as Flood Design Class 4 per ASCE/SEI 24-14. Flood Design Class 4 structures are evaluated for risk relative to the 100-year recurrence interval flood (plus a minimum freeboard) or the 500-year recurrence interval flood, whichever is higher.

The flood risk of Old Saybrook's Lifeline Facilities is generally low except for:

- The Elm street electrical substation, which is the responsibility of Eversource; and
- The on-site subsurface sanitary wasewater treatment at certain communities. The Old Saybrook Water Pollution Control Authority (WPCA) recently completed the "Old Saybrook Wastewater Pollution Control Authority [WPCA]) Draft Study" (2016-17) study to evaluate the use of Community Systems for high risk communities.

See **Attachment 4** for a detailed description of the flood risk of each of Old Saybrook's Lifeline Facilities.

Location of Lifeline Facilities relative to FEMA special flood hazard areas. Green indicates FEMA AE zones (100-year recurrence interval flood) and brown indicates the 500-year recurrence interval flood.

HIGH LOSS POTENTIAL FACILITIES

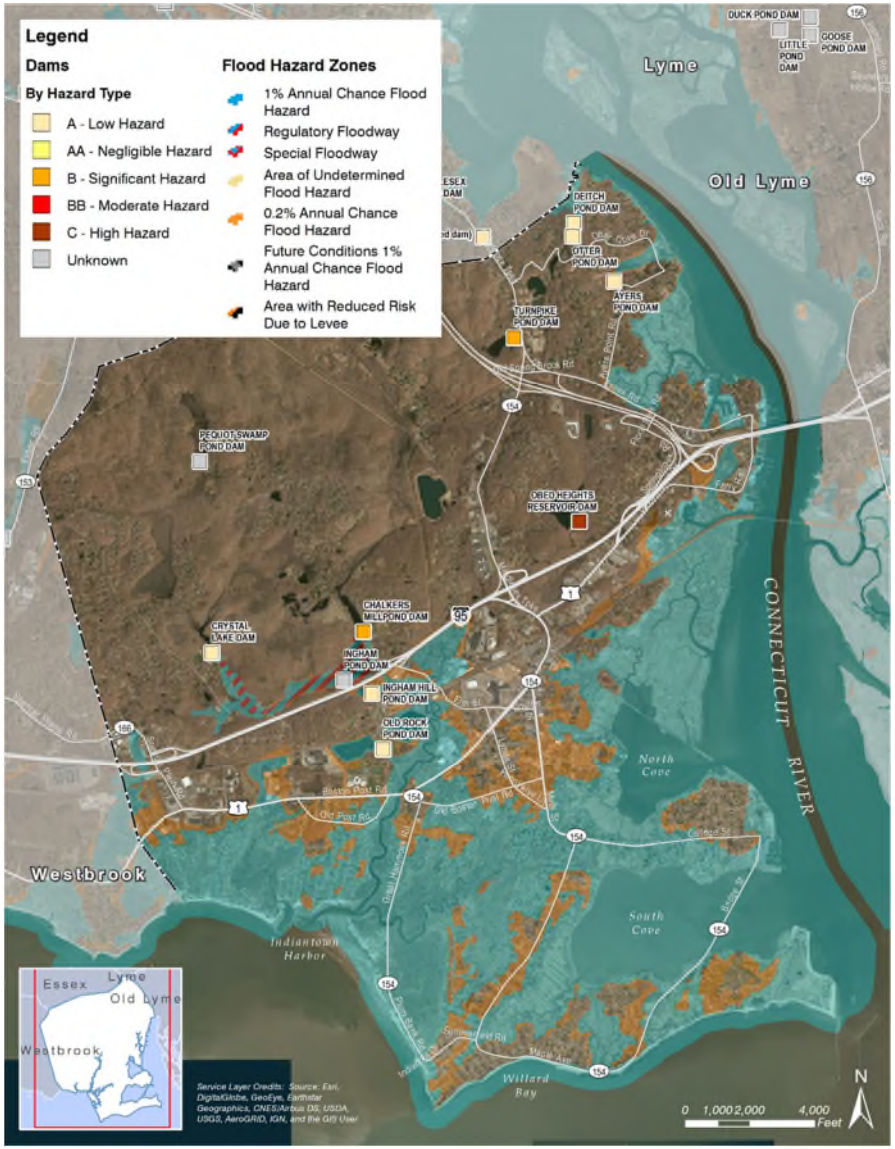
High potential loss facilities are those facilities that would result in significant loos of property of life should they fail. The only facilties located within Old Saybrook are dams, two of which are classified as high hazard or significant hazard dams (Class C and Class B). High Loss Potential Facilities are not classified or regulated using ASCE/SEI 24-14. At a minimum, Class C and B dams should be evaluated for risk relative to the 500-year recurrence interval flood.

A detailed assessment of dam failure risk was beyond the scope of this study. In general, coastal flooding can negatively impact dams by: 1) coastal floodwaters overtopping the dam spillway and/or dam crest; 2) scour or erosion, resulting in damage to the dam or spillway; and/or 3) temporary changes to the hydrologic and geohydrologic conditions that could induce piping or stability failures.

A preliminary determination of the location of the dams relative to the limits of coastal flood inundation was performed. The following describes the coastal flood conditions in the vicinity of the Old Saybrook Class C and B dams.

