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Attachment 4: Vulnerability and Risk

Old Saybrook Coastal Resilience and Adaptation Study **GZA**

Attachment 4: Vulnerability and Risk

This attachment summarizes the results of a detailed evaluation of the Town's vulnerability to coastal flooding, including the effects of sea level rise, and the predicted consequences. The product of the flood event, vulnerability and consequences (all in terms of probability of occurrence) constitutes the coastal flood "risk". Determination of the coastal flood risk is a necessary step in planning for resilience and adaptation and identifying available and appropriate mitigation measures.

This evaluation specifically looks at the vulnerability and consequences of the flood hazards detailed in **Attachment 2.** The vulnerability and consequences are evaluated categorically as follows:

- Economic Risk
- Commercial and Industrial Districts
- Essential Facilities
- Lifeline Facilities
- High Potential Loss Facilities
- Shelter and Evacuation Requirements
- Historic Districts
- Hazardous Waste Facilities
- High Occupancy and Vulnerable Population Facilities
- Transportation Infrastructure
- Natural Resources: Marshes
- Natural Resources: Beaches

Coastal flooding is characterized in terms similar to those used by FEMA. Structures, businesses, property-owners, tenants and residents located:

- Within the limits of the 100-year recurrence interval flood are considered to be in a high flood hazard zone;
- Within the limits between the 100 and 500-year recurrence interval floods are located in a low to moderate flood hazard zone;
- Outside the limits of the 500-year recurrence interval flood are located in a low flood hazard zone.

The evaluation of the coastal flood risk also considers the type of asset and its relative importance to resilience, adaptation and public safety based on use and occupancy. 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 acceptable risk and appropriate level of flood protection.

Although not evaluated by FEMA for the National Flood Insurance program (NFIP), structures, businesses, property-owners, tenants and residents located within flood inundation areas with recurrence intervals less than 100-years (i.e., more frequent flooding) are considered to be in very high flood hazard zones. These include areas predicted to experience "chronic flood inundation" in the future.

The presence of waves, along with flood inundation, can significantly increase the 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).

Economic Risk

Attachment 4: Vulnerability and Risk

Predicted Building Damage Loss

GZA performed an updated HAZUS-MH (Hazus) analysis to estimate of coastal flood-related economic loss (Hazus Flood Event Report). Hazus is a regional multi-hazard loss estimation model that was developed by the Federal Emergency Management Agency (FEMA) and the National Institute of Building Sciences (NIBS). The primary purpose of Hazus is to provide a methodology and software application to develop multi-hazard losses at a regional scale. These loss estimates would be used primarily by local, state and regional officials to plan and stimulate efforts to reduce risks from multi-hazards and to prepare for emergency response and recovery. Hazus analyzes the risk on a census block scale. Old Saybrook contains 311 census blocks.

The analyses were performed for coastal flooding (per FEMA hazard characterization as represented on effective FEMA Firms for 100-year recurrence interval and interpolated other intervals) for the following recurrence interval flood: 10-year; 25-year; 50-year; 100-year and 500-year. A combined analysis was performed to estimate the Average Annualized Loss (AAL). The "Averaged Annualized Loss" (AAL) is the expected loss per year if averaged over many years.

The estimated values for Old Saybrook were compared to Middlesex County values using the FEMA's HAZUS Average Annualized Loss Viewer, 2016.

Current Asset Value

There are an estimated 5,874 buildings in the region with a total building replacement value (excluding contents) of 2,050 million dollars (2010 dollars). Approximately 89.33% of the buildings (and 72.45% of the building value) are associated with residential housing. See **Table 4-1** for total Old Saybrook asset value based on 2010 census data. As indicated in the Town of Old Saybrook & Borough of Fenwick Natural Hazards Mitigation Plan Update, 2014 (NHMP, 2014), 2011 Town assessment data indicates lightly different valuations (shown in parenthesis in Table 3-1). The 2011 assessment also carries additional categories. Of particular interest, public utilities ($3,770,600) and vacant land ($52,244,500). The 2011 assessment also distinguishes between residential (shown below) and apartments ($1,689,200).

Table 4-1 Old Saybrook Building Exposure and Occupancy Type

Occupancy	Exposure ($1000)	Percent of Total
Residential	1,485,236 (2,020,973)	72.4% (86%)
Commercial	404,804 (244,953)	19.7% (10%)
Industrial	92,785 (20,974)	4.5% (1%)
Agricultural	4,762	0.2%
Religion	28,859	1.4%
Government	19,222	.9%
Education	14,444	.7%
Total	2,050,112 (2,344,698)	100%

The 2011 assessment grand list also categorizes assets as:

Real Estate:	$2,332,996,248	94%
Personal Property:	$54,298,520	2%
Motor Vehicles:	$94,404,640	4%

Predicted Scenario Impacts

FEMA 10-year Flood:

The following presents the predicted building damage by occupancy type, number of structures and percent damage. The Hazus flood scenario analysis indicates that during the predicted FEMA 10-year recurrence interval it is estimated that about 296 buildings will be at least moderately damaged, all residential.

	1-10		11-20		21-30		31-40		41-50		Substantially	
Occupancy	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Agriculture	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Commercial	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Education	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Government	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Industrial	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Religion	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Residential	1	0.34	56	18.86	181	60.94	18	6.06	41	13.80	0	0.00
Total	**1**		**56**		**181**		**18**		**41**		**0**	

Table 4-2 Old Saybrook Estimated Building Damage during 10-year Recurrence Interval Flood

FEMA 25-year Flood:

The following presents the predicted building damage by occupancy type, number of structures and percent damage. The Hazus flood scenario analysis indicates that during the predicted FEMA 25-year recurrence interval it is estimated that about 380 buildings will be at least moderately damaged, all residential.

	1-10		11-20		21-30		31-40		41-50		Substantially	
Occupancy	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Agriculture	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Commercial	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Education	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Government	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Industrial	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Religion	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Residential	1	0.26	62	16.27	166	43.57	86	22.57	66	17.32	0	0.00
Total	**1**		**62**		**166**		**86**		**66**		**0**	

Table 4-3 Old Saybrook Estimated Building Damage during 25-year Recurrence Interval Flood

FEMA 50-year Flood:

The following presents the predicted building damage by occupancy type, number of structures and percent damage. The Hazus flood scenario analysis indicates that during the predicted FEMA 50-year recurrence interval it is estimated that about 542 buildings will be at least moderately damaged, all residential.

	1-10		11-20		21-30		31-40		41-50		Substantially	
Occupancy	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**
Agriculture	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Commercial	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Education	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Government	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Industrial	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Religion	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Residential	2	0.37	93	17.10	165	30.33	150	27.57	131	24.08	3	0.55
Total	**2**		**93**		**165**		**150**		**131**		**3**	

Table 4-4 Old Saybrook Estimated Building Damage during 50-year Recurrence Interval Flood

FEMA 100-year Base Flood:

The following presents the predicted building damage by occupancy type, number of structures and percent damage. The Hazus flood scenario analysis indicates that during the predicted FEMA 100-year recurrence interval Base Flood it is estimated that about 910 buildings will be at least moderately damaged, mostly residential with 3 commercial. Nine building are predicted to be destroyed (damages exceed substantially damaged criterion).

	1-10		11-20		21-30		31-40		41-50		Substantially	
Occupancy	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**
Agriculture	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Commercial	3	100.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Education	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Government	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Industrial	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Religion	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Residential	5	0.55	263	28.74	236	25.79	118	12.90	284	31.04	9	0.98
Total	**8**		**263**		**236**		**118**		**284**		**9**	

Table 4-5 Old Saybrook Estimated Building Damage during 100-year FEMA Base Flood

FEMA 500-year Flood:

The following presents the predicted building damage by occupancy type, number of structures and percent damage. The Hazus flood scenario analysis indicates that during the predicted FEMA 500-year recurrence interval Base Flood it is estimated that about 2,624 buildings will be at least moderately damaged, mostly residential with 8 commercial. Five hundred and twenty-eight (528) buildings are predicted to be destroyed (damages exceed substantially damaged criterion).

	1-10		11-20		21-30		31-40		41-50		Substantially	
Occupancy	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Agriculture	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Commercial	0	0.00	6	75.00	1	12.50	1	12.50	0	0.00	0	0.00
Education	0	0.00	1	100.00	0	0.00	0	0.00	0	0.00	0	0.00
Government	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Industrial	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	100.00
Religion	0	0.00	1	100.00	0	0.00	0	0.00	0	0.00	0	0.00
Residential	1	0.04	31	1.19	295	11.29	765	29.27	995	38.06	527	20.16
Total	**1**		**39**		**296**		**766**		**995**		**528**	

Table 4-6 Old Saybrook Estimated Building Damage during 500-year Recurrence Interval Flood

Predicted Average Annualized Loss

Table 4-7 presents the Hazus-predicted Average Annualized Loss (AAL) for Old Saybrook. The predicted AAL is $16 million. Assuming a Town population of about 10,199 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 Fairfield County to be $77.4M, which represents a per capita average AAL within Middlesex County of $467 related to predicted flood losses. Damage to residential buildings accounts for a majority of the total loss, with privately-owned commercial and industrial buildings accounting for the 35 percent (%) of the loss. **Figure 4-1** shows the geographic distribution (by census block) of the estimated AAL.

Category:	10 yr	25 yr	50 yr	100 yr	500 yr	AAL
Residential	$51M	$67M	$99M	$156M	$580M	
Commercial	$20M	$25M	$33M	$54M	$192M	
Industrial	$6M	$7M	$10M	$15M	$59M	
Others	$6M	$8M	$10M	$15M	$51M	
Total	$83M	$107M	$153M	$240M	$882M	$16M

*Note: Dollars indicated are in Millions.

Table 4-7 Old Saybrook Estimated Average Annualized Loss (AAL)

Attachment 4: Vulnerability and Risk

These costs include building, content, inventory and business interruption losses, as indicated below.

(Millions of dollars)

Category	Area	Residential	Commercial	Industrial	Others	Total
Building Loss						
	Building	6.25	1.04	0.27	0.19	7.74
	Content	4.33	2.57	0.74	0.87	8.51
	Inventory	0.00	0.05	0.07	0.00	0.12
	Subtotal	**10.57**	**3.66**	**1.07**	**1.06**	**16.36**
Business Interruption						
	Income	0.00	0.01	0.00	0.00	0.01
	Relocation	0.01	0.00	0.00	0.00	0.01
	Rental Income	0.00	0.00	0.00	0.00	0.00
	Wage	0.00	0.01	0.00	0.03	0.03
	Subtotal	**0.01**	**0.02**	**0.00**	**0.03**	**0.05**
ALL	**Total**	**10.58**	**3.67**	**1.07**	**1.09**	**16.41**

Table 4-8 Old Saybrook Estimated AAL Building Related Economic Loss

Distribution of Average Annualized Loss

The predicted distribution of economic loss, based on Hazus simulations, is presented on **Figure 4-1** in terms of estimated Average Annualized Loss (AAL). The predicted high loss area around North Cove (in red) is due to the presence of high values assets (both private and municipal, such as the school) and the exposure to coastal flooding.

Uncertainty

Loss estimations using HAZUS-MH are highly uncertain, in particular relative to the predicted damage and resulting economic loss. The analysis is sensitive to flood depth and makes assumptions relative to: building floor elevations and percent damage (using generic depth-damage relationships). It also estimates loss based on a census block scale (i.e., not a building scale). Hazus reasonably predicts the number of structures impacted. Significant uncertainty with economic loss AAL analyses is also due to the uncertainty related to flood probability. Uncertainty can be reduced by performing more site-specific analysis (i.e., Level 2 and 3 analyses, using elevation certificates and building scale analyses). Uncertainty can also be reduced by comparing results to observed impact and losses. Unfortunately, there is limited historical loss data that is relevant to low probability storms.

An estimate of observed losses during Tropical Storm Irene and Hurricane Sandy are presented in NHMP, 2014. Based on the observed peak water levels, these storms are generally on the order of 10 to 20 - year return periods as predicted by FEMA. As shown in NHMP, 2014:

Tropical Storm Irene:

FEMA Damage Class	# Residences	Estimated Cost
Affected	195	$192,000
Minor	15	$225,000
Major	8	$400,000
Destroyed	0	$0

Hurricane Sandy:

FEMA Damage Class	# Residences	Estimated Cost
Affected	274	$274,000
Minor	61	$915,000
Major	8	$400,000
Destroyed	4	$600,000

The numbers of building affected ranged from 218 to 347, which are generally consistent with the Hazus simulations. The estimated building damages due to these storms ranged from $817,000 (average $3,750 per building) to $2,189,000 (average $6,310 per building), were significantly less than that predicted by Hazus (+/-$29,000,000 for the 10-year recurrence interval flood, which corresponds to an average of about $98,000 per building). However, this comparison (which is based on relatively minor, high probability storms) may not be representative of more intense storms (i.e., > 50-year recurrence interval) which will have larger waves, deeper water and more intense winds, and Hazus may reasonably estimate losses during these types of coastal floods.

Additional costs incurred by the Town from these two storms (and reimbursed by FEMA) ranged from about $375,000 to $567,000.

NFIP Insurance Policies

As of November 30, 2016, there are 1,492 NFIP flood policies in the Town. Of these NFIP-insured properties, 61 are in the VE Zone and 852 are in AE Zones. Based on the Town's 2014 Natural Hazards Mitigation Plan (2014 NHMP) there are approximately 2,100 structures located within the A, AE, and VE zones. Nine hundred and thirteen (913) of the approximately 2,100 structures located in the SFHA are insured under the NFIP.

There has been a total of 628 paid claims since 1978 totaling $14.2 Million in paid losses (average of about $364,000 per year). The average premium for properties located within a FEMA SFHA is $1,867 (with total premium costs of $1,742,537). Three properties, making multiple claims, accounted for about 4% of the $14.2M in paid losses.

Structures on 14 repetitive loss properties were demolished and rebuilt over the last 10 years. Five repetitive loss structures are in the process of being rebuilt. An additional 75 homes located within FEMA special flood hazard zones have been made compliant with local, State and federal flood regulations.

The number of total NFIP policies in the Town is less than half of the number of buildings located within FEMA SFHAs. The number of NFIP policies in the Town corresponding to VE zones is less than half of the number of buildings located within the VE zone.

Thirty-seven percent (37%) of the NFIP-insured structures are located outside of the SFHA and have accounted for just under eight percent (8%) in paid losses through the NFIP.

The Biggert-Waters Flood Insurance Reform Act of 2012, which was temporally rescinded, will (if implemented) significantly increase the cost of premiums in the Town. The effect of climate change, which will result in more properties being included within future SFHAs (and to greater flood depths) and will further increase future insurance costs.

Attachment 4: Vulnerability and Risk

Potential Risk to the Town Budget

The Town's vulnerability to coastal flood risk will likely impact the Town Budget, including:

- Increase in public works costs;
- Increase in public safety costs;
- Decrease in property tax revenue; and
- Increase in interest rates for municipal bonds.

The increase in public works costs are related to: 1) roadway repair and improvements due to an increase in the extent and frequency of coastal flooding; 2) stormwater management; 3) implementation of flood mitigation measures; and 4) sanitary wastewater treatment. The magnitude of certain mitigation measures, such as roadway improvements, could require municipal bonds to finance.

The increase in public safety costs are related to: 1) developing capabilities for providing emergency response services during floods; 2) expanding shelter requirements; and 3) the increased frequency of flood-related emergency response events.

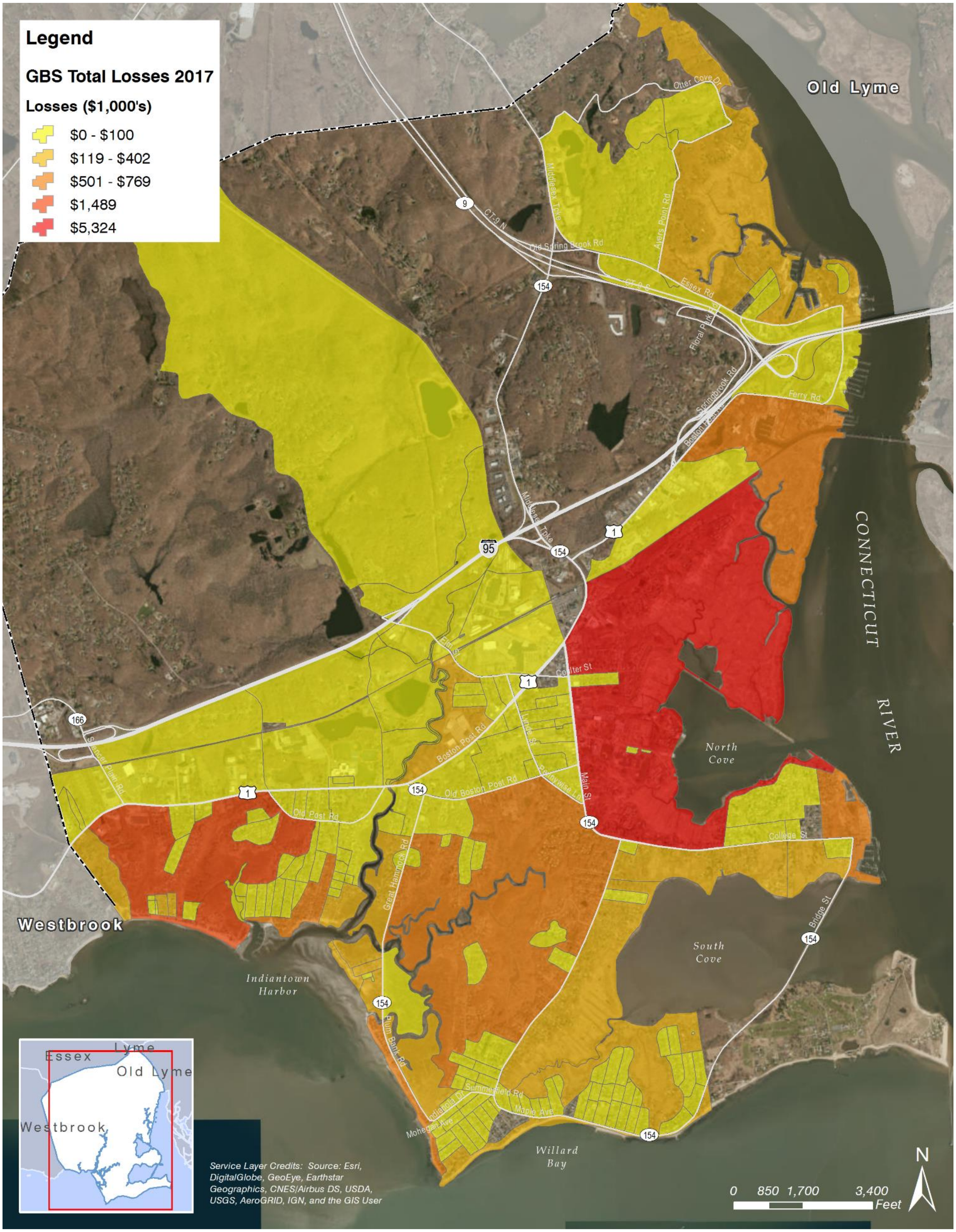
The decrease in property tax revenue is related to: 1) loss of taxable structures due to periodic, flood-induced damage and abandonment; 2) loss of commercial activity (e.g., restaurants) due to periodic, flood-induced damage, disruption of service and inconvenience; and 3) the weighted loss of waterfront properties, which typically have higher appraised values.

Effects on Municipal Bond Rating

The Town's vulnerability to coastal flood risk may impact the Town's municipal credit score. According to Moody's, municipalities and states will face higher interest rates that are directly related to flood vulnerability, representing a future hidden cost to taxpayers.

Attachment 4: Vulnerability and Risk

Figure 4-1 Geographic Distribution of Hazus Average Annualized Loss



Commercial and Industrial Districts

Commercial and Industrial Districts

The vulnerability of Commercial Districts is evaluated relative to coastal flooding, up to the 100-year recurrence interval flood (FEMA BFE). The coastal flood risk of Old Saybrook's commercial and industrial districts renges from Low to High. 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).

Due to their coastal setting, Saybrook Point SP-1 through SP-3 Distícts and the Marine Commercial Districts have the highest coastal flood risk.

Saybrook Point SP-1 through SP-3 Districts

Saybrook Point SP-1 through SP-3 Districts are coastally located along the shoreline of the Connecticut River and are highly vulnerable to coastal flooding. These areas experienced extensive flooding during recent storms (Sandy and Irene) and building and infrastructure damage.

As shown in **Figures 4-2** through **4-5**, the coastal flood risk of the SP-1 through SP-3 districts is High, with the area flooding during high frequency flood events. Further, road access to these areas becomes impossible during even high probability floods resulting in loss of business. The High flood risk makes this area the commercial district within Old Saybrook with the greatest flood vulnerability and potential for loss, including property damage, loss of income and disruption of service. This area is also vulnerable to significant wave effects. As shown in **Figure 4-2**, much of the area is located within a FEMA VE special flood hazard zone due to its exposure to waves greater than 3 feet in height.

Central Business B-1District

The Central Business District B-1 is located (almost entirely) outside the FEMA BFE. The exception are the eastern portions of the district located near the North Cove. See **Figure 4-6**. This vulnerability is expected to increase significantly in the future with sea level rise.

Shopping Center Business B-2 District

The Shopping Center Business B-2 District is located approximately 40% within the limits of the FEMA AE special flood hazard zone. See **Figure 4-7**. This area is vulnerable to coastal flooding propagating up the Oyster River and surrounding marsh. This area will also be flooded during higher probability flood events (about 10-year recurrence interval flood). This vulnerability is expected to increase significantly in the future with sea level rise.

Restricted Business B-3 District

The Restricted Business B-3 District is located within three separate areas. Two of these are located outside the FEMA AE special flood hazard zone. The third (see **Figure 4-7**) is located partially within the FEMA AE special flood hazard zone. This area will also be flooded during higher probability flood events (about 50-year recurrence interval flood). This vulnerability is expected to increase significantly in the future with sea level rise.

Gateway Business B-4 District

The Restricted Business B-4 District developable areas are located outside the FEMA AE special flood hazard zone.