- Obed Heights Reservoir Dam: the Obed Heights Reservoir and Dam are located at a high ground elevation, approximately 60 feet NAVD88 and outside the limits of current and future coastal flooding.
- Chalkers Millpond Dam: The Chalkers Millpond Dam is a low earthen dam located at the southern extent of the Chalkers Millpond. The spillway is located at the east end of the dam. Based on recent Lidar data, the crest elevation of the dam appears to be about Elevation 20 to 22 feet NAVD88. The spillway discharges to a drainage swale that appears to be hydraulically connected to the Oyster River via several roadway drainage culverts. The area immediately downgradient from the dam is classified as a FEMA A zone. Although the risk to the dam due to coastal flooding appears low, further investigation is required to evaluate the potential effect of coastal flooding at the spillway.
- Turnpike Pond Dam: The Turnpike Dam is located at a high ground elevation, approximately 56 feet NAVD88 and outside the limits of current and future coastal flooding.

See **Attachment 4** for a detailed description of the flood risk of each of Old Saybrook's High Loss Potential Facilities.



Location of Old Saybrook Dams relative to FEMA special flood hazard areas

SHELTERING AND EVACUATION

GZA completed a FEMA Hazus analysis to evaluate flood-related losses resulting in the following predictions for shelter requirements. This analysis relates displacement and shelter needs to building damage. The following summarizes predicted displaced people and shelter needs for different recurrence interval floods:

- 10-year return period flood: 256 households displaced, 648 people seeking temporary shelter
- 25-year return period flood: 305 households displaced, 801 people seeking temporary shelter
- 50-year return period flood: 431 households displaced, 1,161 people seeking temporary shelter
- 100-year return period flood: 1,166 households displaced, 3,096 people seeking temporary shelter
- 500-year return period flood: 1,811 households displaced, 4,709 people seeking temporary shelter

Old Saybrook Public Emergency Shelter (Old Saybrook High School) relative to FEMA special flood hazard areas. Green indicates FEMA AE zones (100-year recurrence interval flood) and brown indicates the 500-year recurrence interval flood.

A detailed analysis of New England hurricane evacuation needs and capabilities was also performed by the USACE and FEMA and presented in "New England Hurricane Evacuation Study, Technical Data Report", dated June 2016. Per this study, evacuation statistics were developed for three evacuation zones within Old Saybrook:

- Zone 1 (Category 1 and 2 hurricanes flood inundation): about 8,200 to 10,750 people are vulnerable, will be impacted and may require evacuation;
- Zone 2 (Category 3 and 4 hurricanes flood inundation): about an additional 90 to 260 people may require evacuation; and
- Zone 3 (areas located outside of coastal flood inundation): about an additional 440 to 800 people may require evacuation.

For comparison, the 10 through 50-year recurrence interval floods can be considered to be analogous to Zone 1, and the 100 to 500-year recurrence interval floods can be considered to be analogous to Zone 2.

A percentage of evacuating people will require shelter within Old Saybrook and the remainder of evacuating people will shelter out-of-town. Old Saybrook's current public shelter capacity is about 450 to 500 people. "Sheltering at home" is also an alternative, in particular for smaller, higher frequency flood events.

A key consideration for evacuation is the predicted road flooding which will restrict residents' ability to evacuate once flooding occurs.

See **Attachment 4** for a detailed description of the flood risk of each of Old Saybrook's Sheltering and Evacuation needs and capabilities.

COMMUNITIES

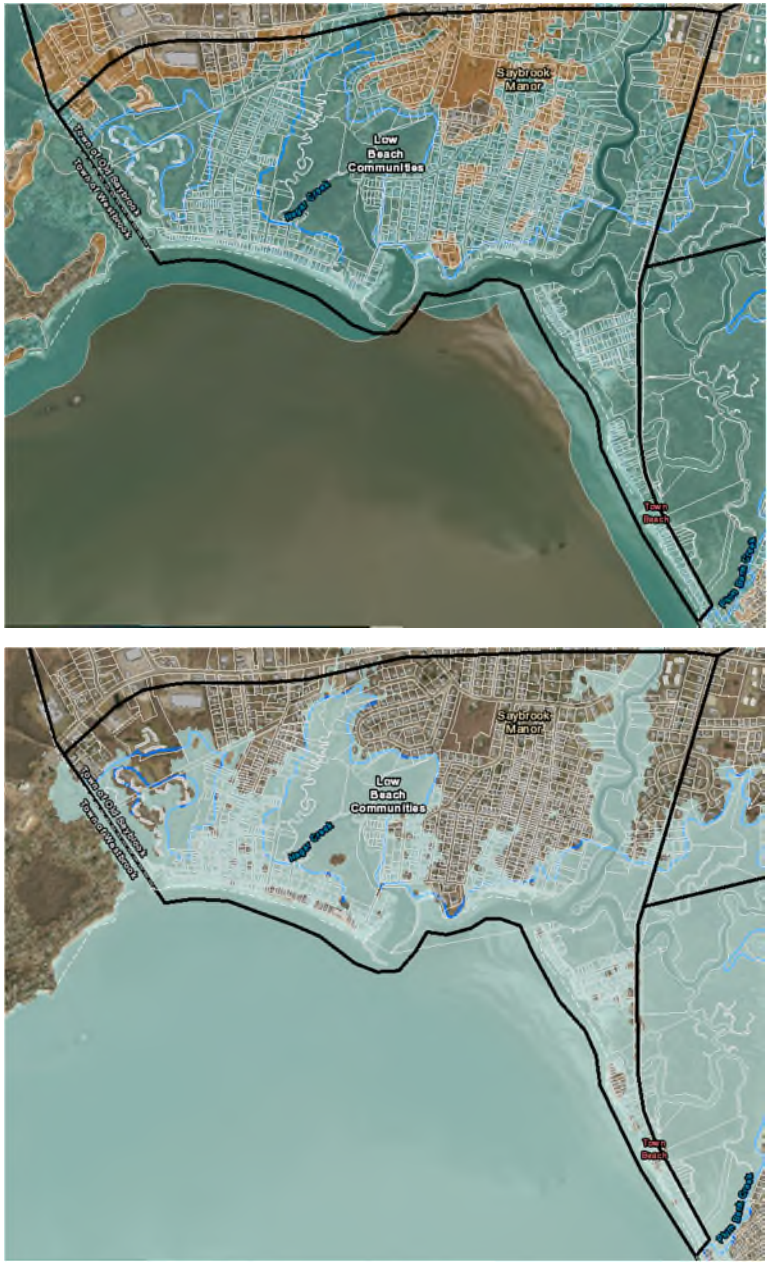
	Current	2041	2066	2116
LOCATION				
Low Beach Communities	High	High	High	High
Cornfield Point to Fen-wood	Moderate	Moderate to High	High	High
Saybrook Point and Town Center	High	High	High	High