Industrial I-1 District

The Industrial I-1 District located outside the FEMA AE special flood hazard zone, with a few localized areas within – see **Figure 4-8**. This vulnerability is expected to increase significantly in the future with sea level rise.

Marine Commercial District

The Marine Commercial District is coastally located along the shoreline of the Connecticut River and vulnerable to coastal flooding. As shown on **Figures 3-11 and 3-12**, areas within this district are located within the FEMA AE special flood hazard zone. This vulnerability is expected to increase significantly in the future with sea level rise.

Note: 1. The eastern portions of the district, near the North Cove, are located within FEMA AE Zone.

COMMERCIAL AND INDUSTRIAL DISTRICTS

LOCATION	Current	2041	2066	2116
Saybrook Point SP-1 through SP-3	High	High	High	High
Central Business B-1[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

Table 4-9 Commercial and Industrial Districts Risk Profile

Attachment 4: Vulnerability and Risk

Figure 4-2 Saybrook Point SP-1 through SP-3 Districts relative to FEMA FIRM

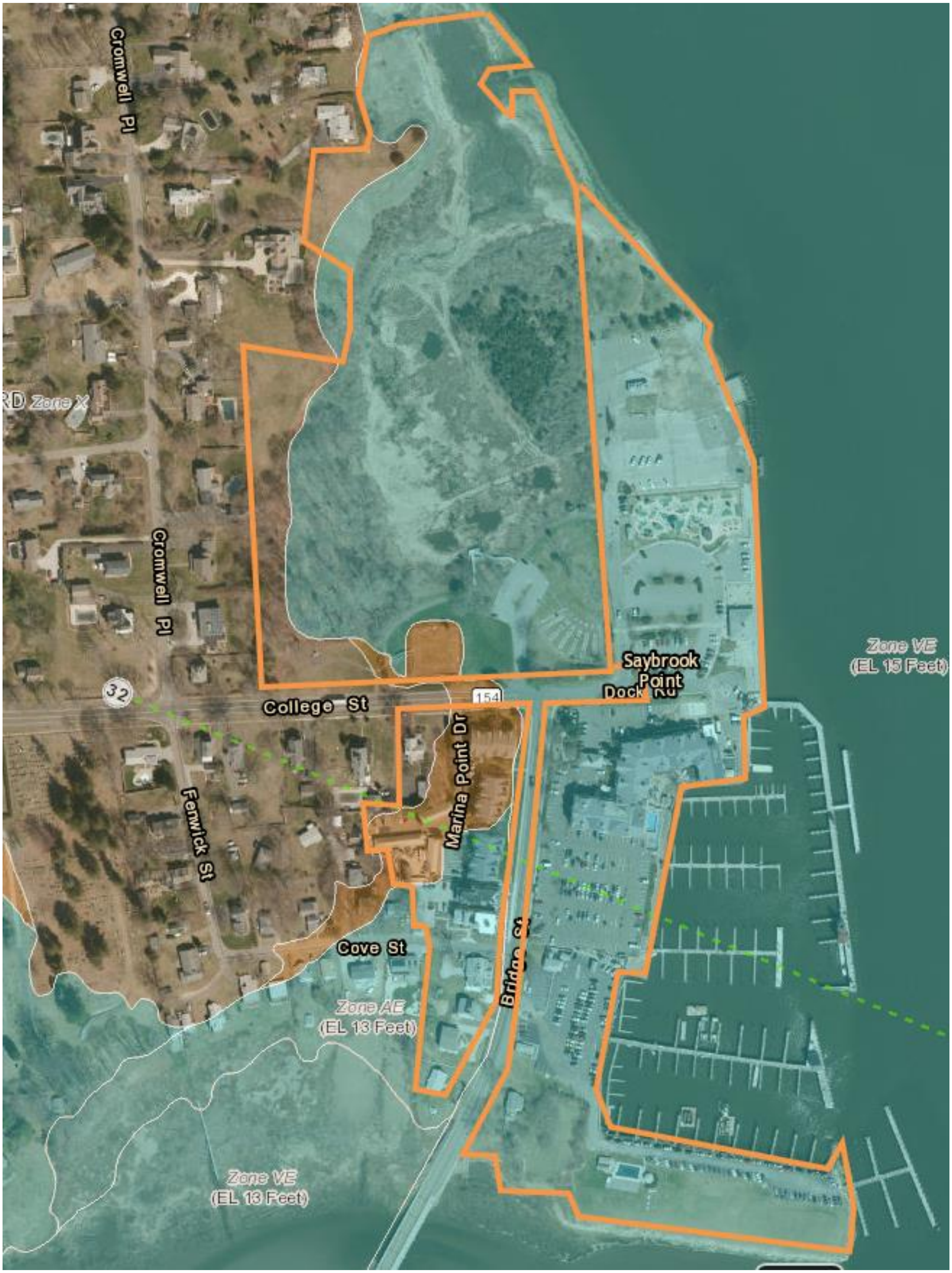


Figure 4-3 Saybrook Point SP-1 through SP-3 Districts relative to 2 year recurrence interval flood A FIRM

Figure 4-4 Saybrook Point SP-1 through SP-3 Districts relative to 10 year recurrence interval flood A FIRM

Figure 4-5 Saybrook Point SP-1 through SP-3 Districts relative to 50 year recurrence interval flood A FIRM

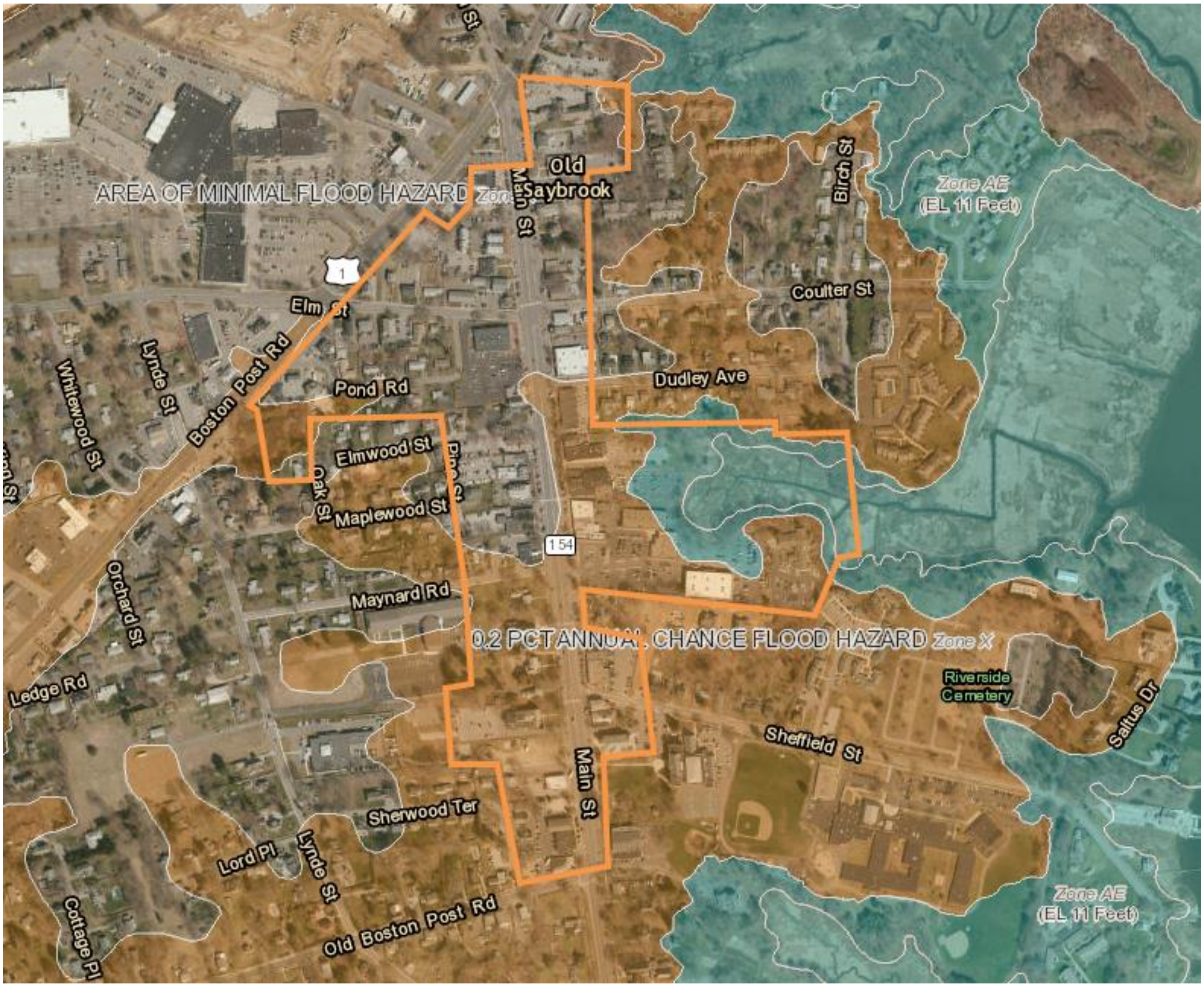


Figure 4-6 Central Business Districts B-1 relative to FEMA FIRM

Figure 4-7 Shopping Center B-2 Business District relative to FEMA FIRM

Figure 4-8 Restricted Business B-3 District relative to FEMA FIRM

Figure 4-9 Industrial I-1 District relative to FEMA FIRM

Figure 4-10 Marine Commercial District relative to FEMA FIRM

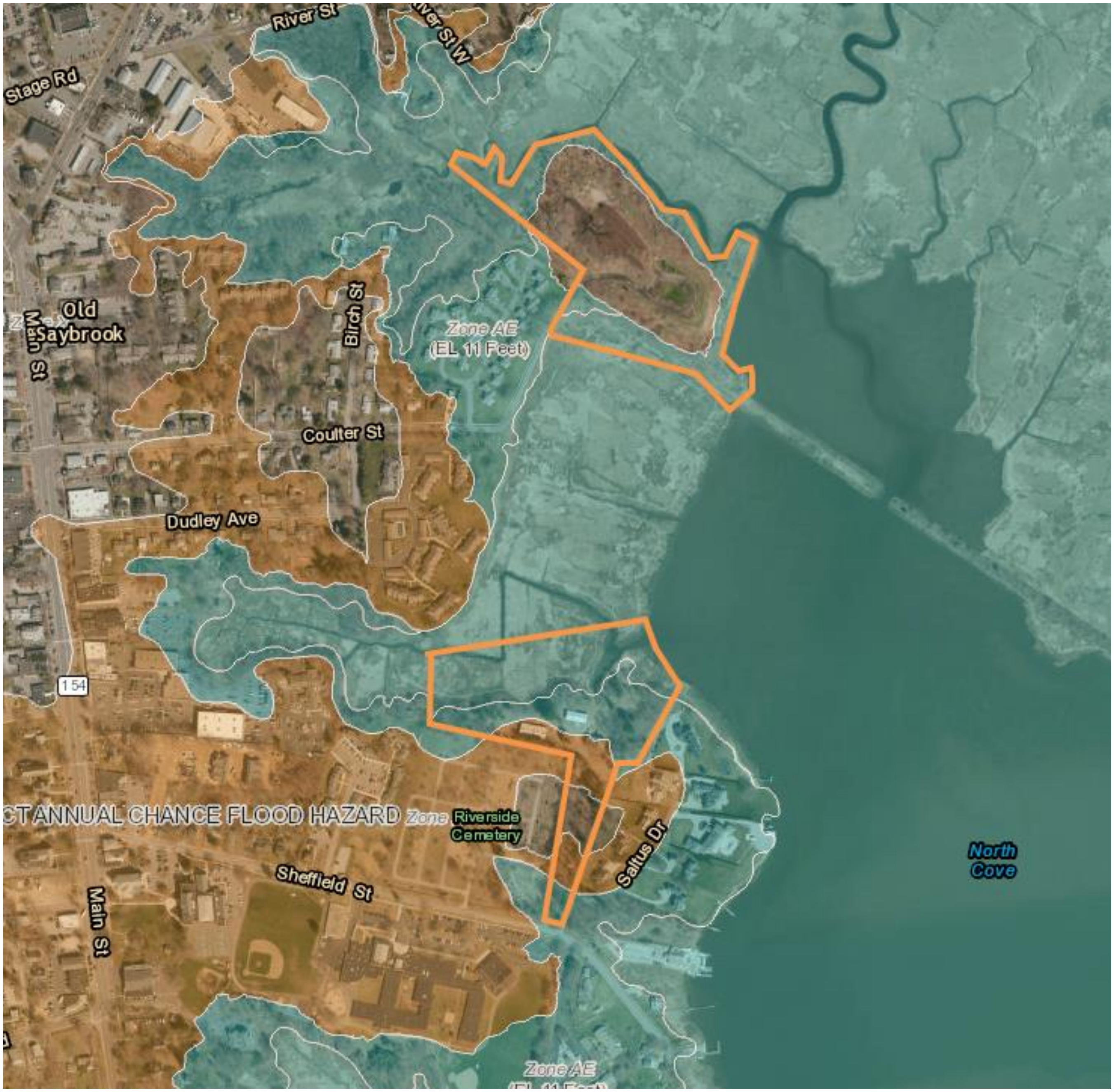


Figure 4-11 Marine Commercial Districts relative to FEMA FIRM

Communities

COMMUNITIES

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

Communities

The following provides an overview of the vulnerability of the Town's communities. The communities primarily consist of residential and commercial structures, 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).

Low Beach Communities

With frontage on Long Island Sound and surrounded by tidal marsh, the Low Beach Communities (including Chalker Beach; Indiantown; Meadowood; Saybrook Manor; Great Hammock Beach and Plum Bank) are very vulnerable to coastal flooding and have a High Risk. As shown of **Figure 4-12,** these communities are located entirely within the FEMA AE zone and developed beaches fronting on the Sound are exposed to high waves and located within a FEMA VE zone. As shown in **Figure 4-13**, these communities are also vulnerable to frequent flooding. **Figure 4-13** shows the limits of the 2-year recurrence interval flood. By the years 2040 to 2050, the inundated areas shown in **Figure 4-13** will be chronically flooded (i.e., flooding on average 26 times per year). **Figure 4-14** shows the limits of the 10-year recurrence interval flood. **Figure 4-15** shows the predicted wave heights during 100-year recurrence interval flood, with 3 to 5 foot high waves (significant wave height) breaking in the vicinity of the houses south of Beach and Bel Aire Manor Roads and west of Plum Bank Road.

Cornfield Point to Fenwood

The topography is variable within these communities, with much of the area located at higher elevation outside the limits of the FEMA AE special flood hazard zone. About 10% to 20% of the parcels within this area are located within the FEMA AE zone. Except for parcels located along the Sound at Cornfield Point, coastal flooding occurs primarily from overtopping of the banks of the tidal marsh.

As shown on **Figure 4-16**, during coastal floods, higher areas become isolated with flooded roads and limited egress and ingress. These areas abutting the tidal marsh begin to be flooded during high probability flooding (e.g., the 2-year recurrence interval flood). The effect of sea level rise will be to increases the frequency of coastal flood inundation within these areas.

Saybrook Point and Town Center

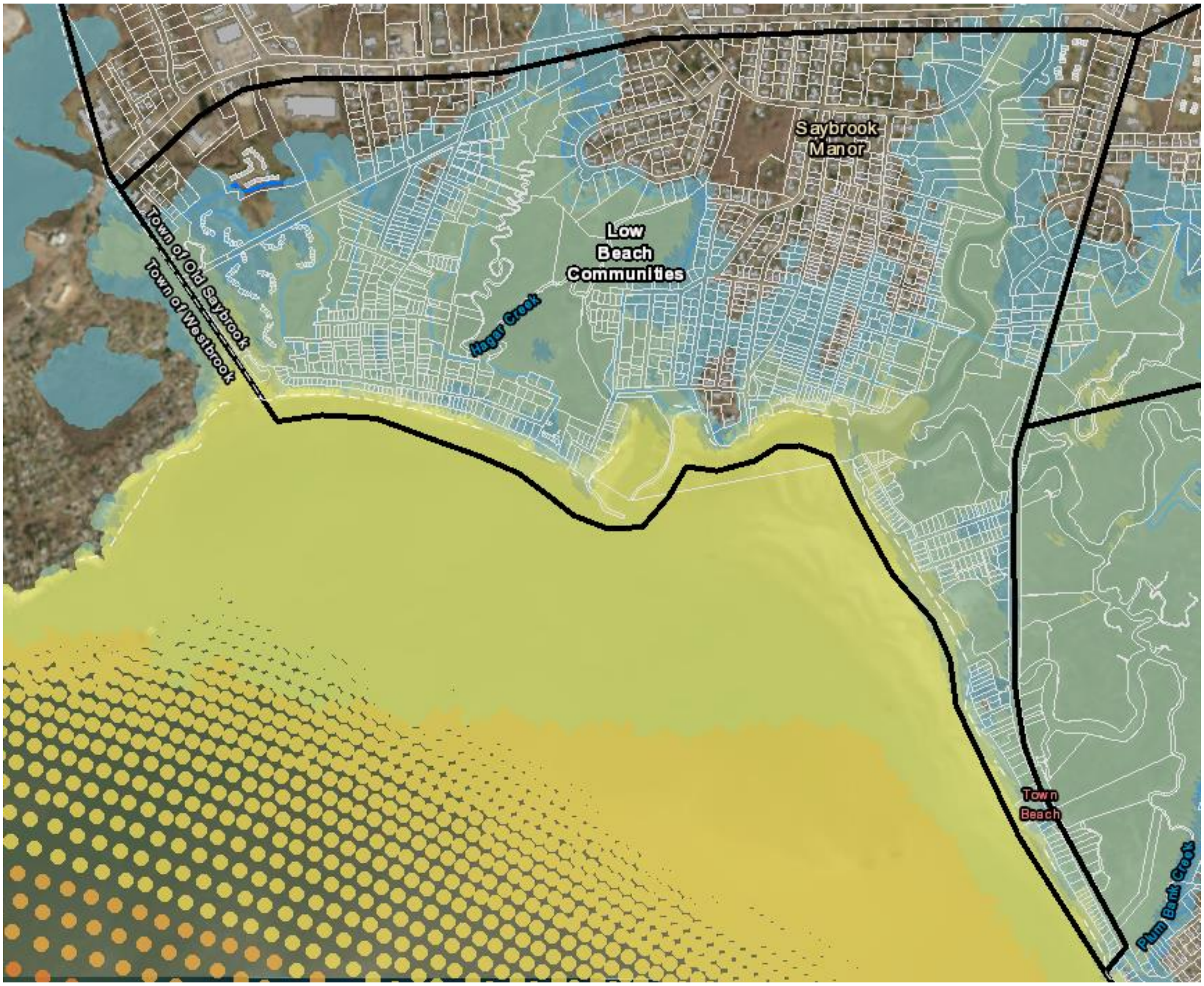
Route 154 and Saybrook point are very vulnerable to coastal flooding. Figure 4-17 shows the limits of the FEMA special flood hazard zones in this area. These areas begin to be flooded during high probability flooding (e.g., the 2-year recurrence interval flood).

Figure 4-12 Low Beach Communities relative to FEMA FIRM

Note: Areas shaded in green represents the FEMA AE zone and areas in brown are located within the limits of the 500-year recurrence interval flood.

Figure 4-13 Low Beach Communities relative to 2-year recurrence interval flood

Figure 4-14 Low Beach Communities relative to 10-year recurrence interval flood



2016 100YR NoSLR Wave Height (ft)

- <1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 9
- >9

Figure 4-15 Low Beach Communities relative to 100-year recurrence Wave Heights

Figure 4-16 Cornfield Point to Fenwood relative to the FEMA FIRM

Note: Areas shaded in green represents the FEMA AE zone and areas in brown are located within the limits of the 500-year recurrence interval flood.

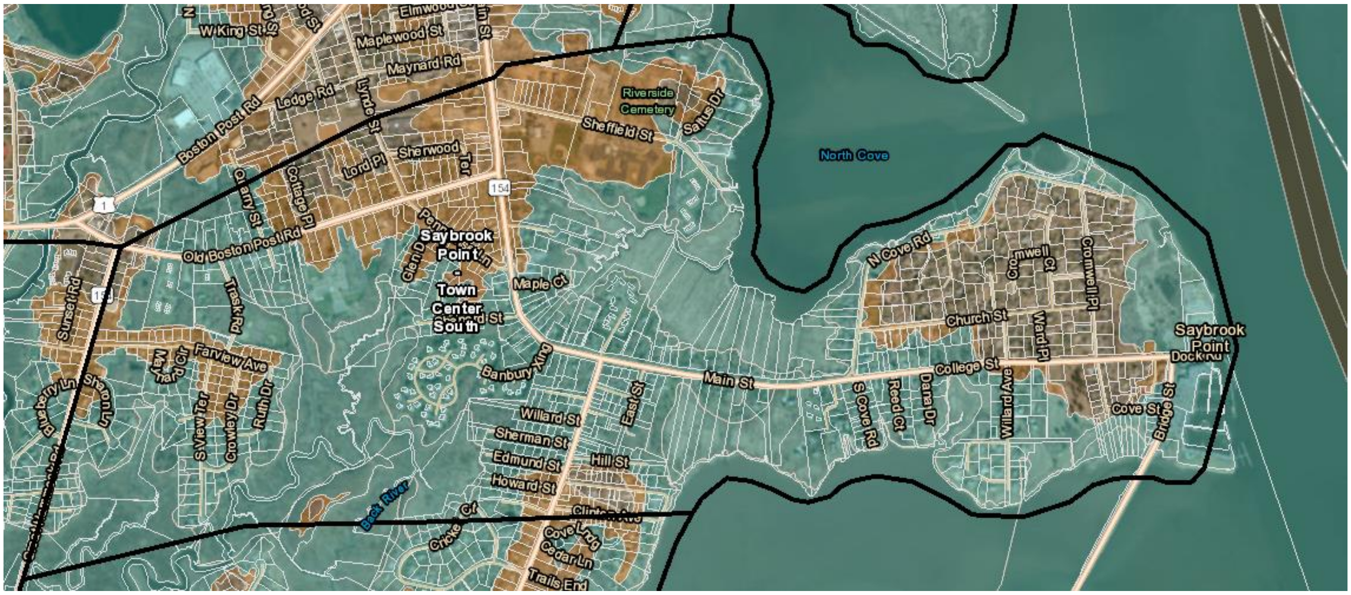


Figure 4-17 Saybrook Point to Town Center relative to the FEMA FIRM

Note: Areas shaded in green represents the FEMA AE zone and areas in brown are located within the limits of the 500-year recurrence interval flood.