Risk Profile of Old Saybrook Communities and Neighborhoods

The vulnerability of Old Saybrook's communities and neighborhoods was evaluated relative to coastal flooding, up to the 100-year recurrence interval flood (FEMA BFE). Different levels of risk apply to different types of Town assets. Communities primarily consist of residential and commercial structures, classified as Flood Design Class 2, and are evaluated for risk relative to the 100-year recurrence interval flood. See **Attachment 2** for explanation of Flood Design Classes per ASCE/SEI 24-14.

With frontage on Long Island Sound and surrounded by tidal marsh, the Low Beach Communities (including Chalker Beach; Indiantown; Saybrook Manor; Great Hammock Beach and Plum Bank) are very vulnerable to coastal flooding and have a High Risk. These communities are located entirely within the FEMA AE zone and have developed beaches fronting on the Sound that are exposed to high waves and located within a FEMA VE zone. These communities are also vulnerable to frequent flooding, with a potential to be chronically inundated by mid-century.

See **Attachment 4** for a detailed description of the flood risk of each of Old Saybrook's communities and neighborhoods. .



Images of the Low Beach Communities relative to FEMA special flood hazard areas (above). Green indicates FEMA AE zones (100-year recurrence interval flood) and brown indicates the 500-year recurrence interval flood. Higher probability flooding, represented by the 10-year recurrence interval flood is shown below.

COMMERCIAL AND INDUSTRIAL DISTRICTS

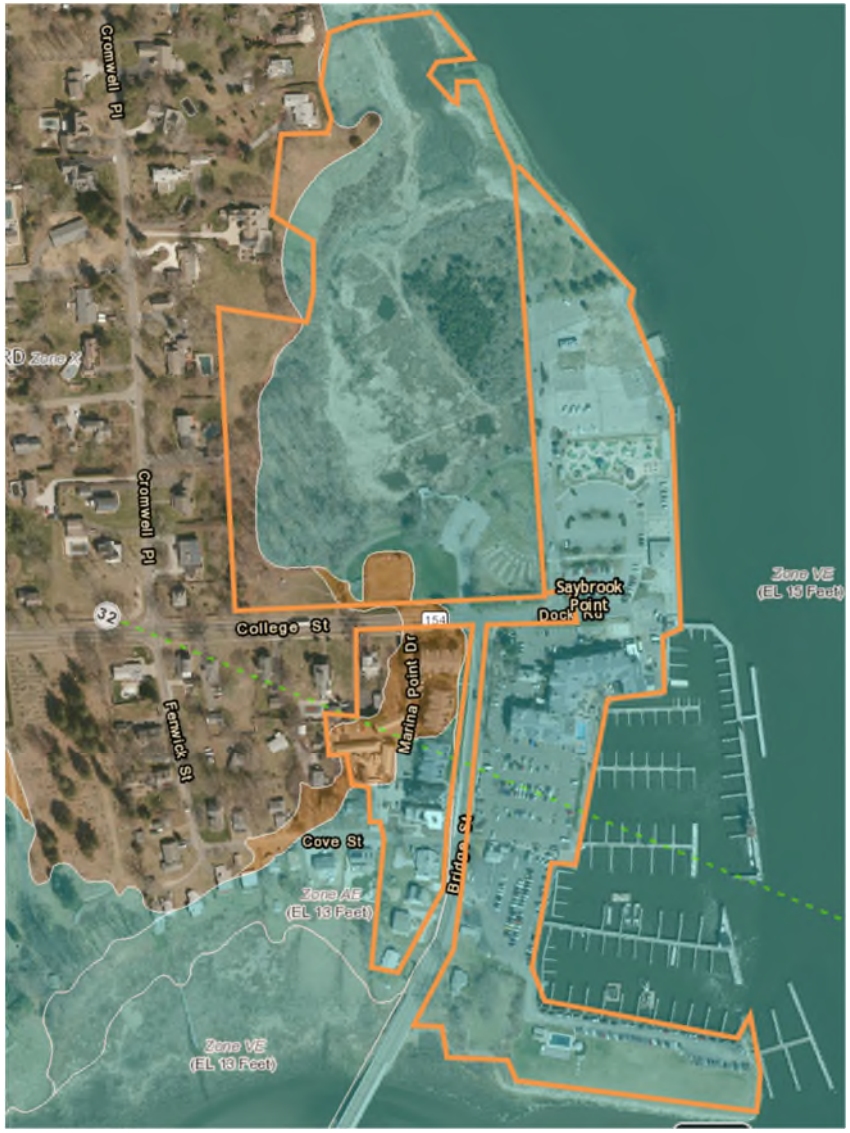
	Current	2041	2066	2116
LOCATION				
Saybrook Point SP-1 through SP-3	High	High	High	High
Central Business B-1	Low	Moderate	Moderate	Moderate
Shopping Center B-2	High	High	High	High
Restricted Business B-3	High	High	High	High
Gateway Business B-4	Low	Moderate	High	High
Industrial I-1	Low	Moderate	High	High
Marine Commercial District	Low	Moderate	High	High

Risk Profile of Old Saybrook Commercial and Industrial Districts

The vulnerability of Old Saybrook's commercial and industrial districts was evaluated relative to coastal flooding, up to the 100-year recurrence interval flood (FEMA BFE). Commercial and industrial structures (not containing hazardous materials) are typically classified as Flood Design Class 2 per ASCE/SEI 24-14. Flood Design Class 2 structures are evaluated for risk relative to the 100-year recurrence interval flood (i.e., FEMA Base Flood). The coastal flood risk of the commercial and industrial districts ranges from Low to High.

Due to their waterfront location and low ground elevation, the Saybrook Point SP-1 through SP-3 Districts and the Marine Commercial Districts have the highest coastal flood risk of the Old Saybrook's commercial districts. SP-1 to SP-4 districts are also effected by: 1) frequent roadway flooding, preventing customer access to the area; and 2) disruption of operations and resulting economic loss. The high real estate value, optimal waterfront location and re-development potential of these districts makes their flood protection a Town priority.

See **Attachment 4** for a detailed description of the flood risk of each of Old Saybrook's commercial and industrial districts.



Saybrook Point Districts SP-1 to SP-3 relative to FEMA special flood hazard areas. Green indicates FEMA AE zones (100-year recurrence interval flood) and brown indicates the 500-year recurrence interval flood.

HISTORIC DISTRICTS

Type of Historic Property	Total Number	Total Number in VE/V Zone	Total Number in AE/A Zone
National Register Federal Historic Properties	17	3	3
State Register Historic Properties	76	1	17
Locally Significant Historic Properties	236	2	38
Other Significance	6	None	None
Total	335	6	58

Vulnerability Profile of Old Saybrook Historic Properties

Location of Old Saybrook Historic Properties relative to FEMA special flood hazard areas. Green indicates FEMA AE zones (100-year recurrence interval flood) and brown indicates the 500-year recurrence interval flood.

There are three historic districts and 335 historic properties located within Old Saybrook. The Historic Districts include: 1) the North Cove Historic District; 2) the South Green Historic District; and 3) the Fenwick Historic District. The first two historic districts were evaluated by this study.

The 335 historic properties located within Old Saybrook include:

- 17 National Register Federal Historic Properties;
- 76 State Register Federal Historic Properties;
- 236 Locally Significant Historic Properties; and
- 6 Historic Properties with Other Significance.

Historic properties are classified as Flood Design Class 2 per ASCE/SEI 24-14 and are evaluated for risk relative to the 100-year recurrence interval flood (i.e., FEMA Base Flood). As summarized in the table, 64 of Old Saybrook's historic properties are located within FEMA special flood hazard zones.

Historic properties, however, are exempt from certain requirements of federal and State flood regulations, providing greater flexibility relative to available flood mitigation alternatives.

See **Attachment 4** for a detailed description of the flood risk of each of Old Saybrook's Historic Districts.

ROADS, BRIDGES AND CULVERTS

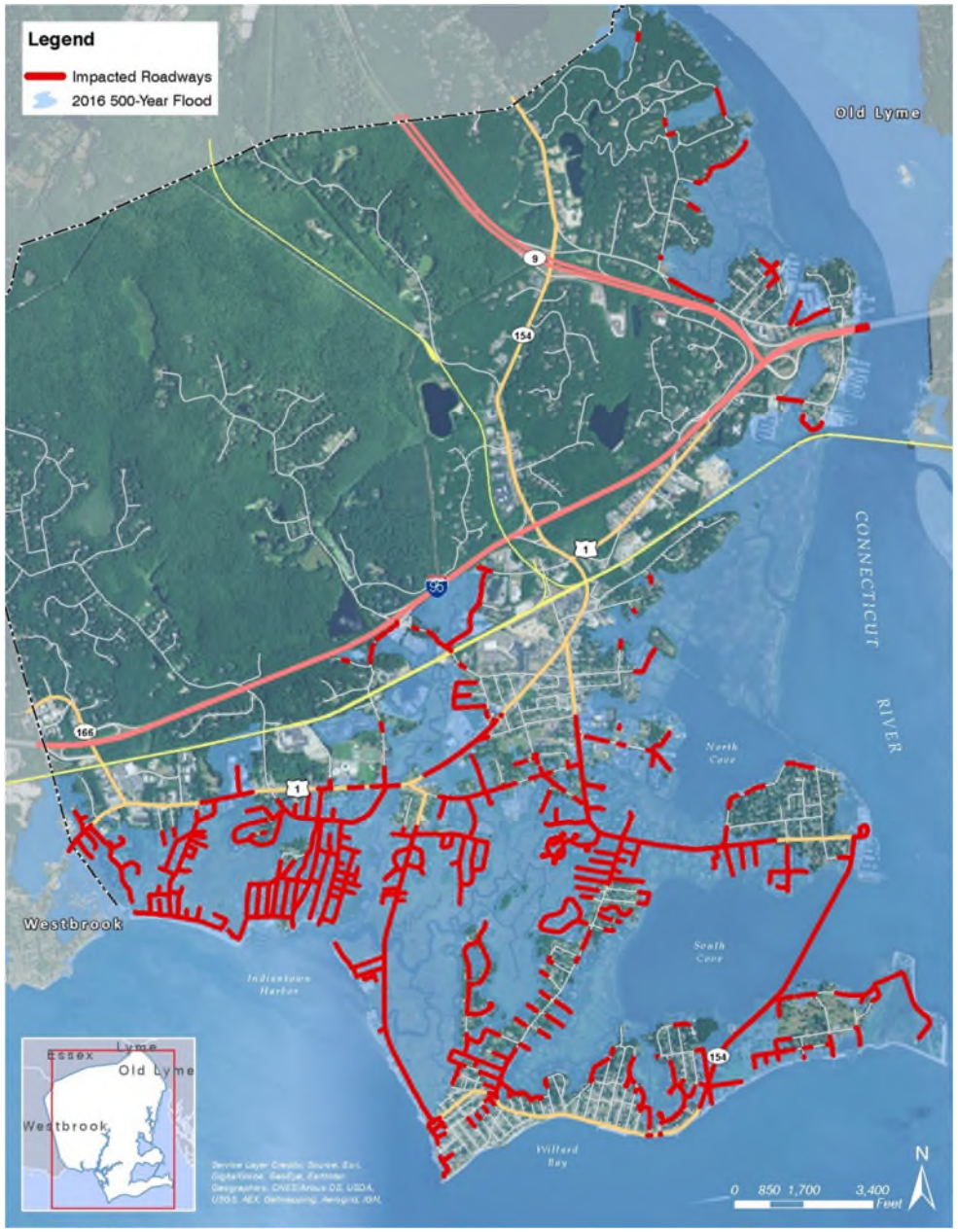
	2-yr	10-yr	20-yr	50-yr	100-yr	500-yr
State (%)	2.9	7.4	9.6	11.3	13.1	16.9
State (miles)	1	2.4	3.2	3.7	4.3	5.6
Municipal (%)	3	8.5	12.4	16.2	20.6	32.3
Municipal (miles)	2.6	7.4	10.7	14.0	17.9	28.0
Private (%)	3.6	10.5	15	23.7	50.4	71.4
Private (miles)	0.1	0.3	0.4	0.7	1.5	2.1
Total (miles)	+/-4	+/-10	+/-14	+/-18.5	+/-24	+/-36