Essential Facilities

Attachment 4: Vulnerability and Risk

Essential Facilities

Essential facilties are those facilities that are necessary for emergency response and recovery and pose a substantial, risk to the community at large in the event of failure, disruption of function, or damage by flooding. 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 Town's Essential Facilities include:

- 2 Police Facilities
- 5 Fire and Rescue Facilities
- 3 Healthcare Facilities
- 1 Emergency Shelters (including 1 school)
- 1 Public Works Garage

There are two police facilities including:

- the Old Saybrook Police Station located at 36 Lynde Street
- the police boat located at a marina just north of I-95

There are five fire and rescue facilities including:

- Old Saybrook Fire Department at 310 Main Street;
- Emergency Management Public Safety Office at 302 Main Street;
- Emergency Management Services Unit 6 Custom Drive;
- Fire Boat located at a marina just north of I-95; and
- Old Saybrook Ambulance Association at 316 Main Street.

The three healthcare facilities include:

- the Middlesex Hospital Urgent Care at 1687 Boston Post Road;
- Middlesex Hospital Primary Care at 154 Main Street; and
- the Connecticut Area River Health District (CRAHD) at 455 Boston Post Road.

The two Middlesex healthcare facilities include walk-in care for non-emergency medical service, laboratory services and X-rays (at the Urgent Care Facility). The Shoreline Medical Center in neighboring Westbrook provides 24/7 emergency care and outpatient diagnostic services.

Public Emergency Shelter:

- The Old Saybrook High School serves as the primary emergency shelter for the Town and is located at 1111 Boston Post Road.

Figure 4-18 indicates the locations of the Essential Facilities relative to FEMA special flood hazard zones.

Police Station

The easternmost edge of the Police Station at 36 Lynde Street appears to be located within the FEMA 500-year recurrence interval flood limits. The ground elevation (based on available LiDAR) in the immediate area around the Police Station is about Elevation 15 feet to 16 feet NAVD88. The FEMA 500-year recurrence stillwater elevation (see **Attachment 2**) is Elevation 15.4 feet NAVD88. (As noted in **Attachment 2**, the FEMA 500-year recurrence interval stillwater elevation appears to be high relative to other data sources. GZA's flood simulations, which were bounded to the USACE NACCS study, indicate 500-year recurrence interval stillwater flood elevation of about 13.6 feet NAVD88 around the buildings.) Additional site survey may indicate that the FEMA map is incorrect based on elevation. The current coastal flood risk for the police station is considered Low due to the building elevation relative to the FEMA 500-year flood elevation. The ground surface elevation around the building should be confirmed.

Fire Department and Emergency Management Facility

The ground elevation (based on available LiDAR) in the immediate area around the Fire Station and the Emergency Management (Town Hall) is at elevation +/-13 feet NAVD. The FEMA 500-year recurrence stillwater elevation (see **Attachment 2**) is Elevation 15.4 feet NAVD88. (As noted in **Attachment 2**, the FEMA 500-year recurrence interval stillwater elevation appears to be high relative to other data sources. GZA's flood simulations, which were bounded to the USACE NACCS study, indicate 500-year recurrence interval stillwater flood elevation of about 13.6 feet NAVD88 around the buildings.) The current coastal flood risk for the fire department and emergency management facility are considered High due to the building elevations relative to the FEMA 500-year flood elevation.

Figure 4-19 indicates the locations of the Fire Department and Emergency Management Facility relative to the 500-year recurrence interval flood limits. **Figure 4-20** shows the vicinity of the Fire Department. **Figure 4-21** shows the vicinity of the Town Hall.

ESSENTIAL FACILITIES COASTAL FLOOD RISK PROFILE

LOCATION	Current	2041	2066	2116
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

Table 4-11 Essential Facilities Risk Profile

Figure 4-18 Location of Essential Facilities relative to Predicted Coastal Flood Limits FEMA FIRM

Note: Areas shaded in green represents the FEMA AE zone and areas in brown are located within the limits of the 500-year recurrence interval flood.

Figure 4-19 Fire Department at 310 Main Street; Emergency Management at 302 Main Street (Town Hall); and Old Saybrook Ambulance Association at 316 Main Street relative to the FEMA FIRM

Note: Areas shaded in green represents the FEMA AE zone and areas in brown are located within the limits of the 500-year recurrence interval flood.

Figure 4-20 Vicinity of Fire Department at 310 Main Street; Ground Surface +/- Elevation 13 feet NAVD88; FEMA 500-year flood +/-15.4 feet NAVD88 Note: Areas shaded in green represents the FEMA AE zone and areas in brown are located within the limits of the 500-year recurrence interval flood.

Figure 4-21 Vicinity of Town Hall; Ground Surface +/- Elevation 13 feet NAVD88;

Old Saybrook Ambulance Association

The Ambulance Association building, with ground surface at the rear of the building at about Elevation 8 feet NAVD88, is located within the FEMA 100-year recurrence interval AE Zone which has a Base Flood Elevation of 11 feet NAVD88 and is near the boundary with the FEMA VE Zone which has a Base Flood Elevation of 15 feet NAVD88. The upland marsh of the North Cove extends to close to the building. The current coastal flood risk for the ambulance facility is considered High due to the building elevations relative to the FEMA 100 year and 500-year flood elevations. **Figure 4-22** shows the roadway leading to the ambulance facility.

Figure 4-22 Vicinity of Fire Department at 310 Main Street; Roadway Leading to Ambulance Facility at 316 Main Street Ground Surface +/- Elevation 10 to 13 feet NAVD88

Public Emergency Shelter

The Old Saybrook High School serves as the primary emergency shelter for the Town and is located at 1111 Boston Post Road. The school building (ground surface at about Elevation 16 feet NAVD88) is outside the limits of the FEMA 500-year recurrence interval flood zone; however, the parking garage is within the 500-year flood limits. The Boston Post Road in the vicinity of the school is flooded during the 100-year and 500-year recurrence interval floods. **Figure 4-23** indicates the locations of the Fire Department and Emergency Management Facility relative to the 500-year recurrence interval flood limits.

Figure 4-23 The Public Emergency Shelter (Old Saybrook High School) with FEMA Flood Hazard Zones

Note: Areas shaded in green represents the FEMA AE zone and areas in brown are located within the limits of the 500-year recurrence interval flood.

Figure 4-24 Vicinity of Emergency Shelter (Old Saybrook High School); Ground Surface +/- Elevation 14 to 16 feet NAVD88

Fire Department and Emergency Management Facility Flood Profile

The Fire Department and Emergency Management Facility are Essential Facilities and are located within the FEMA 500-year recurrence interval (0.2% annual exceedance probability) flood, which is the minimum design basis for Essential Facilities.

Design Basis Flood: Effective FEMA FIRM 500-year Recurrence Interval Flood

Flood Mitigation Goal: Essential facilities (not located within VE or Coastal AE Zones) should be designed with a minimum elevation of the lowest floor at or above the Effective FEMA Base Flood Elevation (BFE) plus 2 feet or the 500-year flood, whichever is higher. Essential facilities not constructed to these criteria should be either: 1) dry floodproofed; or 2) flood protected to above these criteria.

Storm Type: The 500-year coastal flood is expected to be a high intensity hurricane.

FEMA 500-year stillwater elevation: Elevation 15.4 feet

FEMA 500-year Coastal Flood Water Depths: The water depths around the building exterior during the 500-year recurrence interval flood are predicted to be (based on FEMA) about 2 to 3 feet. All of Main Street, in the vicinity of the Fire Station is similarly flooded during this event.

500-year Coastal Flood Waves: The ground elevation (based on available LiDAR) in the immediate area around the Fire Station and the Emergency Management (Town Hall) is at elevation +/-12 to +/- 13 feet NAVD. Wind-generated, depth limited waves will occur during the coastal flood event. Waves are predicted to be less than between 1.5 and 2 feet.

500-year Wind: High winds will occur coincident with coastal flooding during the 500-year recurrence interval flood. The predicted 500-year recurrence interval sustained wind is about 154 miles per hour.

Precipitation: Extreme precipitation, including areas of localized intense precipitation, may occur during this coastal flood event.

Non-Design Basis Floods: The Fire Department and Emergency Management Facilities are located outside the limits of the 100-year recurrence interval and higher probability coastal floods.

Future Risk Due to Sea Level Rise

Permanent modifications to these facilities should consider changes to the future coastal flood hazard due to sea level rise. Sea level rise will increase the flood risk. Based on NOAA 2017 relative sea level rise projections, tidal datum elevations are expected to increase by about 2 feet by the year 2050. Flood stillwater elevations will in the vicinity of the increase Fire Department and Town Hall at approximately the same amount. It should be anticipated that future revisions to the FEMA FIRMs will show an increase in flood risk relative to the FEMA FIRMS effective today.

Old Saybrook Ambulance Facility Flood Profile

The Ambulance Facility is an Essential Facility and is located within the FEMA 100-year recurrence interval (1% annual exceedance probability) AE Flood Zone and may be located within a Coastal AE Zone due to its proximity to the tidal marsh.

Design Basis Flood: Effective FEMA FIRM 500-year Recurrence Interval (0.2% annual exceeedance probability) Flood

Flood Mitigation Goal: Essential facilities (located within VE or Coastal AE Zones) should be designed with a minimum elevation of the bottom of the lowest horizontal structural member at or above the Effective FEMA Base Flood Elevation (BFE) plus 2 feet or the 500-year flood, whichever is higher. Essential facilities not constructed to these criteria should be either: 1) dry floodproofed; or 2) flood protected to above these criteria.

Storm Type: The 500-year coastal flood is expected to be a high intensity hurricane.

FEMA 500-year stillwater elevation: Elevation 15.4 feet

FEMA 500-year Coastal Flood Water Depths: The water depths around the building exterior during the 500-year recurrence interval flood are predicted to be (based on FEMA) about 5 to 7 feet. All of Main Street, in the vicinity of the Fire Station is similarly flooded during this event.

500-year Coastal Flood Waves: The ground elevation (based on available LiDAR) in the immediate area around the Ambulance Facility building is at elevation +/-8 to +/- 10 feet NAVD88. Wind-generated, depth limited waves will occur during the coastal flood event. Waves are predicted to be greater than 3 feet.

500-year Wind: High winds will occur coincident with coastal flooding during the 500-year recurrence interval flood. The predicted 500-year recurrence interval sustained wind is about 154 miles per hour.

Precipitation: Extreme precipitation, including areas of localized intense precipitation, may occur during this coastal flood event.

Non-Design Basis Floods: The Fire Department and Emergency Management Facilities are located within the limits of the 100-year recurrence interval and higher probability coastal floods.

Future Risk Due to Sea Level Rise

Permanent modifications to this facility should consider changes to the future coastal flood hazard due to sea level rise. Sea level rise will increase the flood risk. Based on NOAA 2017 relative sea level rise projections, tidal datum elevations are expected to increase by about 2 feet by the year 2050. Flood stillwater elevations will increase in the vicinity of the ambulance facility at approximately the same amount; however, due to the proximity to the marsh, wave effects will be greater than currently exists. It should be anticipated that future revisions to the FEMA FIRMs will show an increase in flood risk relative to the FEMA FIRMS effective today.

Lifeline Facilities

Lifeline Facilities

Lifeline Facilties include distributive systems and related facilities to provide electric power, oil and natural gas, water and wastewater and communications. The flood vulnerability of Lifeline Facilities should be evaluated relative to the 500-year recurrence interval flood. **Figure 4-25** shows the location of the Lifeline Facilities relative to the effective FEMA special flood hazard zones. Lifeline 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 Town's Lifeline Facilities include:

- Electricity (Eversource)
- Water (Connecticut Water Company)
- Natural Gas (Southern Connecticut Gas)
- Sewer (on-site subsurface disposal; Water Pollution Control Authority)
- Communication (AT&T Connecticut; Fiber Technologies Networks, LLC; Cellular Services)

LIFELINE FACILITIES COASTAL FLOOD RISK PROFILE

	Current	2041	2066	2116
LOCATION				
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	Moderate	High	High

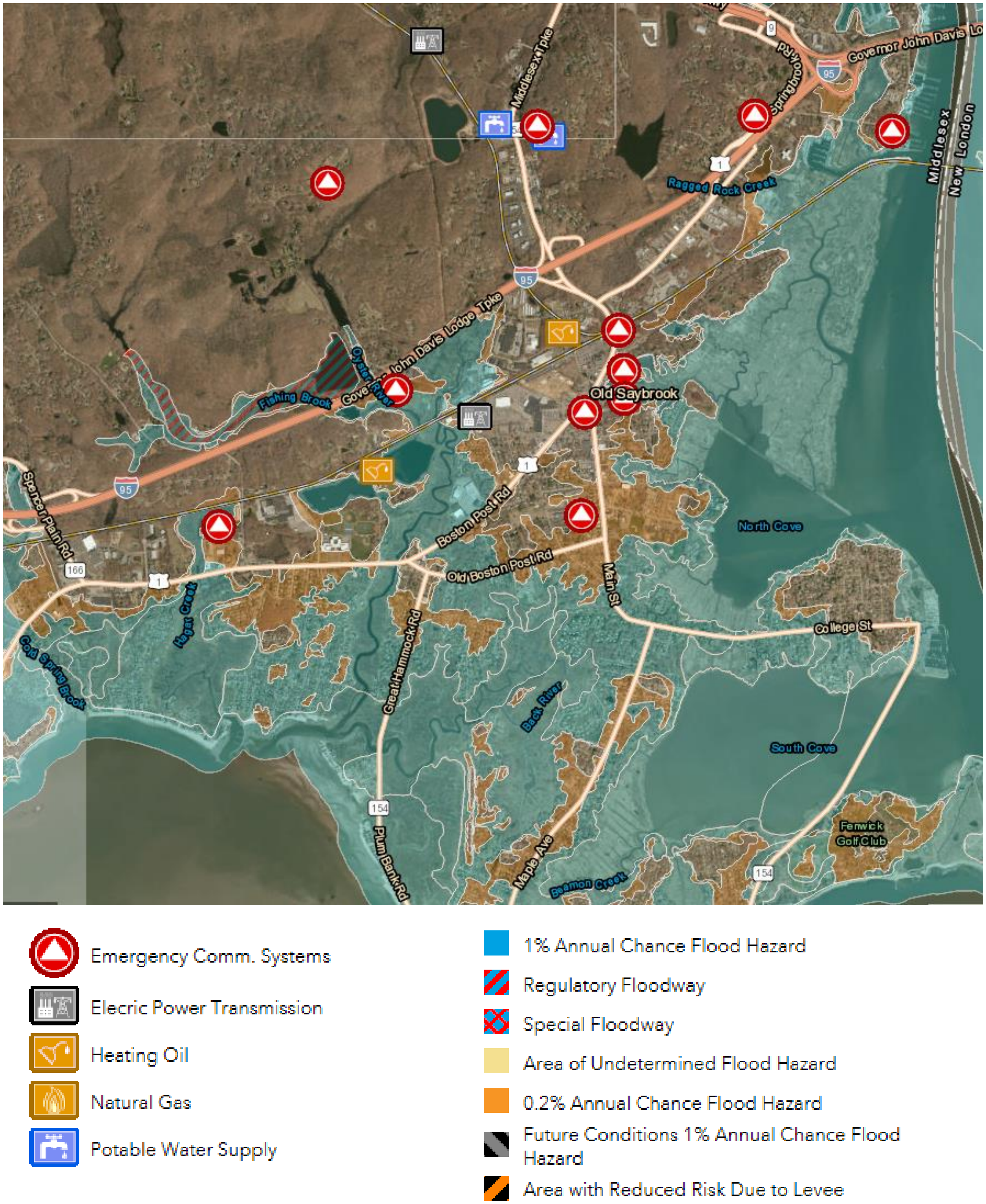
Table 4-12 Lifeline Facilities Risk Profile

Electricity

Electrical service for the Town is provided by Eversource (formerly the Connecticut Power & Light Company) and distributed via overhead transmission lines and two electrical substations located at: 1) Bokum Road; and 2) Elm Street. **Figure 4-26** shows the location of the electrical substations relative to the effective FEMA special flood hazard zones.

No public power generation occurs within the limits of Old Saybrook and power generation facilities are located outside of the Town limits. The coastal flood vulnerability to the electrical service is primarily due to: damage to overhead power lines due to wind-related damage (e.g., tree limbs); damage to poles due to high wind; and potential flooding of electrical substations.

Figure 4-25 Location of Old Saybrook Lifeline Facilities relative to effective FEMA FIRM Flood Hazard Zones Note: Areas shaded in green represents the FEMA AE zone and areas in brown are located within the limits of the 500-year recurrence interval flood.



Eversource has an on-going program of system resilience and hardening to minimize outages, in particular focused on tree maintenance (>90% of outages are due to falling limbs on power lines) and electrical system hardening.

The vulnerability of the Old Saybrook Eversource electrical substations was evaluated relative to the current FEMA 500-year recurrence interval coastal flood. The Bokum Substation, located north of I-95 has a Low Risk to coastal flooding. The Elm Street electrical substation Moderate Risk to coastal flooding due to its location within the effective FEMA FIRM 500-year recurrence interval flood zone.

The ground elevation (based on available LiDAR) in the immediate area around the Eversource Elm Street substation is about Elevation 14 feet NAVD88. The FEMA 500-year recurrence stillwater elevation (see **Attachment 2**) is Elevation 15.4 feet NAVD88. (As noted in **Attachment 2**, the FEMA 500-year recurrence interval stillwater elevation appears to be high relative to other data sources). GZA's flood simulations, which were bounded to the USACE NACCS study, indicate 500-year recurrence interval stillwater flood elevation of about 13.6 feet NAVD88 around the buildings.)

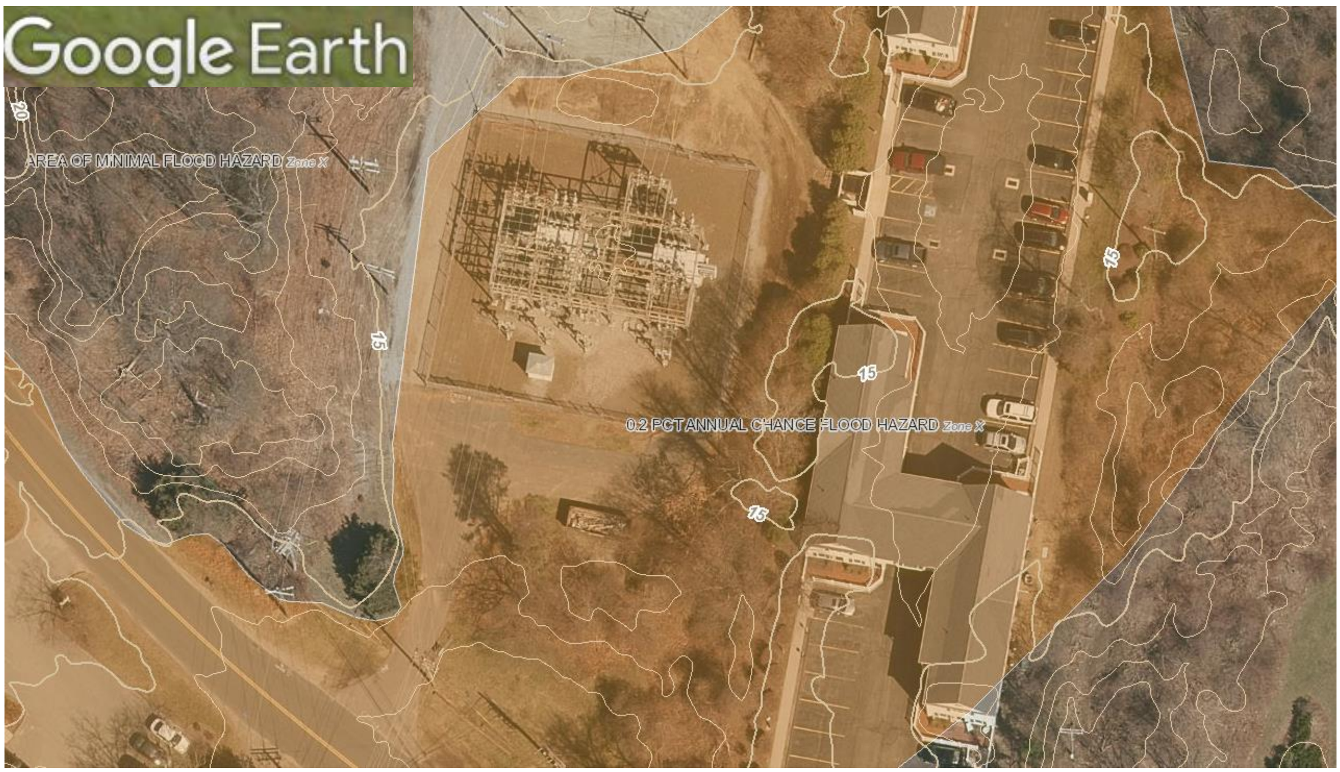


Figure 4-26 Location of Eversource Elm Street Substation relative to effective FEMA FIRM Flood Hazard Zones

Note: Areas shaded in green represents the FEMA AE zone and areas in brown are located within the limits of the 500-year recurrence interval flood.

Figure 4-27 Vicinity of Eversource Elm Street Substation; Ground Surface Elevation +/- 14 feet NAVD88

Water

The Connecticut Water Company supplies drinking water in Old Saybrook via a central public water supply system. The CWC Guilford-Chester Division, a State-regulated public utility, provides service to the portion of the Town located to the south of I-95 and the railroad, but also extends north to include Floral Park, Middlesex Turnpike to the area just south of Route 9, and the Spencer Plain Road area. Houses and buildings in the remainder of town rely on private, on-site wells. The water system consists of the Obed Heights 1.09-million-gallon reserve storage tank, transmission water mains and distribution lines. The drinking water originates at a surface water supply reservoir in Killingworth and is supplemented by water wells. The Town created two Aquifer Protection Zones to protect groundwater supply sources.

The locations of the water tank and Aquifer Protection Zones are outside of the limits of the FEMA special flood hazard zones and areas of predicted future coastal flooding.

Wastewater

Town residents and businesses currently utilize, exclusively, individual on-site septic systems. Many of these systems are vulnerable due to shallow groundwater and the effects of coastal flooding and sea level rise. The Town established a Decentralized Wastewater Management District (WWMD) in August 2009 for the purpose of protecting the public health and the environment through improvements to the treatment of wastewater (per Article II of Chapter 173). Decentralized wastewater management approaches seek to deal with wastewater needs closer to the source of wastewater generation using smaller, dispersed (decentralized) treatment and disposal/recharge methods. Enhancing the existing on-site wastewater systems through the use of a Decentralized Wastewater Management Program (DWMP) proactively upgrades certain on-site systems and increases the extent of management of these systems.

The Town adopted WWMD boundaries that include: 1) approximately 1900 lots located within 15 neighborhood focus areas; and 2) Upgrade Program Standards for improvements. The areas were selected primarily based on physical characteristics such as density of houses, proximity to water bodies and marshes and shallow depth to groundwater. Upgrade Program Standards apply to on-site septic systems in 10 of the 15 focus areas (Ref. https://www.oswpca.org/). As of 2016, the Upgrade Program is in the 2nd Phase with over 500 on-site septic systems installed and over 800 designated "Upgrade Compliant" that include on-site septic systems in 10 of the 15 focus areas.

The Old Saybrook Water Pollution Control Authority (WPCA) recently completed a second study, “Old Saybrook Wastewater Pollution Control Authority [WPCA]) Draft Study” (2016-17) to evaluate the use of a Community System to improve the remaining 800 systems. The WPCA Draft Study included a cost and feasibility evaluation of following three options:

1. On-site Repairs
2. Community System(s) with dispersal of wastewater into the ground
3. Community System(s) with dispersal of wastewater into the Connecticut River

During the development of the WPCA Draft Study, GZA discussed and provided the WPCA’s engineering consultant, Wright-Pierce, with a memorandum on July 3, 2017 presenting relevant coastal flooding data in relation to the WWMD. **Attachment 4, Appendix A** includes this memorandum that presents coastal flood information relevant to the Old Saybrook WWMD, including tides, sea level rise and storm surge and waves.

High Potential Loss Facilities

High Potential Loss

High potential loss are those facilities, such as dams, whose failure can result in catastrophic loss of human life. The Connecticut Department of Energy and Environmental Protection (DEEP) requires the registration of all dams over six feet in height. As of 2017, there were eleven such dams in Old Saybrook:

Class C High Hazard Dam:	Obed Heights Reservoir Dam
Class B Significant Hazard Dams:	Chalkers Millpond Dam; Turnpike Pond Dam
Class BB Moderate Hazard Dam:	None
Class A Low Hazard Dams:	Old Rock Pond Dam, Ingham Hill Pond Dam, Crystal Lake Dam, Ayers Pond Dam, Otter Pond Dam, and Deitch Pond Dam
Class AA Negligible Hazard Dams:	None
Unclassified:	Pequot Swamp Pond Dam, Ingham Pond Dam

Dam classifications include:

- Class C High hazard potential dams: Failure could cause any of the following: probable loss of life; major damage to habitable structures, residences, hospitals, convalescent homes, schools, etc.; damage to main highways; or great economic loss.
- Class B Significant hazard potential dams: Failure could cause: possible loss of life; minor damage to habitable structures, residences, hospitals, convalescent homes, schools, etc.; damage to or interruption of the use of service of utilities; damage to primary roadways and railroads; or significant economic loss.
- Class BB Moderate hazard potential dams: failure could result in: damage to normally unoccupied storage structures; damage to paved local roadways; or moderate economic loss.
- Class A Low hazard potential dams: Failure could cause: damage to agricultural land; damage to unimproved roadways or minimal economic loss.
- Class AA Negligible hazard potential dams: failure would result in: no measurable damage to roadways; no measurable damage to land and structures; and negligible economic loss.

High potential loss 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 is 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; 3) temporary changes to the hydrologic and geohydrologic conditions that could induce piping or stability failures.

A preliminary determination of the location of the dam locations relative to the limits of coastal flood inundation was performed. **Figure 4-28** shows the location of the eleven dams relative to the effective FEMA FIRM. 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.

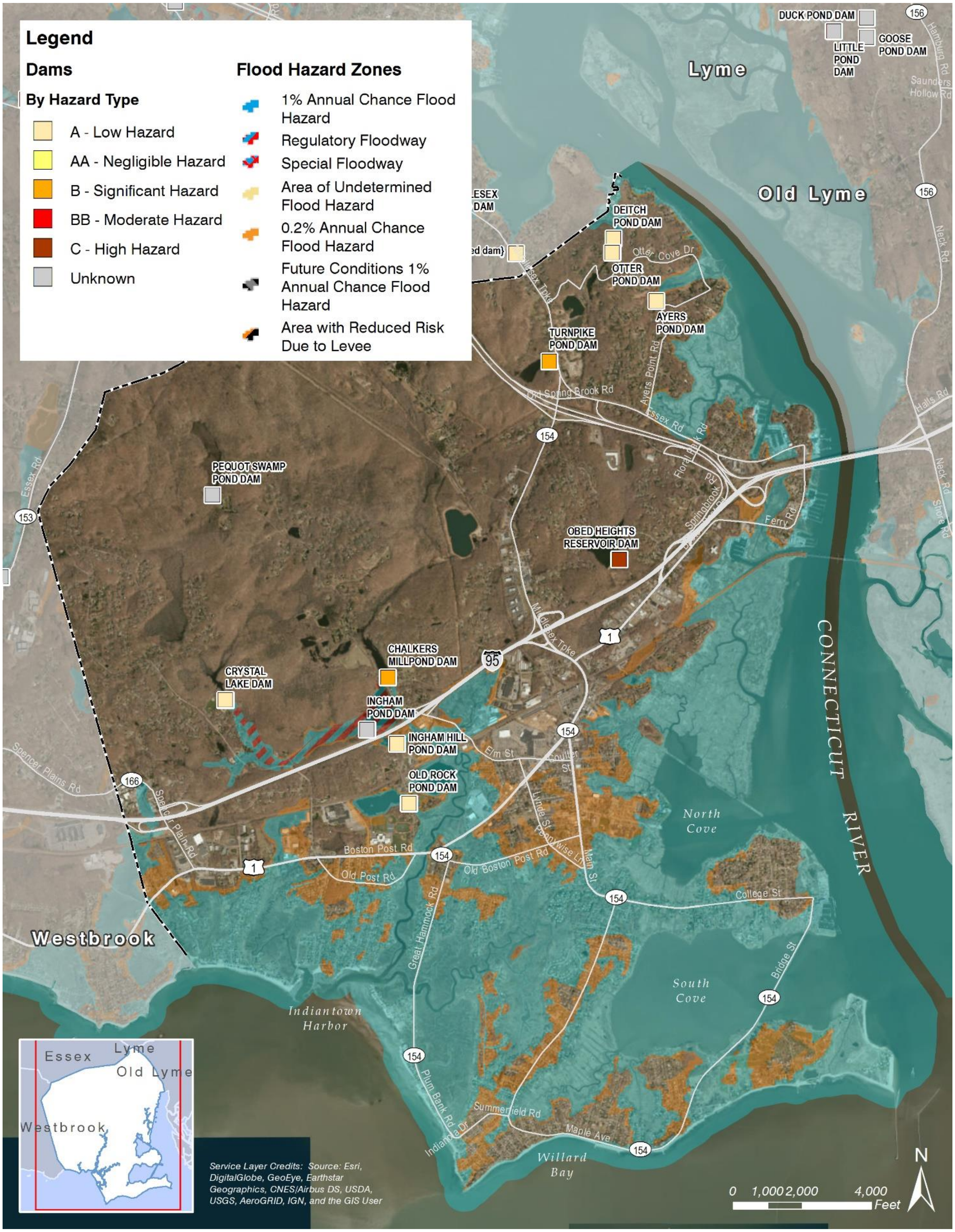


Figure 4-28 Location of Old Saybrook Dams relative to FEMA Special Flood Hazard Zones

Note: Areas shaded in green represents the FEMA AE zone and areas in brown are located within the limits of the 500-year recurrence interval flood.

Sheltering and Evacuation

Sheltering and Evacuation

Storm evacuation and sheltering capacity are key considerations relative to resilience to coastal flooding.

A detailed analysis of New England hurricane evacuation needs and capabilities is presented in "New England Hurricane Evacuation Study, Technical Data Report", June 2016, prepared by the USACE and FEMA. The study was developed to "… evaluate the major factors that must be considered in hurricane preparedness and to provide emergency management officials in Connecticut, Rhode Island and Massachusetts timely, state-of-the-art information needed for sound hurricane evacuation decision-making. State, county and town agencies can use the technical data presented in this report to supplement and/or revise their hurricane evacuation plans and operational procedures, enabling them to more effectively respond to future hurricane threats." This study provides estimates of Old Saybrook evacuation requirements related to coastal flood events.

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 to the USACE/FEMA study referenced above, GZA completed a 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 presents 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

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

Behavioral analyses indicate that: 1) during a Category 2 hurricane, about 65% to 70% of the people will evacuate; 2) during a Category 3 hurricane about 71% to 76% of the people will evacuate; and 3) during a Category 4 hurricane, about 82% to 85% of the people will evacuate. The evacuation response time (near full evacuation) ranges from about 3 hours (rapid response, a time when most families are together and can be motivated to respond quickly) to about 6 hours (medium response, weekend days and any evening hours when most families have been rejoined at their residences and can be mobilized in relatively short order) to about 9 hours (long response, nighttime hours, during the middle of a normal weekday when most families are scattered). The mean number of vehicles available to evacuate are based on about 1.8 people per vehicle.

A portion 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. This assumes that emergency response services can be provided by the Town during and after the storm. Larger storms will significantly impact "sheltering at home" capabilities due to: 1) flooding of the residence; 2) wind-damage to the residence; 3) the increased likelihood of secondary effects including fire, loss of power, loss of water and loss of sanitary systems); and 4) the diminished capacity of the Town to provide emergency response services.

Historic Properties

Historic Properties

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 are included in this study.

<u>North Cove Historic District:</u>

The North Cove Historic District is 37-acres in extent and is located on Saybrook Point. The District was listed on the National Register of Historic Places in 1994. The District extends to the north and east along North Cove Road from just north of Church Street on the west to past Cromwell Place to the east. The District also includes a small area along Cromwell Place that extends south from the intersection with North Cove Road for approximately 330 feet. The District is of historical significance because it was the site of the first settlement of the Saybrook Colony (1645) and is an example of a small maritime development between 1645 and 1927. Most housing stock was built between 1700 and 1855. The District includes the Black Horse Tavern and the William Tully House, both separately listed on the National Register. **Figure 4-29** shows the limits of the District relative to the FEMA special flood hazard zones.

The northern shoreline of the District is vulnerable to high waves (characterized as a FEMA VE zone); one historic building is located within the FEMA VE zone (175 North Cove Road). The District starts to be flooded during the 20-year recurrence interval flood.

Figure 4-29 The North Cove Historic District relative to FEMA Special Flood Hazard Zones
Note: Areas shaded in green represents the FEMA AE zone and areas in brown are located within the limits of the 500-year recurrence interval flood.

<u>South Green Historic District:</u>

The South Green Historic District is 20-acres historic district located around the intersection of Main Street and Old Boston Post Road. The District was listed on the National Register of Historic Places in 1976. The district encompasses the historic town green of Old Saybrook, which was founded in the 1630s. Most of the buildings located around the green were built between 1760 and 1900. Among the buildings in the district are the c. 1767 Gen. William Hart House and the c. 1785 Humphrey Pratt Tavern, which are individually listed on the National Register. **Figure 4-30** shows the limits of the District relative to the

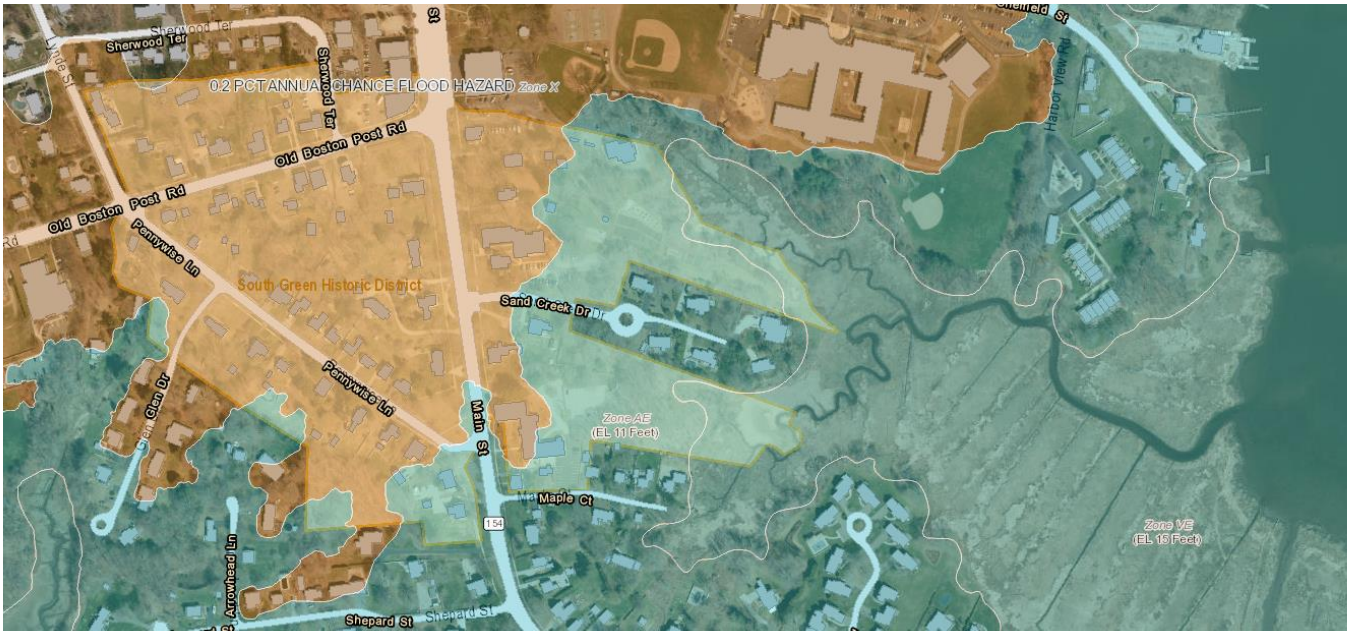


Figure 4-30 The South Green Historic District relative to FEMA Special Flood Hazard Zones

Note: Areas shaded in green represents the FEMA AE zone and areas in brown are located within the limits of the 500-year recurrence interval flood.

FEMA special flood hazard zones. Several properties are located within the FEMA AE zone. Sea level rise will extend the limits of flooding within the District.

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 below, 64 of Old Saybrook's historic properties are located within FEMA special flood hazard zones. **Figure 4-31** show the locations of the historic properties relative to the FEMA special flood hazard zones.

Table 4-13 Historic Properties Risk Profile

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

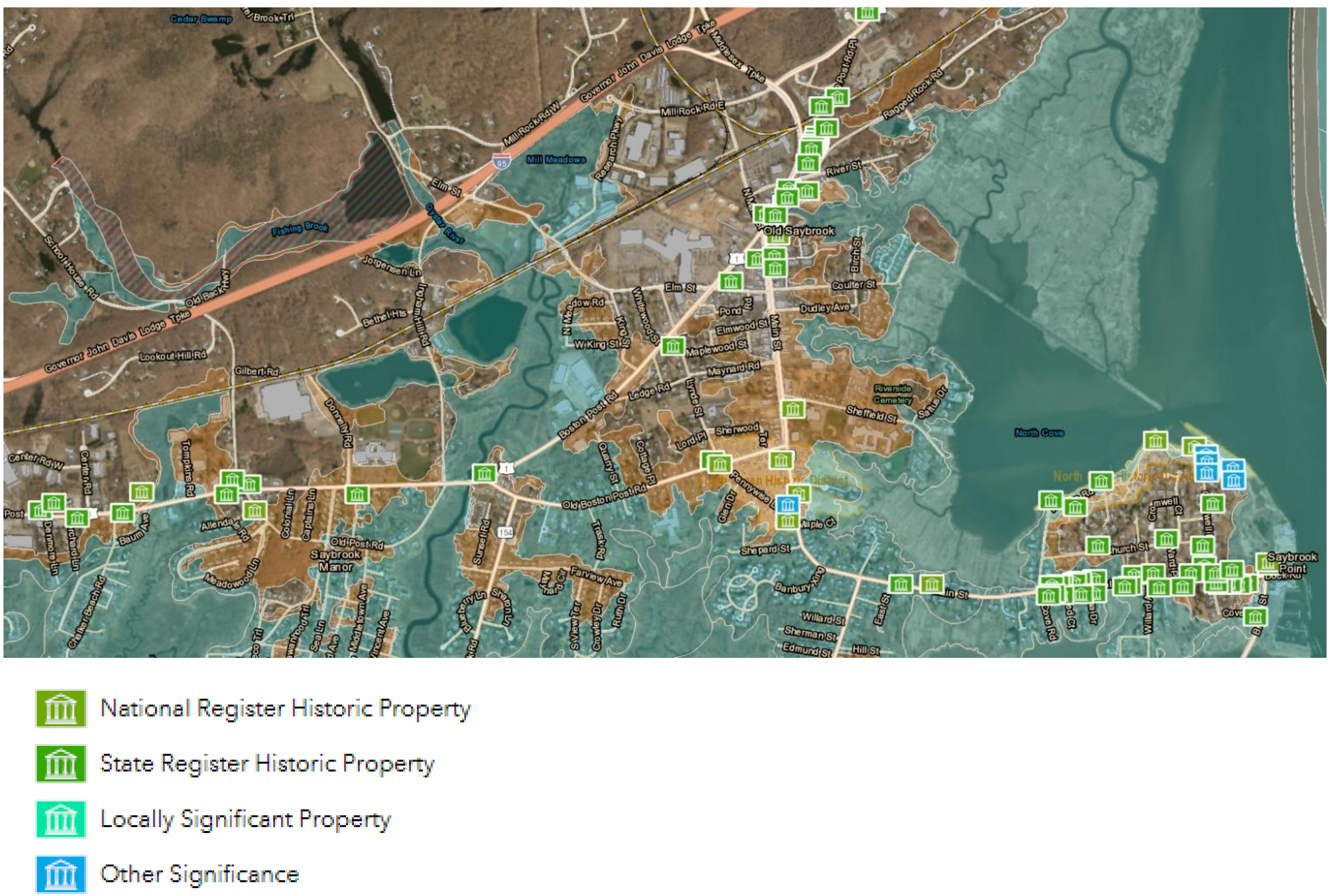


Figure 4-31 Old Saybrook Historic Properties relative to FEMA Special Flood Hazard Zones

Notes: Historic properties at Cornfield Point and within Fenwick are not indicated. FEMA AE zone limits shown in green and FEMA 500-year recurrence interval flood limits shown in brown.

Hazardous Materials Facilities

Hazardous Materials Facilities

There are 27 HazMat Category IV Facilities identified by the Environmental Protection Agency (EPA) within Old Saybrook, including the following:

- Old Saybrook Transfer Station
- Saybrook Veterinary Hospital
- M&J Bus Company
- Guardian Manufacturing
- Lighthouse Printing
- Fortune Plastics
- Paragon Products
- CT Valley Industries
- SSHC Inc.
- Vijon Studio
- Design X
- Stencil Ease
- Essex Cabinets
- Hanford Cabinets
- Saybrook Strip Shop
- Ryther Purdy
- Kiwi Engineering
- Opcon
- Documotion
- SNET
- Target Custom Manufacturing
- Tilcon
- C & M Technology
- Asterick, Inc.
- Fluopolymer
- Infiltrator

Animal shelters are included because these facilities are often repositories for hazardous waste.

Figure 4-32 shows the locations of the facilities relative to FEMA special flood hazard zones. Dependent upon the quantity of highly toxic substances, these facilities are classified as either Flood Design Class 3 or Class 4 per ASCE/SEI 24-14. Flood Design Class 3 structures are evaluated relative to the 100-year recurrence interval flood (i.e., FEMA Base Flood) and 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.