Vulnerability Profile of Old Saybrook Roads

A detailed analysis of roadway impacts due to coastal flooding was performed and is presented in **Attachment 4.** There is a total of approximately 135 miles of roadway in Old Saybrook including about 47 miles of State roads and 88 miles of Town roads. There are 22 bridges including highway and railroad bridges, river crossing and the causeway. There are 11 drainage culverts.

GZA estimated the location and extent of roadway inundation under current coastal flood conditions, including storm events corresponding to the following recurrence intervals: 2-year; 10-year; 20-year; 50-year; 100-year; and 500-year recurrence interval floods - see table above. About 24 miles and 36 miles of roadway are vulnerable under the current coastal flood risk scenarios of the 100-yr and 500-yr recurrence interval floods, respectively. These flood recurrence intervals represent the appropriate evaluation risk levels for transportation infrastructure investment planning at State and municipal levels. The total impacted roadway under these coastal flood scenarios represent about 24% to 36%, respectively, of the roads within the Town. More frequent flood events, such as the 2-year and 10-year return periods should be specifically considered as important due to their high frequency and "chronic flood inundation" potential.

See **Attachment 4** for the comprehensive analysis of roadway flood risks.



Inundated roads during the 500-year recurrence interval flood

ROADS, BRIDGES AND CULVERTS cont.

Overtopped Bridges	Approximate Bridge Deck Elevation (feet, NAVD88)[1]	Estimated current 100-year recurrence interval stillwater elevation (feet, NAV-D88)	Estimated 100-year recurrence interval wave crest elevation (feet, NAVD88)
South Cove Causeway:			
North Bridge over South Cove	6	10	15 (VE)
Middle Bridge over South Cove	6	10	15 VE)
South Bridge over South Cove	8	10	15 (VE)
Great Hammock Road Bridge over Back River	6	10.5	13 (Coastal AE)
Nehantic Trail Bridge over Hagar Creek	10	10.5	14 (VE)
Plum Blank Road Bridge over Plum Blank Creek	7	10	14 (VE)
Route 1 Bridge over Oyster River	13	11.5	12.5
Sequassen Avenue Bridge over tidal	6	10	13 (VE)

Vulnerability Profile of Old Saybrook Bridges. Estimated deck elevations, flood stillwater elevations and wave crest elevations are shown.

A detailed analysis of roadway impacts due to coastal flooding was performed and is presented in **Attachment 4.** Based on the flood elevations relative to bridge deck elevations, a preliminary evaluation of bridge damage potential during the current 100-year recurrence interval flood is:

- South Cove Causeway Bridges: High
- Great Hammock Road Bridge over Back River: High
- Nehantic Trail Bridge over Hager Creek: Moderate
- Plum Bank Road Bridge over Plum Bank Creek: High
- Route 1 Bridge over Oyster River: Low
- Sequassen Avenue Bridge over tidal creek: High

Bridge damage potential is a function of: 1) deck elevation relative to stillwater and wave crest elevations (resulting in hydrostatic and hydrodynamic loads); 2) debris impacts to substructure and superstructure; 3) hydrodynamic loads to piers ; and 4) scours around piers. The potential for bridge overtopping or damage, and the very high cost to elevate or replace the bridges, is a key transportation issue for the Town. Due to the low deck elevation of many of the Town bridge, bridge flooding and temporary loss of use will occur frequently in the future.

South Cove Causeway during Irene showing wave overtopping bridge deck. This photo, by Mara Lavitt, won a first-place award in the Connecticut SPJ contest. "Thrill seekers on the causeway between Old Saybrook and Fenwick Point during Tropical Storm Irene, on Aug. 28, 2011." The tide gage data indicated a peak water level during Irene of about Elevation 6.5 feet NAVD (about or slightly higher than the bridge deck elevation). In comparison, the same tide gage measured a peak water level of about Elevation 8 feet NAVD during Sandy.