Of the 27 waste facilities, 9 are located within FEMA special flood hazard zones. These include:

- Opcon at 167 Elm Street (Research Parkway)
- Paragon Products at 175 Elm Street (Research Parkway)
- Ryther Purdy at 174 Elm Street (Research Parkway)
- M&J Bus Company at 130 Ingham Hill Road
- Essex Cabinets at 91 School House Road
- Target Custom Manufacturing at 164 Old Boston Post Road
- Design X at 83 Spencer Plain Road
- Vijon Studios at 97 Spencer Plain Road
- SSHC Inc. at 4 Custom Drive

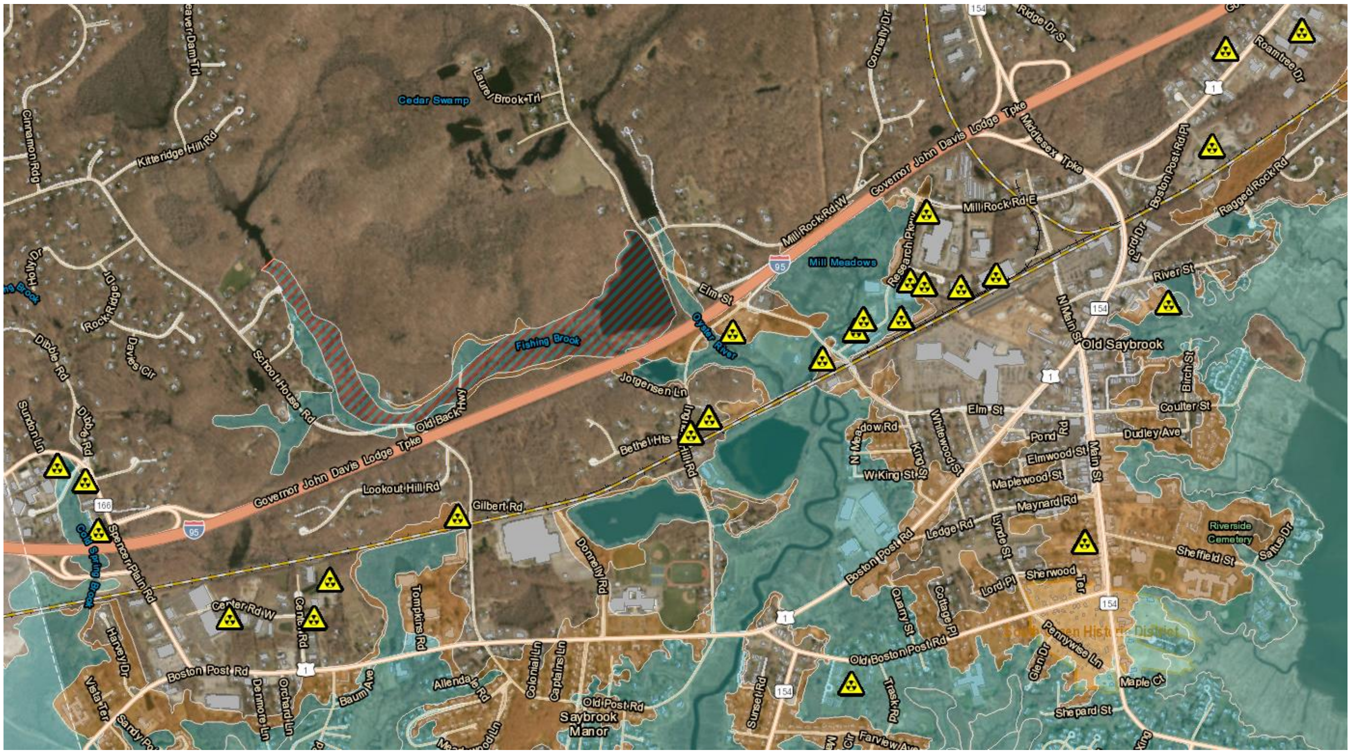


Figure 4-32 Old Saybrook Hazardous Materials Facilities relative to FEMA Special Flood Hazard Zones
Note: FEMA AE zone limits shown in green and FEMA 500-year recurrence interval flood limits shown in brown.

Support, High Occupancy and Vulnerable Populations Facilities

Support, High Occupancy, and Vulnerable Populations Facilities

Support, High Occupancy and Vulnerable Population Facilities (SHOVPFs) are facilities that represent a substantial risk to human life in the event of flood hazards. In Old Saybrook, these areas include:

- Town Administration Buildings
- Grocery & Supply Stores
- Theaters
- Elementary and Secondary Schools, & Buildings with College or Adult Education Classrooms
- Religious Institutions
- Museums and Galleries
- Community Centers & Other Recreational Facilities
- Athletic Facilities
- Care Facilities (including Nursing Homes)
- Pre-School and Child Care Facilities
- Hotels and Inns

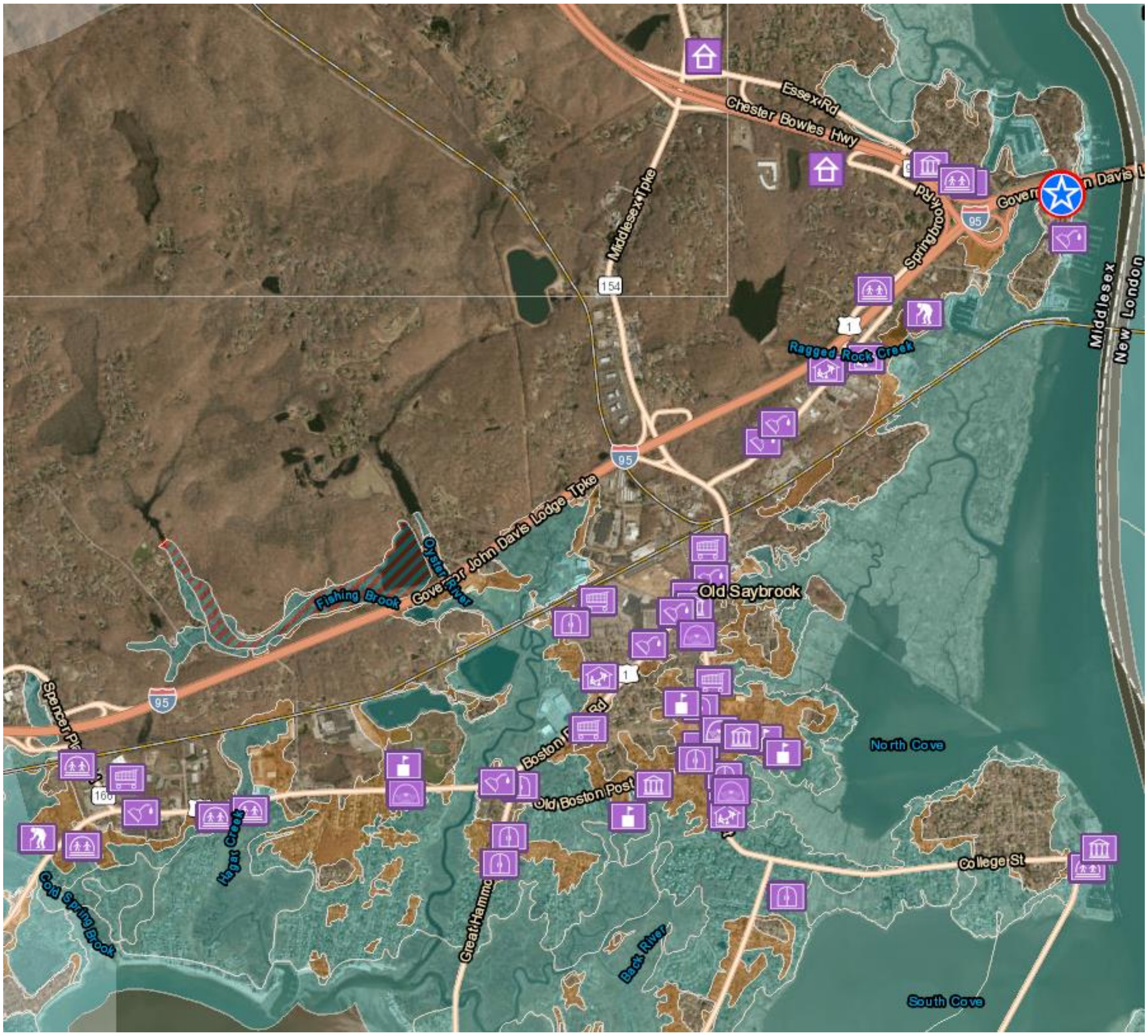
These facilities are classified as Flood Design Class 3 per ASCE/SEI 24-14 and are evaluated for risk relative to the 100-year recurrence interval flood (i.e., FEMA Base Flood).

Figure 4-33 shows the locations of the SHOVPFs relative to FEMA special flood hazard zones. The following are located within the FEMA AE special flood hazard zone (none of these are located within a Coastal AE zone):

- Hotels: Pier Blue Guesthouse
- Schools: Kathleen E. Goodwin Elementary School; Community Nursery School
- Museum and galleries: The general William Hart House and Hart House Gardens,
- Religious Institutions: First Church of Christ, Full Gospel Tabernacle Church, St. Paul Lutheran Church, Valley Shore Assembly of God
- Grocery & Supply: Town Beach Store

The following are located within a FEMA VE special flood hazard zone:

- Town Administration: Vicki G. Duffy Pavilion
- Hotels: Saybrook Point Inn and Spa



Community Centers and other Rec. Facilities
Fueling (Gas) Stations
Grocery and Supply Stores
Hotels and Inns
Military
Museums and Galleries
Preschool and child care facilities
Rehabilitation Nursing Home
Religious Institutions
Schools
Theaters
Town Administration Buildings

Figure 4-33 Support, High Occupancy and Vulnerable Population Facilities relative to FEMA Special Flood Hazard Zones

Note: FEMA AE zone limits shown in green and FEMA 500-year recurrence interval flood limits shown in brown.

Roads, Bridges and Culverts

Attachment 4: Vulnerability and Risk

Roads, Bridges and Culverts

TRANSPORTATION INFRASTRUCTURE: ROADWAYS, BRIDGES AND CULVERTS

The Town is served by major highways (Interstate 95 and Route 9), major arterials such as U.S. Route 1, CT Route 154 and Route 166, and a network of smaller roads that provide access throughout the Town and serve as collectors for the major arterials and highways. The Town is also served by several bus routes of the 9 Town Transit District, as well as a train station which offers a stop on both Amtrak's Northeast Regional service and the Shore Line East Railroad. The Town's piers, dock and marinas, while not formally part of the Town's transportation system, are available to provide water access and egress.

An overview of the roadways, bridges and culverts, by jurisdiction, is presented below and is followed by a detailed list of each road and bridge included for analysis for this evaluation.

Roads

The State roads make up approximately 47 miles of total roadway within Old Saybrook. The four (4) key State roads include:

- Interstate I-95 (Connecticut Turnpike)
- Route 9 (Chester Bowles Highway)
- Route 1 (Boston Post Road)
- Route 154 (Main Street and College Street; Bridge Street and Maple Avenue; Indianola Drive; Plum Bank Road and Great Hammock Road; South Cove Causeway)
- Route 166 (Spencer Plain Road)

Municipal roads make up approximately 88 miles of total roadway within Old Saybrook. "Key" roads (including both municipal and State roads) are the main arteries serving Old Saybrook and also provide Town ingress and egress (to State highways). These roads are also essential for providing emergency response services and for evacuation. In addition to the State roads, key municipal roads include the following:

- Essex Road
- Ferry Road
- Springbrook Road
- Elm Street
- Lynde Street
- Pennywise Lane
- Sheffield Street
- Old Boston Post Road
- Chalker Beach Road
- Baum Avenue
- Sea Lane

Bridges

There are 22 bridges in Old Saybrook, including bridges where I-95 (Connecticut Turnpike) overpasses Town and State roads, Amtrak rail bridges overpassing Town and State roads, culverts supporting roadways at rivers, and the South Cove Causeway.

Six (6) I-95 (Connecticut Turnpike) bridges located within the Town limits:

- I-95 Bridge over School House Road
- I-95 Bridge over Elm Street
- I-95 Bridge over Middlesex Turnpike
- I-95 Bridge over Springbrook Road
- I-95 Bridge over Essex Road
- I-95 Bridge over Route 9

Three (3) Amtrak Rail bridges:

- Amtrak Rail Bridge over the Connecticut River
- Amtrak Bridge over Elm Street
- Amtrak Bridge over the Oyster River

Five (5) State bridges, including three bridge structures that are part of the South Cove Causeway:

- Raymond E. Baldwin Bridge over the Connecticut River
- Route 1 Bridge over the Oyster River
- Causeway Middle Bridge over South Cove (Route 154)
- Causeway North Bridge over South Cove (Route 154)
- Causeway South Bridge over South Cove (Route 154)

Eight (8) Town bridges:

- Great Hammock Road Bridge over Back River
- Ingham Hill Road Bridge over Amtrak
- Nehantic Trail Bridge over Hager Creek
- Plum Bank Road Bridge over Plum Bank Creek
- School House Road Bridge over Amtrak
- Sequassen Avenue Bridge over Crab Creek (in Borough of Fenwick)
- Spencer Plain Rd Bridge over I-95
- Spencer Plain Road Bridge over Amtrak

Culverts

There are 111 culverts within Old Saybrook, most of which are used to support road waterway crossings.

Figure 4-34 presents the locations of the key roadways and the Amtrak rail line, including bridges, roadway culverts, the Old Saybrook Train Station, bus station and the ferry terminal. Primary, key roads are loosely identified as the State roads providing ingress and egress to the Town as well as the major neighborhood arteries that access these roads. **Figure 4-35** presents the piers, docks and marinas.

TRANSPORTATION INFRASTRUCTURE: VULNERABILITY EVALUATION

A discussion of the transportation infrastructure component and system vulnerability is presented below.

Roads, Bridges and Culverts

The roads, bridges and culverts, collectively, make up the Town's roadway system. Flooding of some or all of these components will affect the utility of the roadway system and (at least temporarily) make these roadways inaccessible to vehicles. Flooding may also result in physical damage of the roadway system, repair and/or replacement cost and longer-term disruption of roadway availability.

GZA analyzed coastal flooding of the Towns roadway system in order to estimate 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. The results are presented in **Figures 4-36 through 4-41**. The results indicate the probability, location and extent of roadway being impacted under the current coastal flood risk associated with each flood recurrence interval.

Figure 4-34: Old Saybrook Transportation System

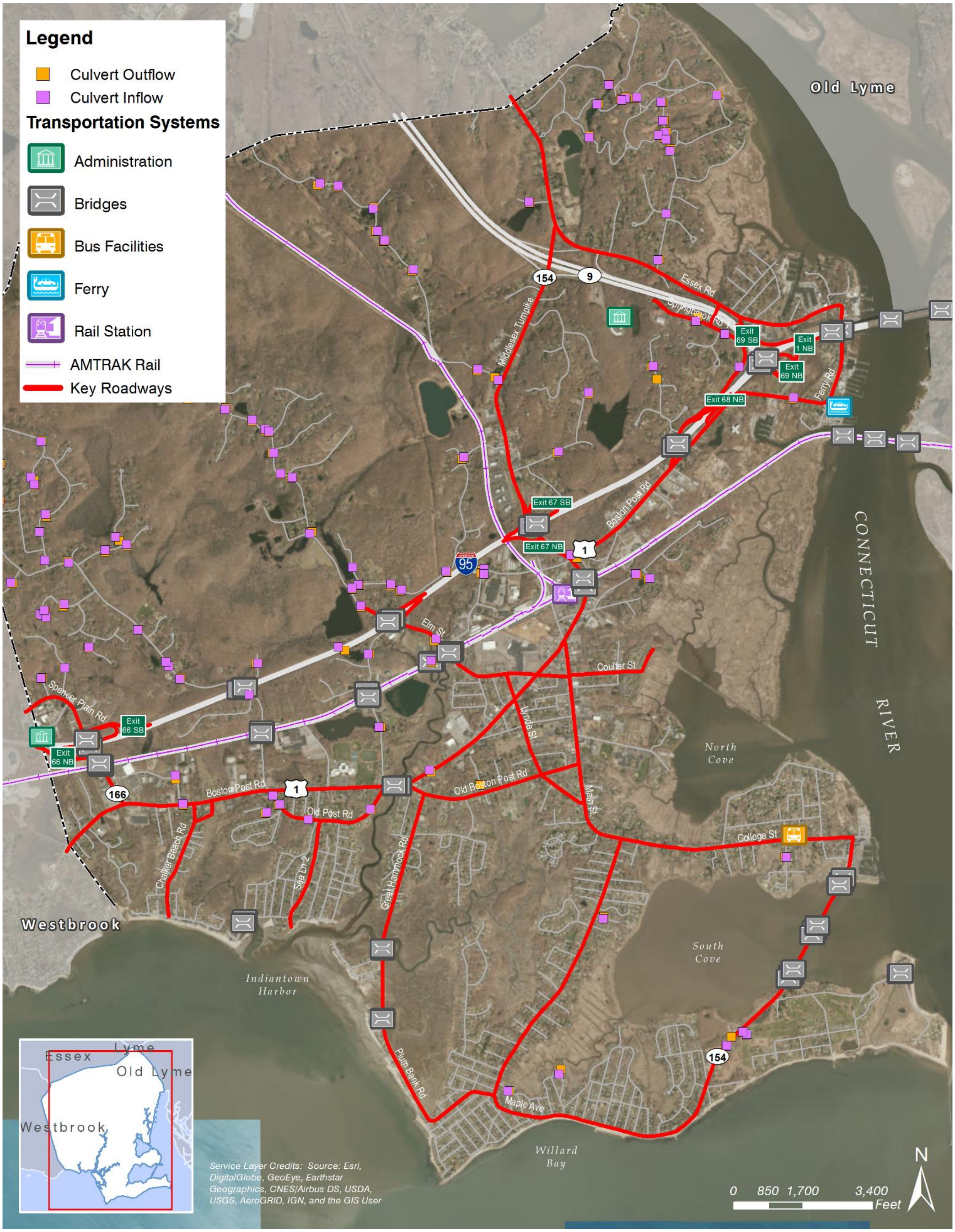


Figure 4-35: Piers, Docks and Marinas

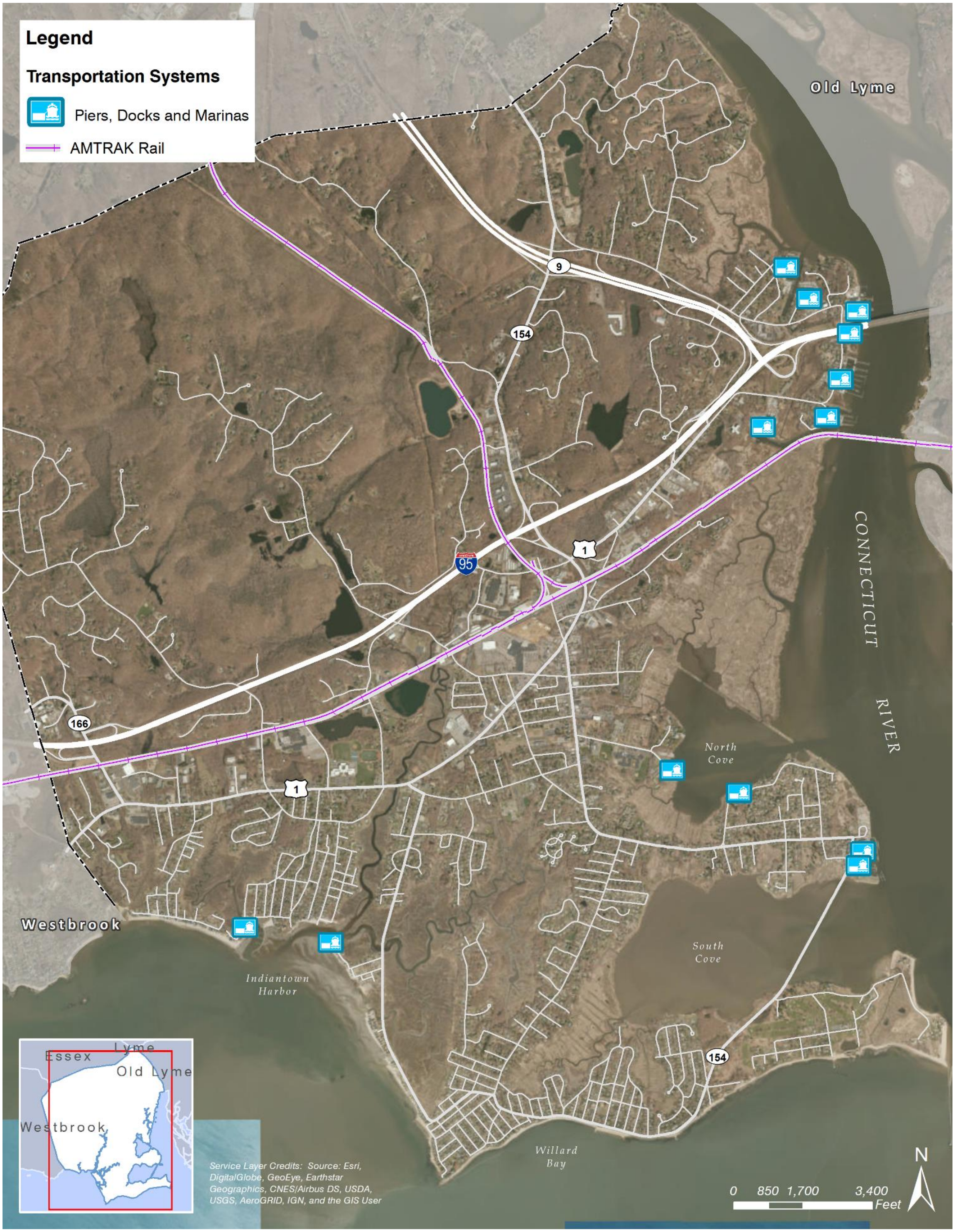


Figure 4-36: Current 2-year Recurrence Interval Flood Risk Roadway Inundation

Figure 4-37: Current 10-year Recurrence Interval Flood Risk Roadway Inundation

Figure 4-38: Current 20-year Recurrence Interval Flood Risk Roadway Inundation

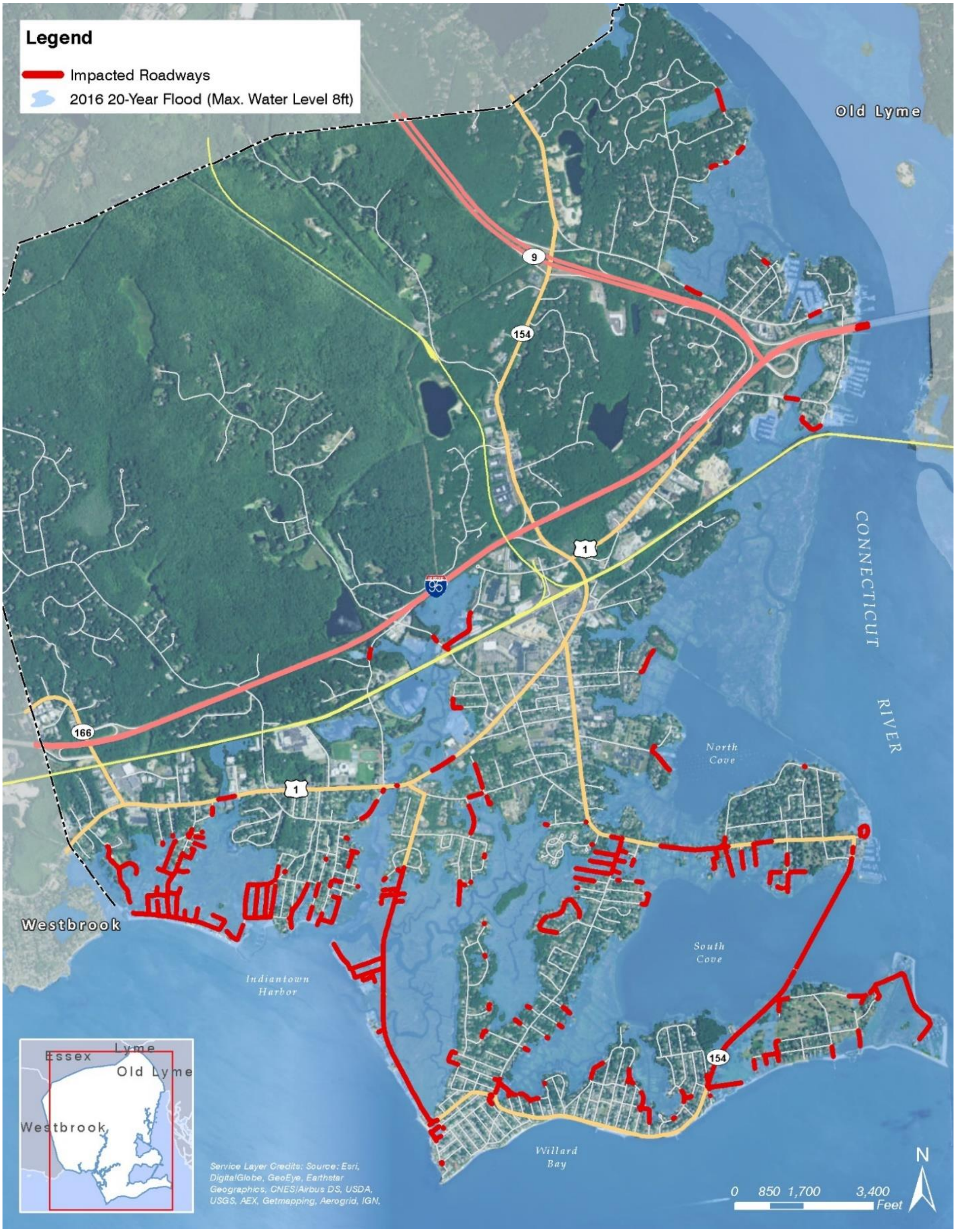


Figure 4-39: Current 50-year Recurrence Interval Flood Risk Roadway Inundation

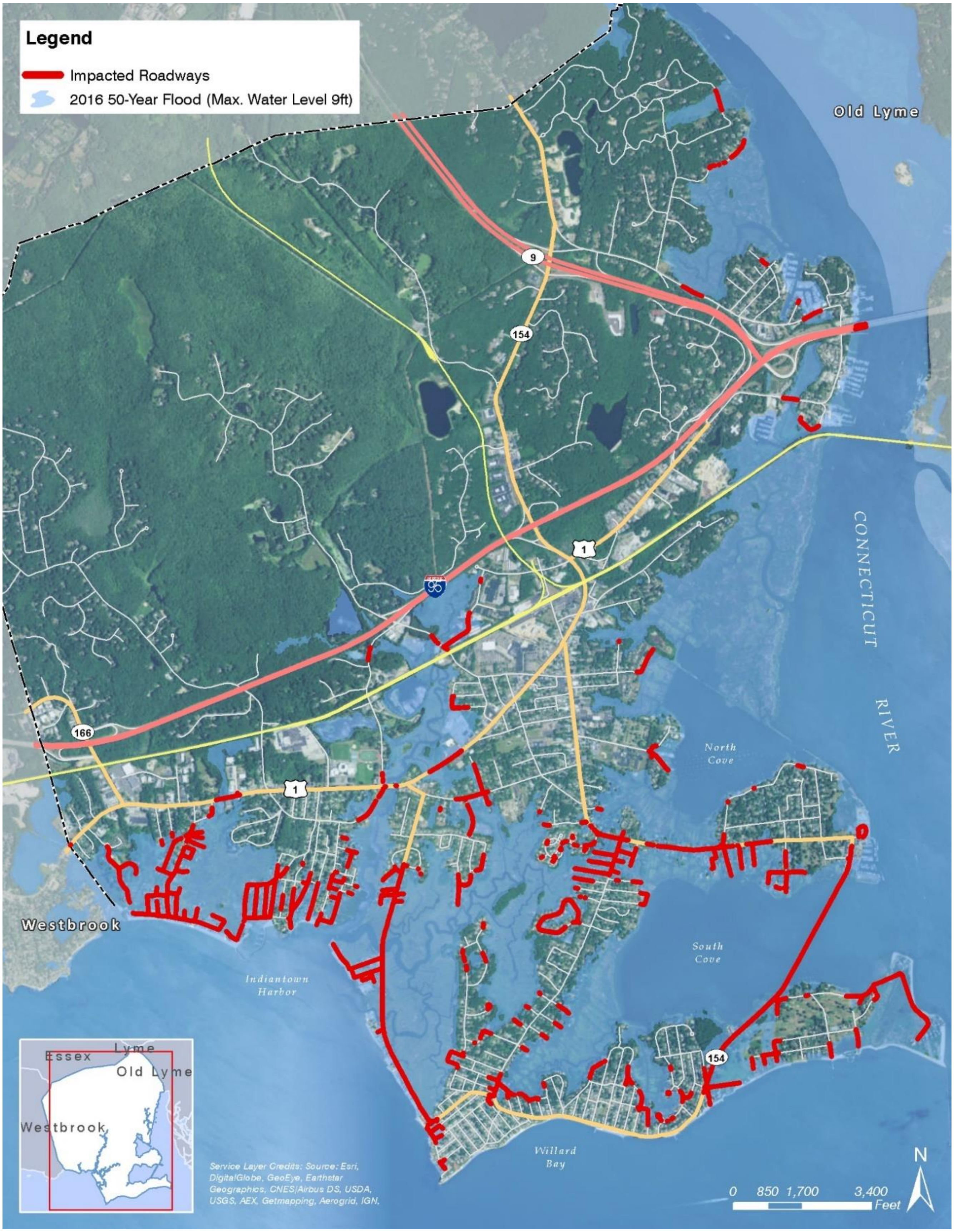


Figure 4-40: Current 100-year Recurrence Interval Flood Risk Roadway Inundation

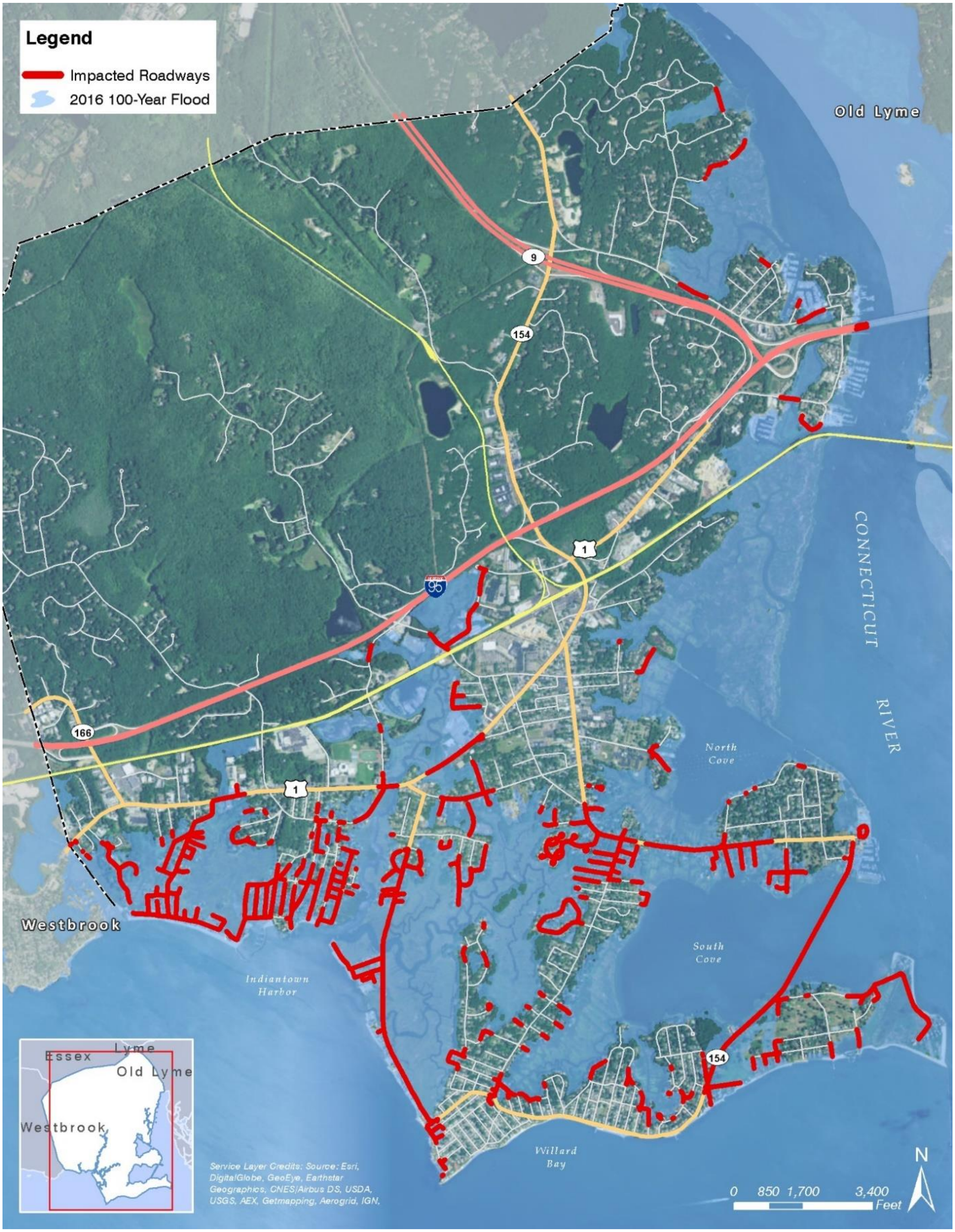


Figure 4-41: Current 500-year Recurrence Interval Flood Risk Roadway Inundation

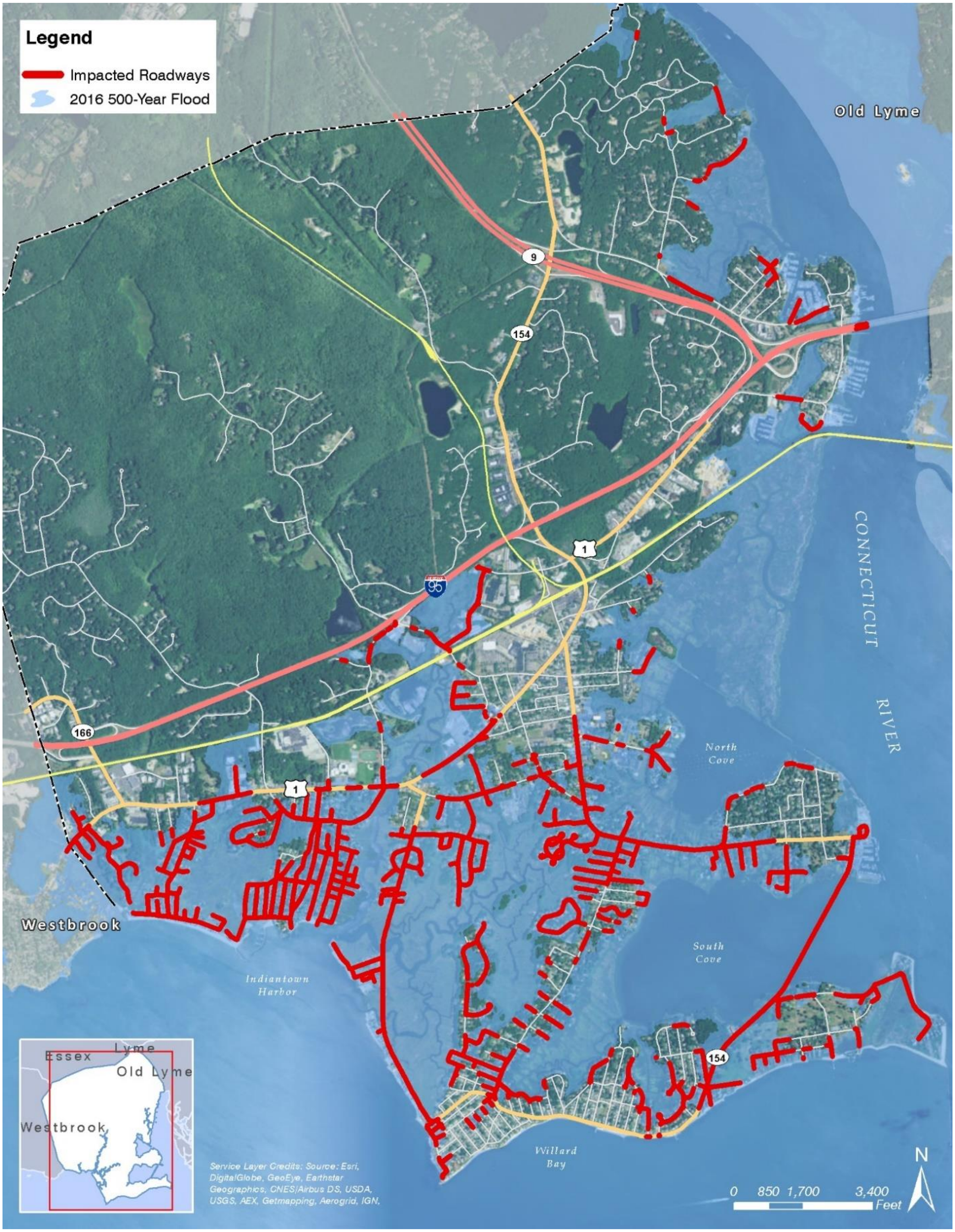


Table 4-14 and **Figure 4-42** present the percentage (and miles) of roadways flooded by coastal flood events in terms of recurrence interval. As presented on **Table 4-14** and **Figure 4-42**, about 24 miles and 36 miles of roadway are vulnerable under the current coastal flood risk scenarios of the 100-yr and 500-yr return period 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 also be considered due to their high frequency and "chronic flood inundation" potential.

Figure 4-42: Probability of Roadway Flood Inundation (in Miles) Due to Coastal Flooding Under the Current Flood Risk

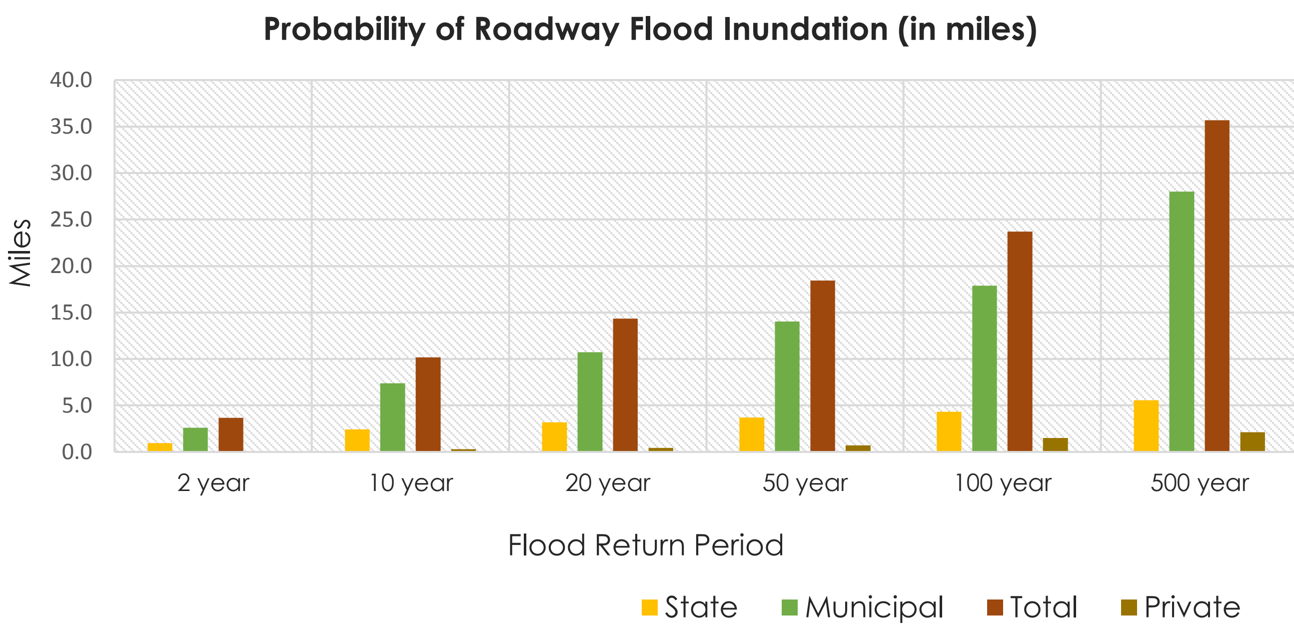


Table 4–14: Probability of Roadway Flood Inundation (in percentage) Due to Coastal Flooding under the Current Flood Risk

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

Chronic Roadway Flood Inundation and Nuisance Roadway Flooding

The term "chronic flood inundation" applies a specific quantitative flood criterion - specifically an average of 26 times per year. Chronic flood inundation has significant implications relative to roadway use limitations and associated negative impacts to businesses and residents. **Figure 4-43** (the current 2-year recurrence interval flood risk) provides a reasonable representation of roadway sections that have both a high probability of being flooded today (in any year, about a 50% chance) <u>and</u> the potential to be chronically flooded by about the year 2050. This represents about 4 miles of roadway.

According to the 2014 Natural Hazard Mitigation Plan Update, a number of roads (listed below) are subject to "nuisance" flooding. Nuisance flooding generally refers to frequent, shallow coastal flooding due to extreme high tides; however, a few of the roads listed below experience flooding due to heavy precipitation and ponding of stormwater run-off, not coastal flooding.

- portions of Elm Street
- 37 College Street near North Cove Road
- Banbury Crossing
- South Cove Causeway
- Plum Bank Road and Salt Meadow Road near Cornfield Park
- Sandy Point Road
- Shetucket Trail
- Fourth Avenue
- Sunset Avenue
- Old Post Road (eastern end)
- Owaneco Trail
- Obed Trail
- Nehantic Trail
- Mohican Trail
- Red Bird Trail; and
- Maple Ave near its intersection at Main and College Streets.

Vulnerable Key Roadways

Figures 4-44 through 4-48 illustrate flood inundation of the key roadways and transportation features during the current 2-year; 10-year; 20-year; 50-year; 100-year; and 500-year recurrence interval floods. **Figure 4-49** indicates the predicted (approximate) flood depths associated with the current 100-year recurrence interval. **Figure 3-52** indicates 100-year recurrence interval wave heights.

Bridges

Eight (8) bridges have bridge decks that will be inundated and exposed to wave action during the current 100-year return period flood (see **Table 4-15**). Three (3) of the bridges are along the South Cove Causeway. Amtrak and I-95 bridge decks are not flooded during the current 100-year recurrence interval flood.

Table 4-15: Summary of Bridges Inundated during Current 100-year Recurrence Interval Coastal Flood

Overtopped Bridges	Approximate Bridge Deck Elevation (feet, NAVD88)[1]	Estimated 2016 100-year return period stillwater elevation (feet, NAVD88)	Estimated 2016 100-year return period wave crest elevation (feet, NAVD88)[2]
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 creek	6	10	13 (VE)

Notes:

1. Bridge deck elevations were estimated based on available LiDAR data and are approximate.

2. The greater of either the GZA simulated wave crest elevation of the effective FEMA Base Flood Elevation (BFE) are indicated in this column. Where the FEMA FIRM was used, the FEMA special flood hazard zone is indicated.

Based on the flood elevations relative to bridge deck elevation, a preliminary evaluation of bridge damage potential during the 2016 100-year return period 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

Based on the flood elevations relative to bridge deck elevation, a preliminary evaluation of bridge damage potential during the 2016 100-year return period 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

Amtrak Railway and Shoreline East Rail Station

The Amtrak Rail lines and Shoreline East Rail Station are located outside current FEMA special flood hazard zones.

Culverts

GZA's evaluation identified roadway culverts that are located within roadway sections that are inundated during the 100-yr return period 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 including the effect of additional surface run-off.