ROADS, BRIDGES AND CULVERTS cont

100-year Recurrence Interval	Number of Culverts
2016	18
2041	18
2066	19
2116	22

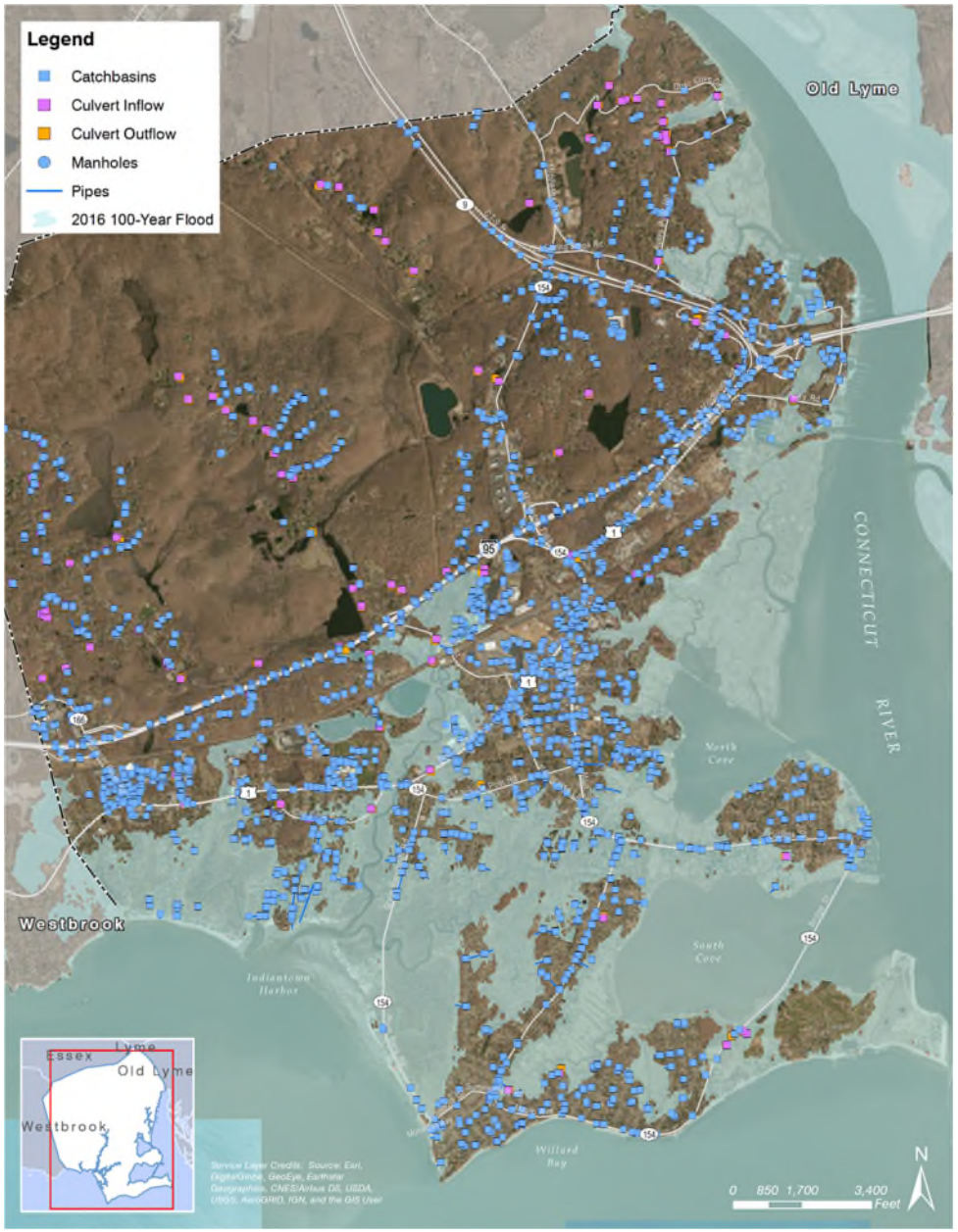
Vulnerability Profile of Old Saybrook Culverts indicating the number of culverts inundated during the 100-year recurrence interval flood.

GZA's evaluation identified roadway culverts located within roadway sections that are inundated during the 100-yr recurrence interval flood under current and future (2041, 2066 and 2116) conditions. This information provides an initial assessment of roadway culverts at risk. GZA has not evaluated the hydraulic capacity of the culverts as part of this study and additional analysis is recommended to evaluate the hydraulic performance of the culverts under different flood conditions.

In addition to the culverts used or river crossings, the overall stormwater management system includes (based on data provided by the Town):

- 108 Culvert Inflows
- 101 Culvert Outflows
- 2,217 storm water catch basins
- 204 outfalls
- 8 stormwater manholes

Stormwater runoff is collected via catch basins and pipes and discharged via gravity flow to drainage outfalls to the Connecticut River, Long Island Sound and local waterways. The Town does not have any stormwater pump stations. Based on the available information, existing outfalls do not have tide gates or backflow preventers. (There are two tide gates in town that are used for control of tidal flow: one at Chalker Beach and another on the Oyster River just south of I-95 near Elm Street. The Chalker Beach tide gate is owned and managed by the Chalker Beach Association and Summerwood Condominiums. The Chalker Beach tide gate functions as a backflow reducer without manual controls. The Oyster River tide gate is owned and operated by the State of Connecticut and can be manually opened and closed.)