Table 4-16: Summary of Roadway Culverts Inundated during 100-year Return Period Coastal Flood

100-year Return Period Flood	Number of Culverts
2016	18
2041	18
2066	19
2116	22

Figure 4-43: Current 2-year Return Period Flood Risk Key Road Inundation

Figure 4-44: Current 10-year Return Period Key Road Flood Inundation

Figure 4-45: Current 20-year Return Period Key Road Flood Inundation

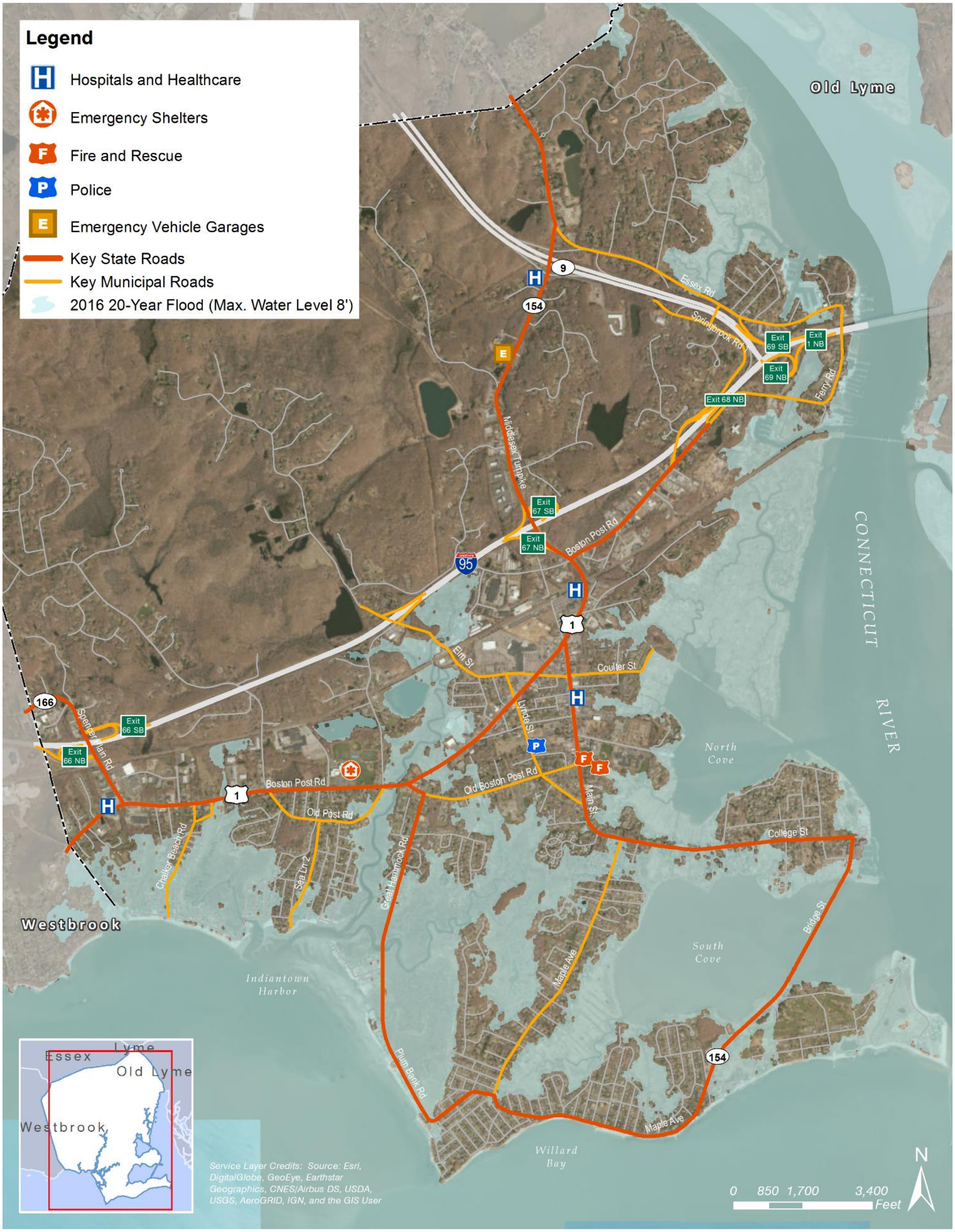


Figure 4-46: Current 50-year Return Period Key Road Flood Inundation

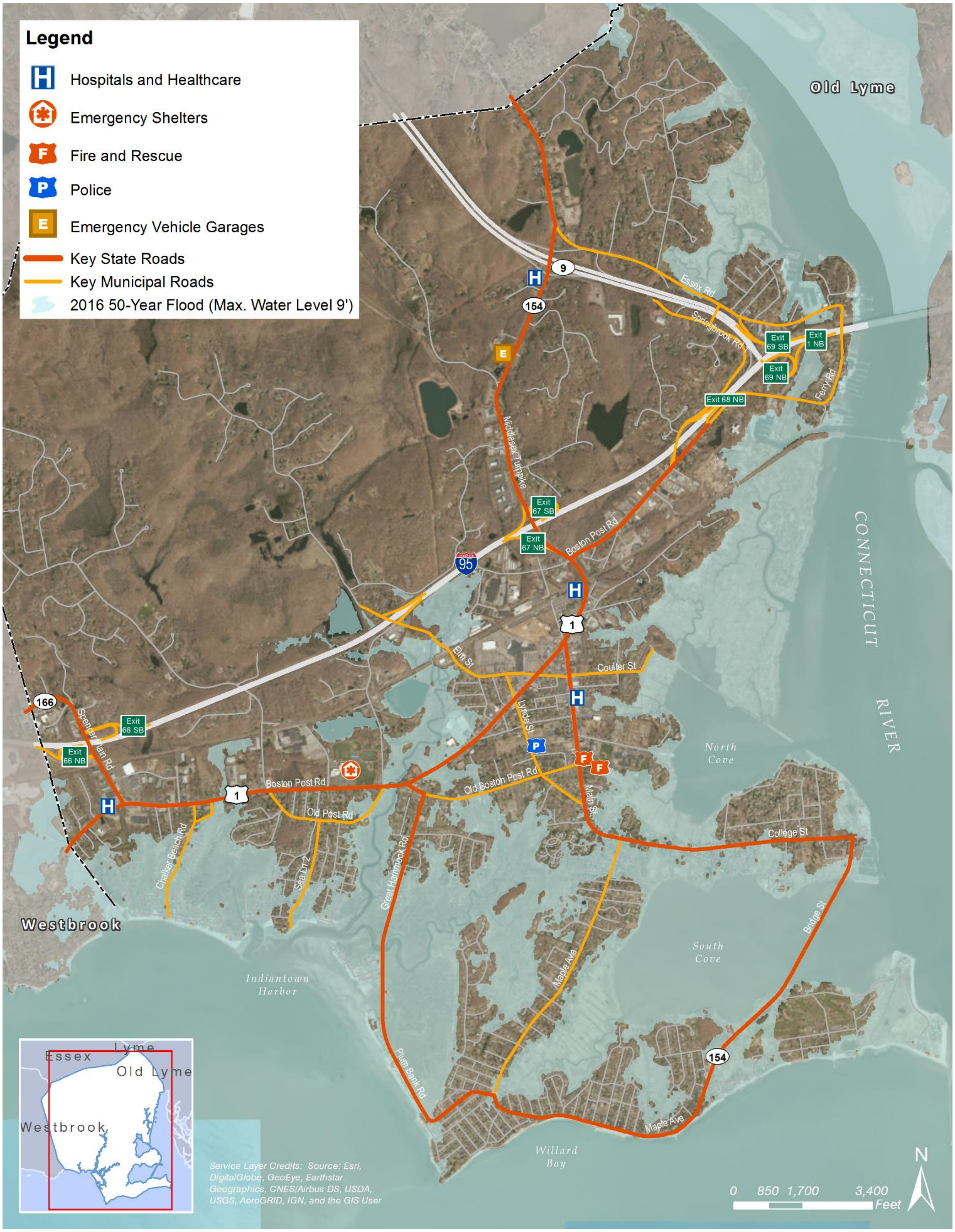


Figure 4-47: Current 100-year Return Period Key Road Flood Inundation

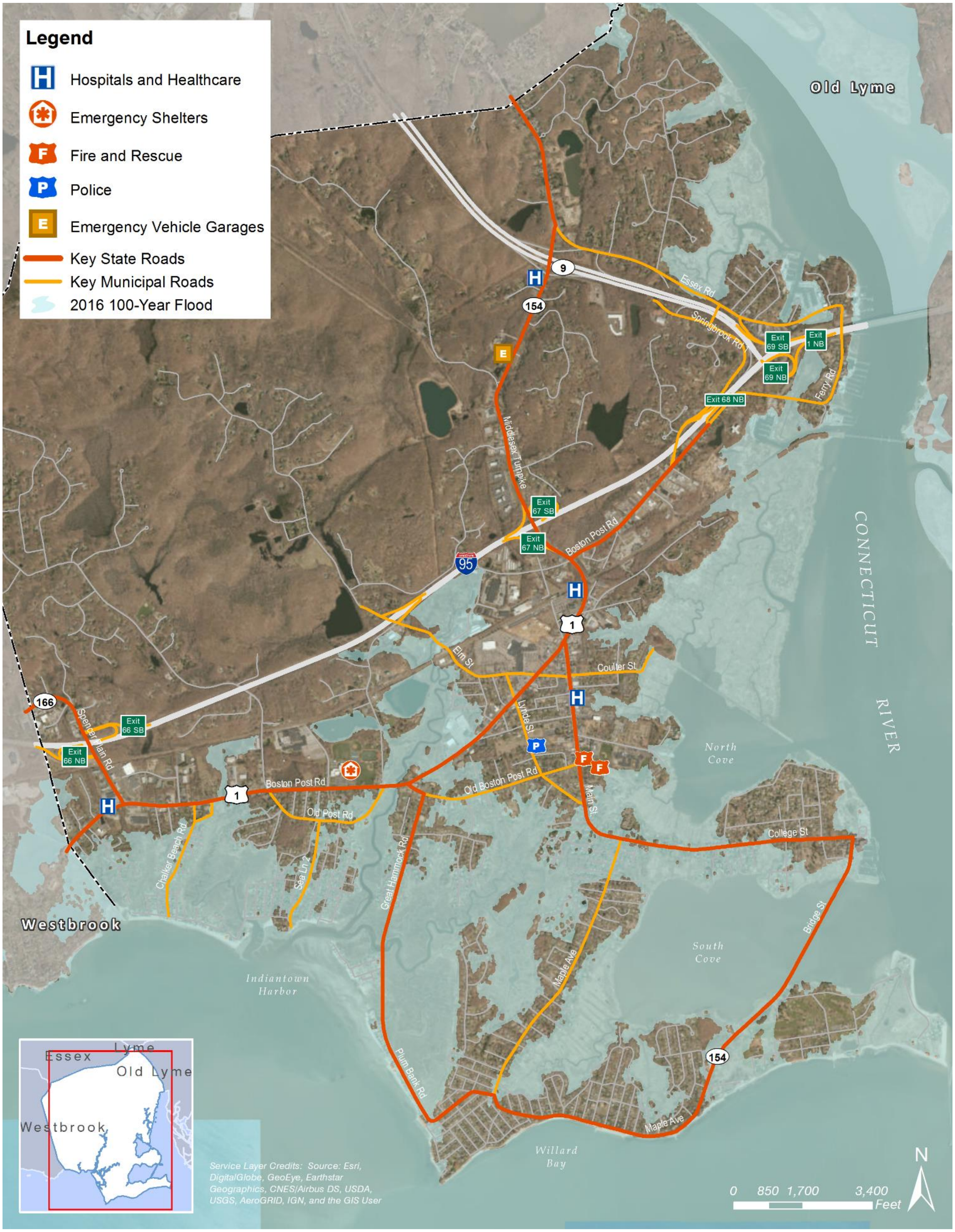


Figure 4-48: 500-year Return Period (2016) Flood Risk Key Road Inundation

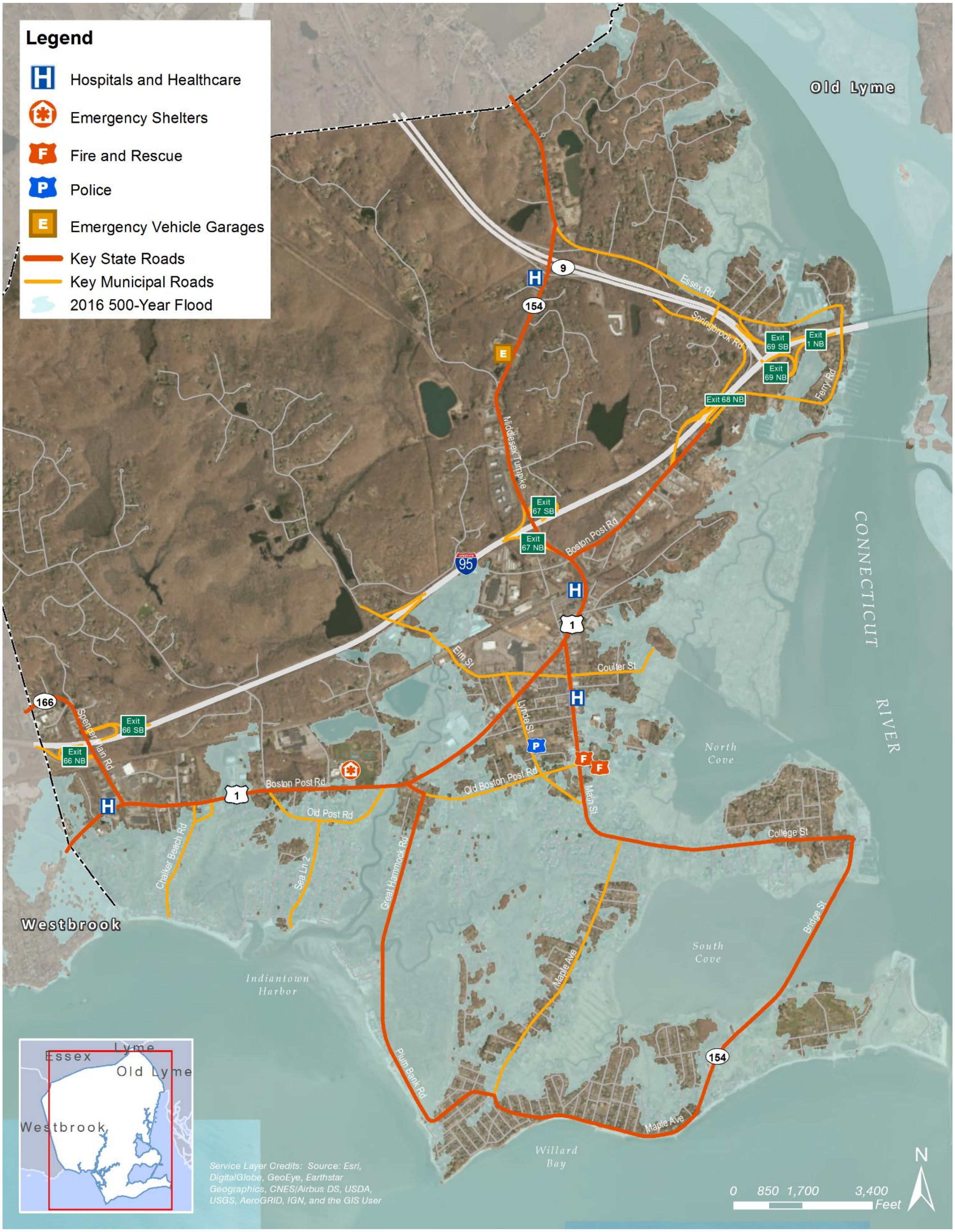


Figure 4-49: 100-year Return Period (2016) Roadway Flood Inundation Depths

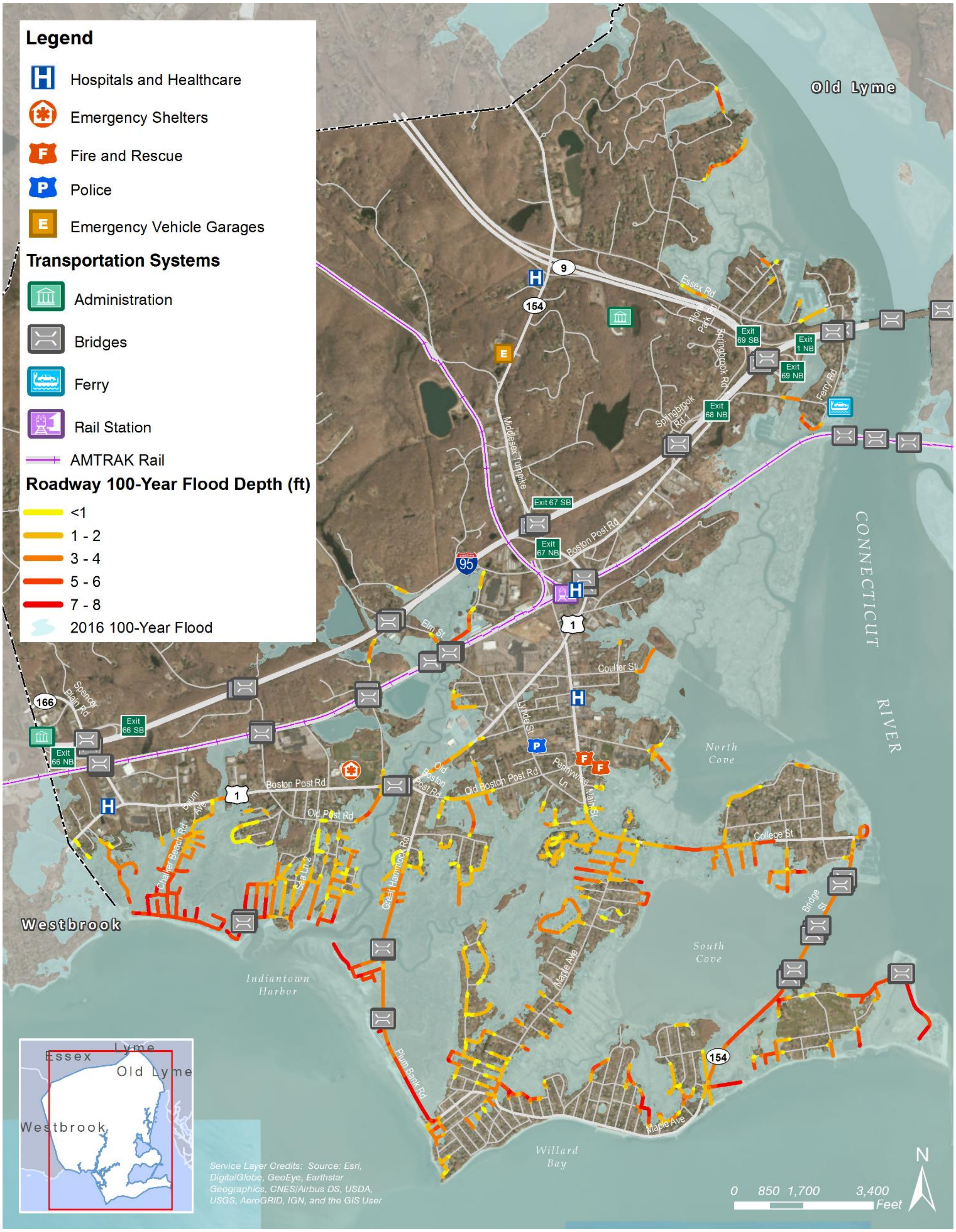
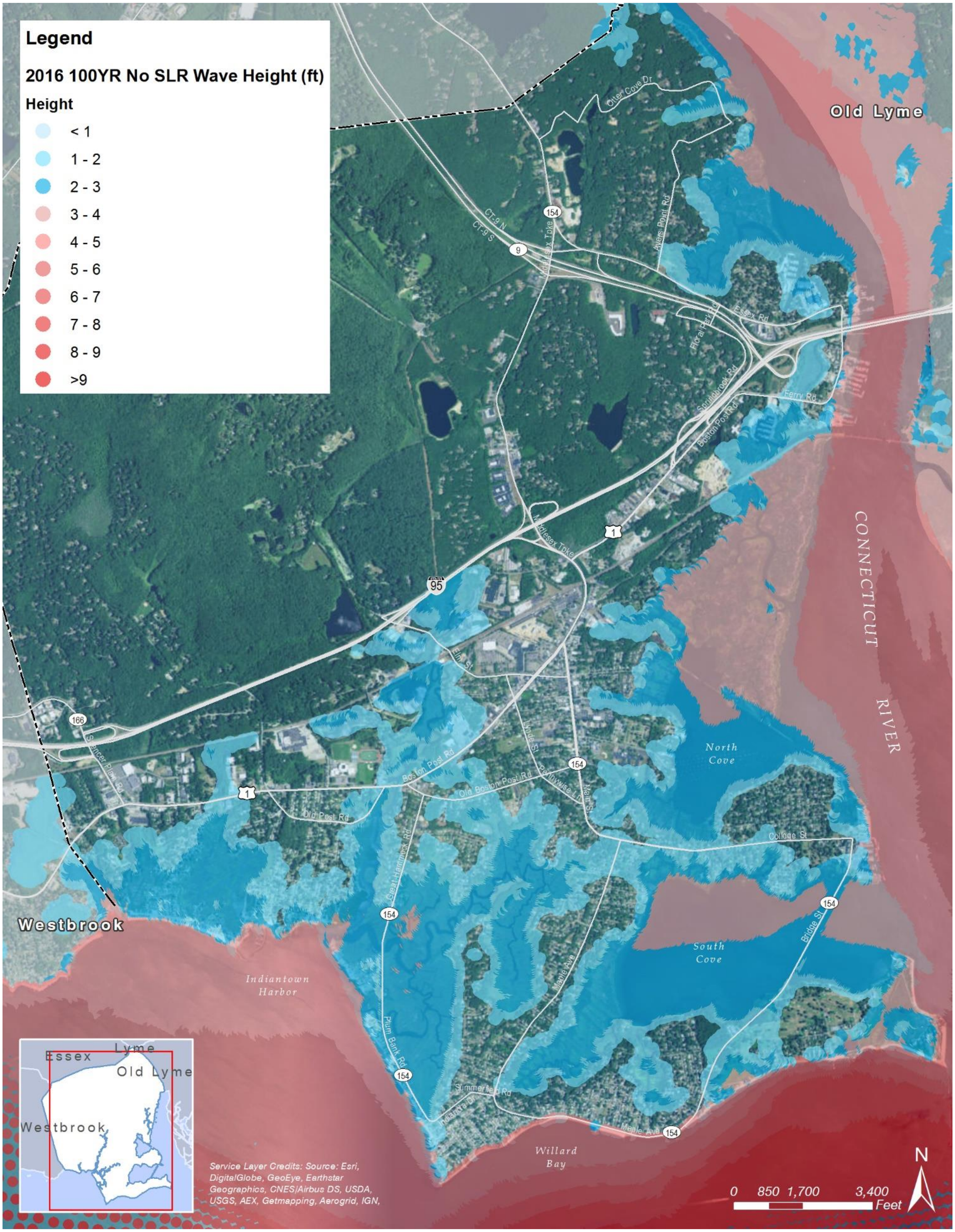


Figure 4-50: 100-year Return Period (2016) Wave Heights



Stormwater Management Infrastructure

Stormwater Management Infrastructure

Stormwater within Old Saybrook is primarily managed through a network of catch basins, manholes, underground piping, culverts and outfalls. Surface stormwater runoff also drains to the marshes and embayments. While much stormwater run-off is to adjacent marshes, green infrastructure is not presently utilized to provide on-site infiltration of stormwater.