Inundated culverts and catch basins relative to the 100-year recurrence interval flood

NATURAL RESOURCES: MARSHES

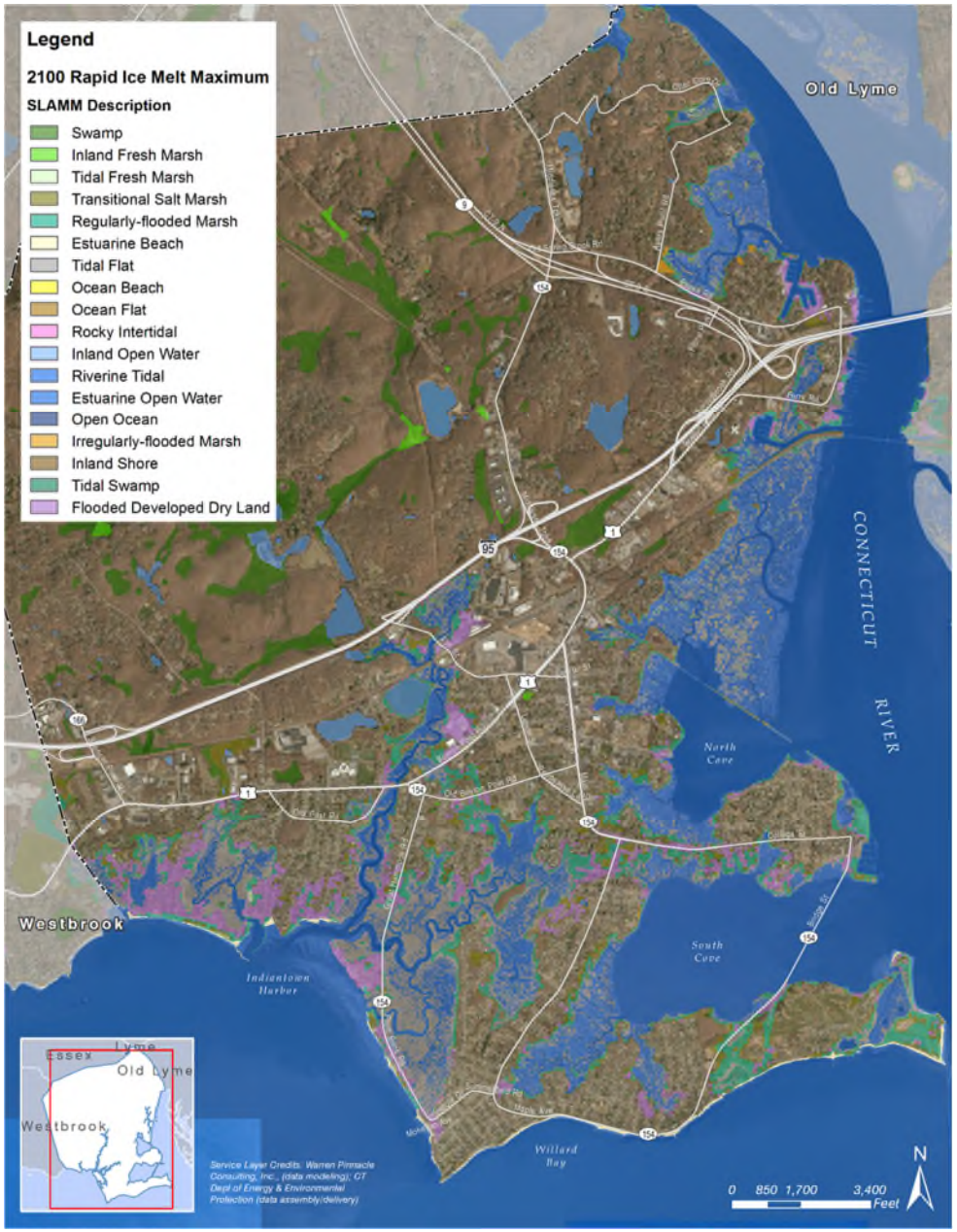
The "Application of the Sea-Level Affecting Marsh Model to Coastal Connecticut", prepared for the New England Interstate Water Pollution Control Commission by Warren Pinnacle Consulting, Inc. provides insight into the behavior of Old Saybrook's marshes when subject to sea level rise. The marshes provide ecological and human benefits, including habitat for fish, shellfish, birds, and other wildlife as well as recreational value and some protection for inland areas from coastal flooding. However, they are highly susceptible to sea level rise and climate change due to:

- land subsidence;
- rapid changes to water depth;
- marsh substrate;
- sea level rise rate relative to sedimentation rate;
- frequency of inundation;
- changes in tidal flow patterns;
- landward migration of tidal waters;
- changes in salinity, water acidity and oxygen content;
- increased flood vulnerability; and
- species diversification.

Because of the complexity of the various factors affecting a marsh's fate, a simple comparison of current marsh elevations to future projections of sea level does not accurately predict wetland vulnerability to sea level rise. Model evaluations of Connecticut's tidal wetlands have been performed (by others) using the Sea Level Affecting Marshes Model (SLAMM). SLAMM simulations were performed starting from the date of the initial wetland cover layer through 2100. Maps and numerical data were output for the years 2025, 2055, 2085, and 2100.

The SLAMM model results for the Rapid Ice Melt maximum sea level rise scenario, which is a reasonable characterization of the predicted sea level rise for Old Saybrook. Under this scenario, significant changes to the marshes begin between 2025 and 2055, at which point most of Old Saybrook's marshes have converted into Low Marsh. Significant loss of beach has also occurred. By 2085, much of the marsh has converted to tidal flat. By 2100, almost all of the marsh is lost and has converted to open estuary water and tidal flat, with almost no beach barrier.

The analysis also indicates that the effect of sea level rise is not just a function of the total amount of sea level rise but also the rate of relative sea level change. The higher rate of sea level change under the SLAMM Rapid Ice Melt maximum sea level rise scenario, relative to scenarios with lower sea level rise projections results in more significant marsh transformation since the rate of sea level rise under the this scenario is occurring faster than the natural marsh accretion rates. See **Attachment 4** for a detailed description the predicted marsh response to sea level rise.



SLAMM Rapid Ice Melt maximum simulation of marsh response at Old Saybrook.

NATURAL RESOURCES: BEACHES

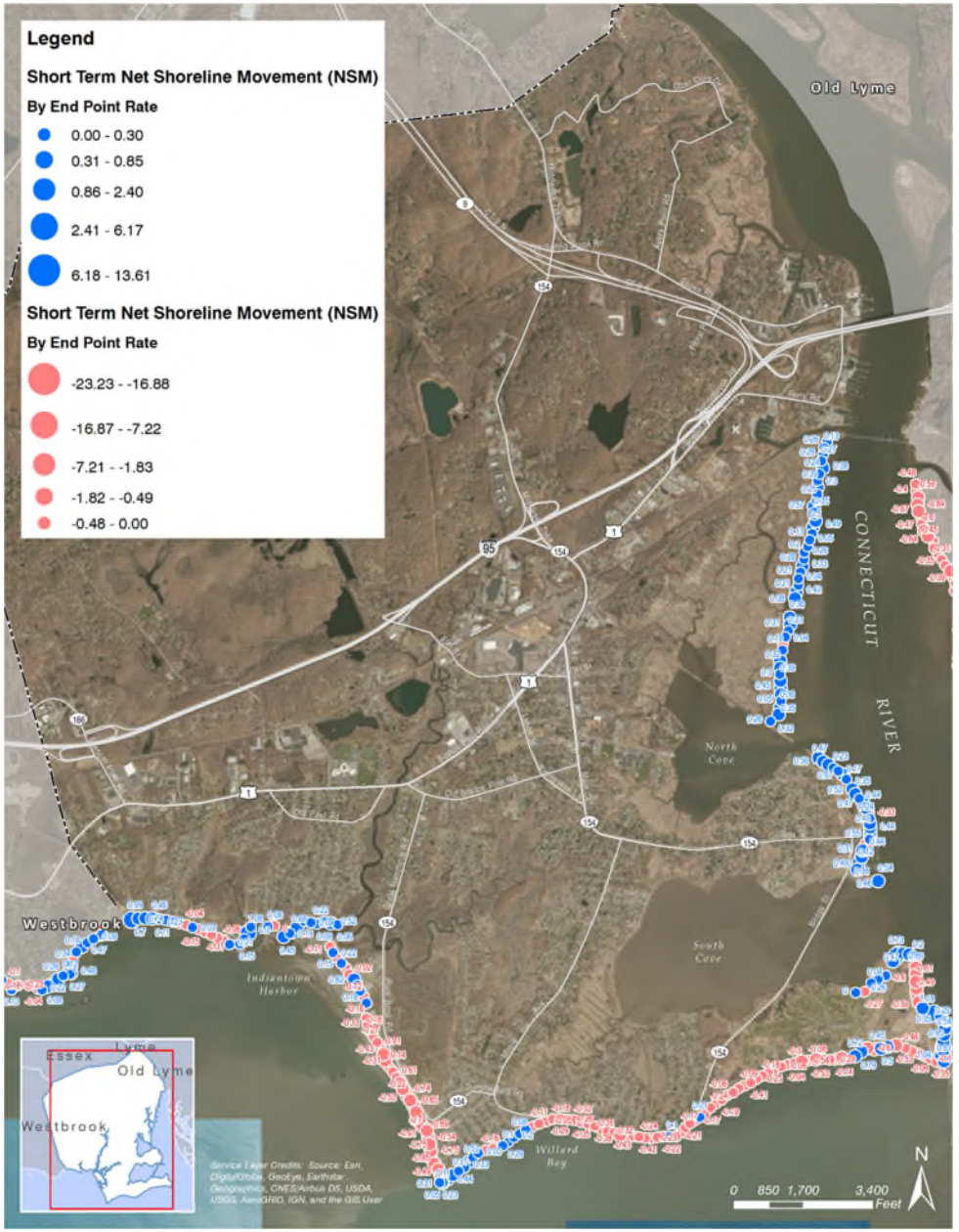
Old Saybrook's southern shoreline includes 14 beaches. Typical of the Connecticut coast, Old Saybrook's beaches consist of barrier spits and pocket beaches. Beach shoreline protection in the form of groins and jetties have been constructed along most of the beaches in Old Saybrook. About 8 miles of the Old Saybrook shoreline is potentially erodible, of which about 2 miles have been significantly affected by erosion. Areas that have been historically affected by shoreline erosion include: Chalker Beach, Chapman Beach, Westbrook, Plum Beach and Great Hammock Beach. The "Analysis of Shoreline Change in Connecticut", completed by University of Connecticut (CLEAR), Sea Grant and the Connecticut Department of Energy and Environmental Protection (DEEP), analyzed how the Connecticut shoreline has changed between the late 1800s and 2006 through loss (erosion) and gain (accretion) over time. Shoreline statistics include:

Old Saybrook – Long Island Sound Beaches
Short-Term (1983 to 2006):
Net Shoreline Movement:
Minimum: -19.9 meters
Maximum: 23.8 meters
Average: -2.6 meters
End Point Rate (average): -0.12 meters/year

Old Saybrook – Connecticut River Shoreline
Short-Term (1983 to 2006):
Net Shoreline Movement:
Minimum: -20.5 meters
Maximum: 2.8 meters
Average: 6.2 meters
End Point Rate (average): 0.28 meter/year

The long term effects of sea level rise on the beaches will be increased erosion and migration of barrier beaches and spits landward. Over the past century, the sea level in Long Island Sound has risen approximately 10 inches. Landward beach migration can progress as long as there are glacial deposits available to replenish the sediment supply and infrastructure does not impede the natural movement of the beach. At Old Saybrook, sediment supply is limited, and the large number of coastal structures impedes natural sediment transport. By 2100, the barrier spits, in particular Plum Bank, may have disappeared entirely.

See **Attachment 4** for a detailed description shoreline change along the Old Saybrook shoreline.



Observed net shoreline change (meters/year) for the period of 1983 to 2006