The stormwater management infrastructure is owned and operated by the Town. The Town is in the process of mapping the town-wide stormwater management infrastructure. Currently, the Town has collected information on approximately sixty percent (%) of the town-wide system. While the data collected to-date is not complete, the data collected to-date includes:

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

Figures 4-51 and 4-**52** present the mapped location of tide gates, catch basins, manholes, culverts and outfalls.

Piped stormwater is discharged via gravity flow to drainage outfalls to the Connecticut River, Long Island Sound and local waterways. The Town also 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.)

There is not, currently, available adequate information to do a detailed assessment of the effects of coastal flooding and sea level rise on the Town's stormwater management system. However, certain challenges to the Town's stormwater management system are evident:

- within low-lying areas such as the beach communities, there is limited elevation change to support gravity flow (either piped or surface run-off) during combined precipitation and coastal flood events, resulting in ponding and street flooding during these events;

- sea level rise will further reduce the hydraulic efficiency of stormwater infrastructure, and in low-lying areas outfalls without tide gates may experience surcharge of the system during high tides and frequent flood events;

- many outfalls are located in shoreline areas subject to erosion, scour and damage from long term and episodic beach erosion and wave-related damage;

- during extreme flood events, most of the stormwater catch basins and manholes located south of Interstate 95 will become inundated, resulting in significant maintenance requirements including sediment removal, etc. and potential for untreated discharge of pollutants that became mobilized during the flood;

- there are specific cases, such as Elm Street at Research Parkway where tidal and flood elevation at the outfall is expected to surcharge the system resulting in street flooding; and

- a likely outcome of climate change will be an increase in the intensity of precipitation (more precipitation and more frequent extreme precipitation events) resulting in greater demand on stormwater infrastructure.

While the stormwater management system is not expected to drain during extreme coastal flood events, it is important that it: 1) does not provide a source of localized flooding due to surcharging of catch basins and manholes; and 2) needs to be operable immediately after the storm to drain flooded areas. The stormwater management system south of I-95 is considered vulnerable to coastal flooding since most outfalls, catch basins and manholes do not have backflow prevention measures.

During the current 100-year recurrence interval flood (see **Figures 4-53** and **4-54**), the following structures will be inundated, with the potential for debris, sediment and pollutant impacts.

- Catch basins: 366 out of 2,217
- Culvert inflows: 13 out of 108
- Culvert Outflows: 20 out of 102
- Manholes: 4 out of 8
- Outfalls: 76 out of 204

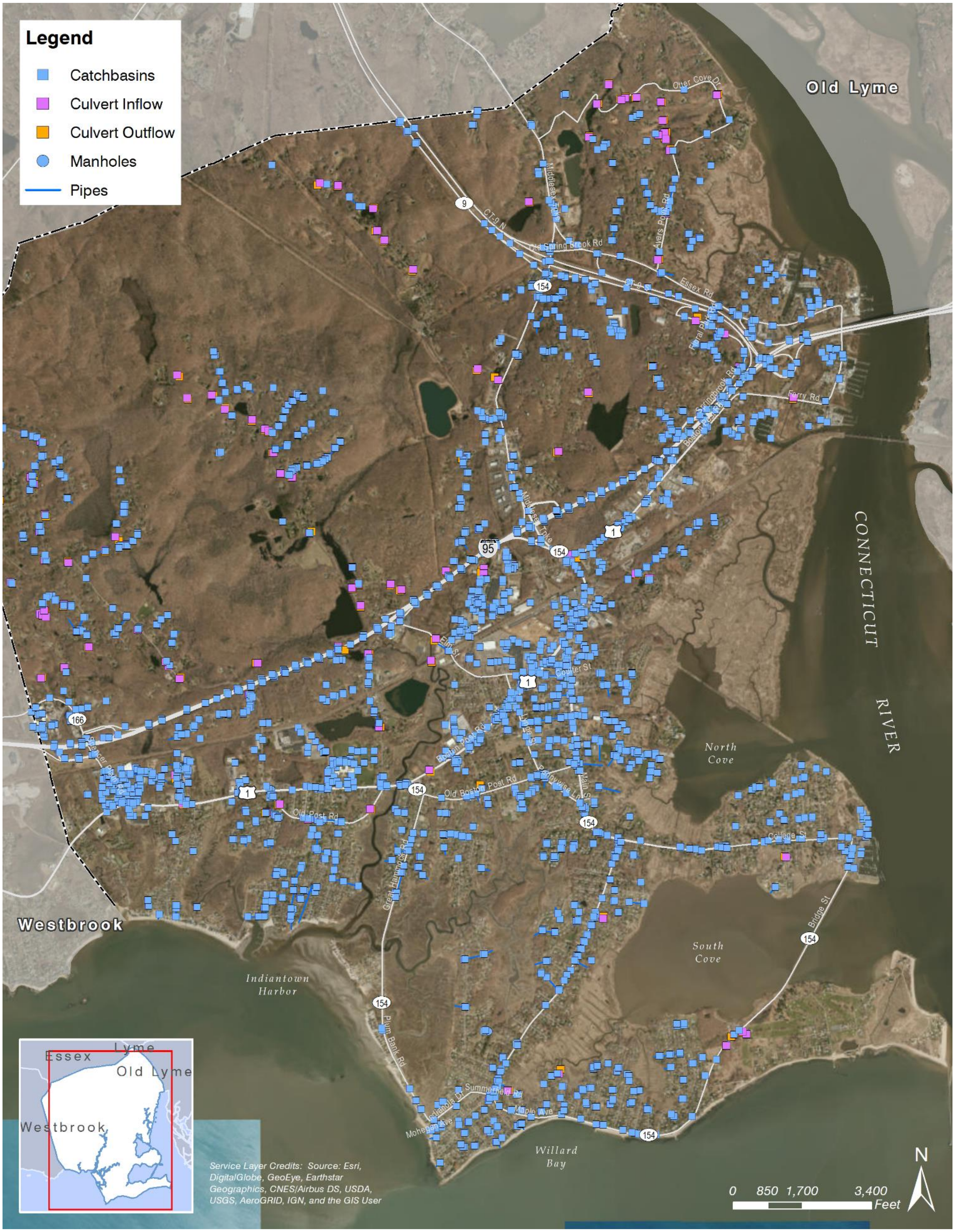


Figure 4-51: Stormwater Catch Basins and Culvert Inflows/Outflows

Figure 4-52: Stormwater Outfalls and Tide Gates

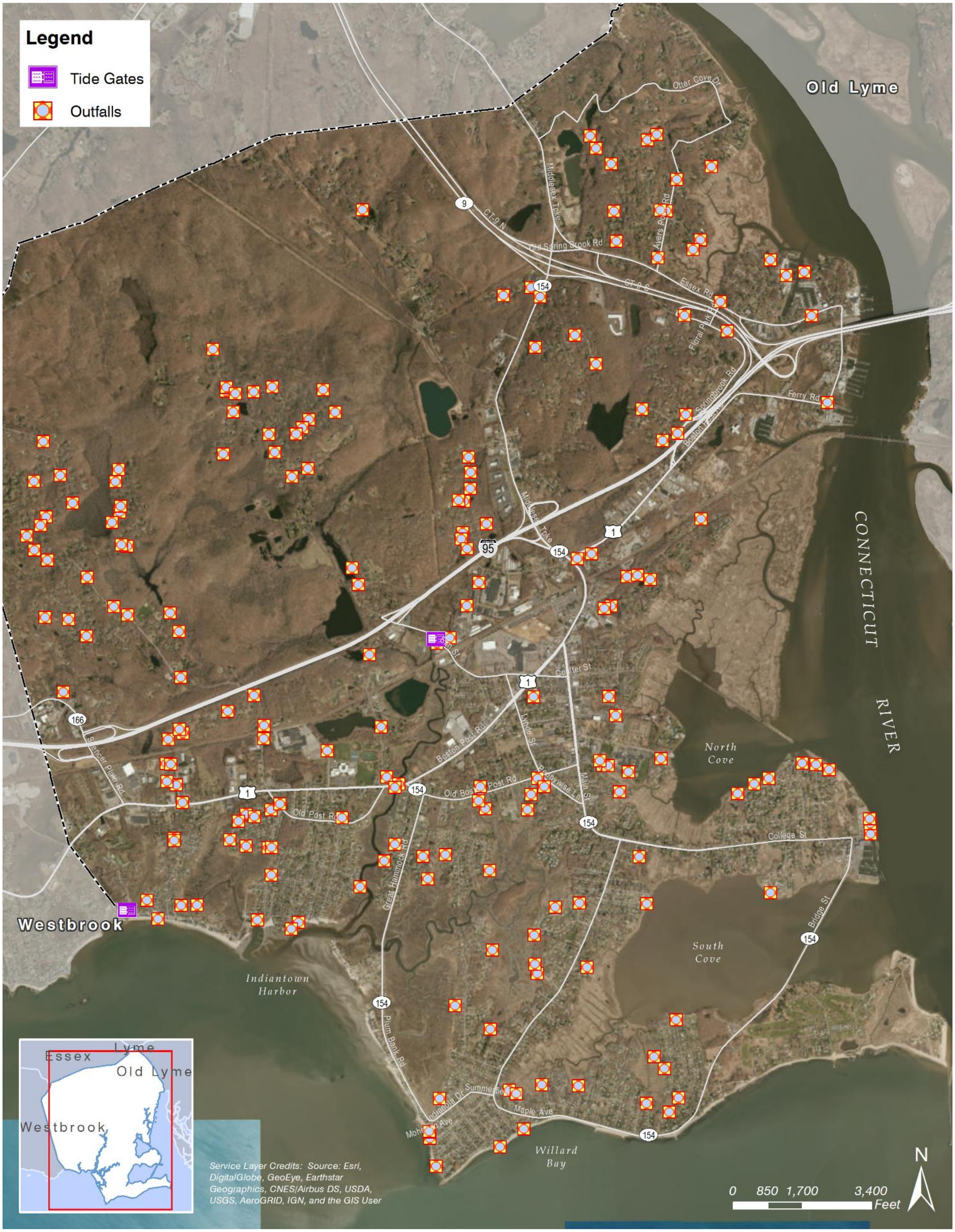


Figure 4-53: Stormwater Catch Basins, Manholes and Culverts and 100-year Recurrence Interval Flood Inundation

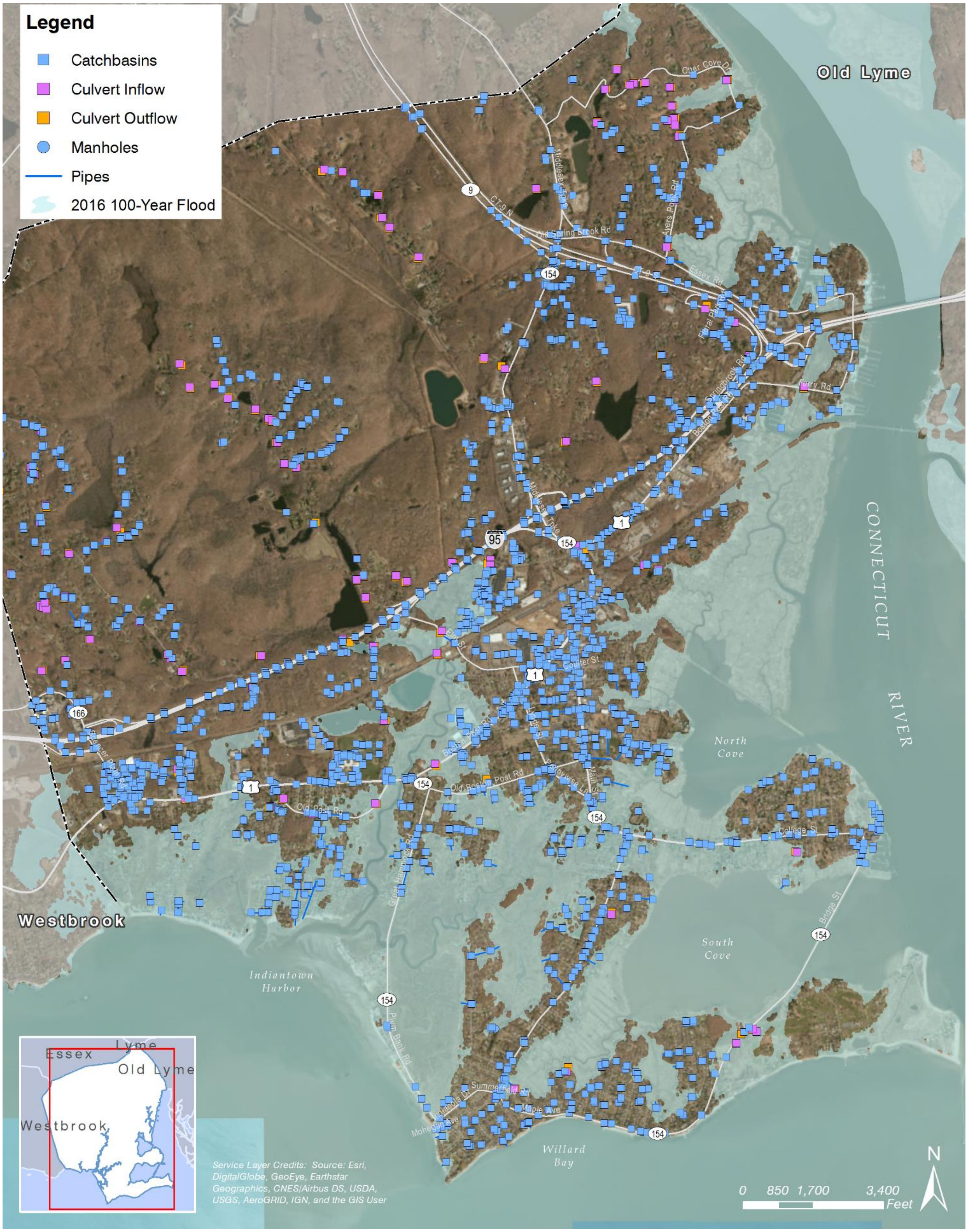
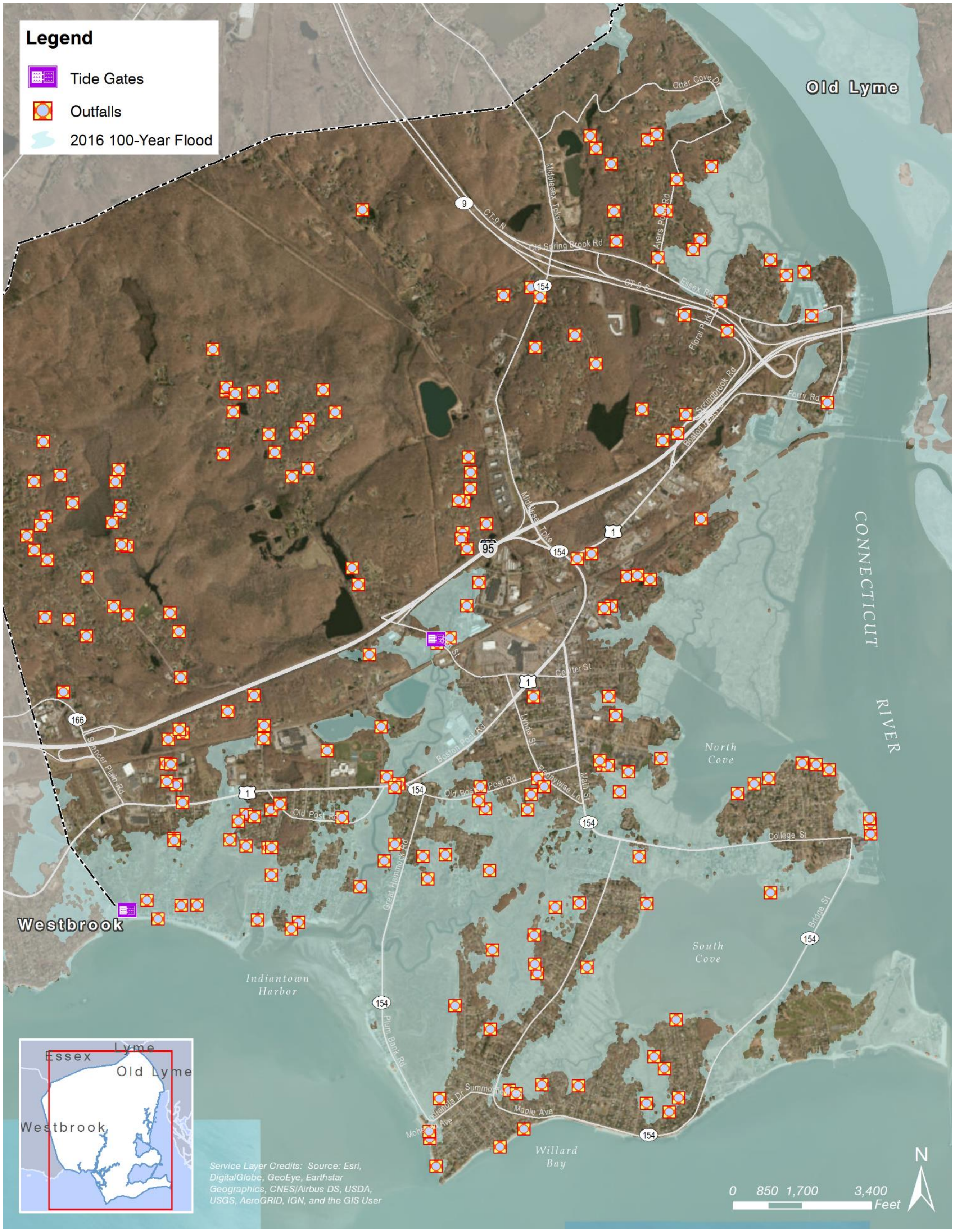


Figure 4-54: Stormwater Outfalls; Tide Gates and 100-year Recurrence Interval Flood Inundation



Natural Resources - Marshes

Natural Resources - Marshes

This section discusses the vulnerability of the Town's tidal salt marshes to coastal flooding and the effects of sea level rise. Maintaining the marshes in the future will require on-going management and restoration activities, planning to accommodate potential changes to habitat, and possible changes to Town land use policies. This section utilizes the results of two key marsh studies:

1. An assessment performed by the Nature Conservancy, entitled "A Salt Marsh Advancement Zone Assessment of Old Saybrook, Connecticut"; and
2. The study "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.

Tidal Marshes and Wetlands: Much of the Old Saybrook land area south of Interstate 95 consists of intertidal salt marshes and tidal wetlands. The largest intertidal marsh systems are: 1) the Plum Bank Marsh Wildlife Area (around the Plum Bank, Oyster and Back Rivers and abutting Long Island Sound); 2) Ragged Rock Creek Marsh Wildlife Area (located around the Ragged Rock Creek and abutting the Lower Connecticut River); 3) the Hager Creek Marsh Wildlife Area (located around Hager and Mud Creeks, abutting Long Island Sound); 4) the Ferry Point Marsh Wildlife Area (abutting the Lower Connecticut River); and 5) the South Cove Wildlife Area (around Beamon Creek and abutting the South Cove).

Lower Connecticut River: In the vicinity of Old Saybrook, the Lower Connecticut River is a tidal estuary and has extensive fresh and brackish tidal wetlands. It also has diverse and critical habitat and is recognized as containing "Wetlands of International Importance" under the intergovernmental Ramsar Convention. As a tidal estuary, with direct connection to Long Island Sound, the Lower Connecticut River shorelines experience water level fluctuations from both tides and coastal storm surges.

Brooks, Creeks and Rivers: The Old Saybrook tidal wetlands and marshes are fed and drained by brooks, creeks and rivers, which discharge into the Lower Connecticut River and Long Island Sound. These include Ragged Rock Creek (Lower Connecticut River), Beamon Creek (South Cove and the Lower Connecticut River), Plum Bank, Back, Hagar and Mud Creeks, Oyster River and Back River (Long Island Sound). Several of these waterways extend upland of the tidal marshes and wetlands, including Oyster River and Fishing Brook, which are hydraulically connected. Coastal flooding propagates inland up these rivers and connect to lakes and ponds (Crystal Lake, Chalkers Millpond and Ingham Ponds).

Marshes: The tidal salt marshes, located at the margin between land and water, are dynamic ecosystems that provide ecological and economic value. The marshes provide habitat for wildlife and fisheries and add to the quality of life and aesthetics of Town residents. The marshes provide some level of resilience to coastal flooding, primarily through wave attenuation and erosion control. The marshes also provide water quality benefits through surface runoff storage and infiltration and pollutant absorption.

Marshes are also some of the most susceptible ecosystems to climate change, in particular accelerated rates of sea level rise. Long-term changes to air and water temperature and precipitation may affect species composition and type of habitat. However, the most significant climate change impact to the marshes will be sea level rise. A climate change effect is the advancement of the marsh in response to sea level rise. Another key issue is the potential for chronic or episodic erosion of beaches that separate the marshes from Long Island Sound, which will increase due to the effects of climate change. Beach erosion is discussed in the next section.

MARSH VULNERABILITY- SEA LEVEL RISE

The following paragraphs are drawn extensively from “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.

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.

Climate-related changes to precipitation rates can also impact freshwater inflows and sediment delivery. Each of these effects can result in habitat stress and loss. The interaction of each of these conditions is very complex. In general, the amount of habitat stress and loss is a function of how fast sea levels will rise relative to plant growth and sediment accretion rates and the rate of below-ground decomposition. If the vertical build rate of the tidal marshes is not fast enough to keep pace with sea level rise, the wetlands will convert to open water or tidal flats.

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 is widely recognized as an effective model to predict wetland response to long term sea level rise. A fundamental assumption in SLAMM is that individual wetland types inhabit a range of vertical elevation that is a function of the local tide range. The SLAMM model computes relative sea level rise for each area at different time steps that is offset by observed and modeled marsh accretion and other factors affecting marsh surface elevation. The following figure, reproduced from the study (with an original source of Titus and Wang, 2008) illustrates the relationship between tides, wetlands and reference elevations for estuarine marsh profiles.

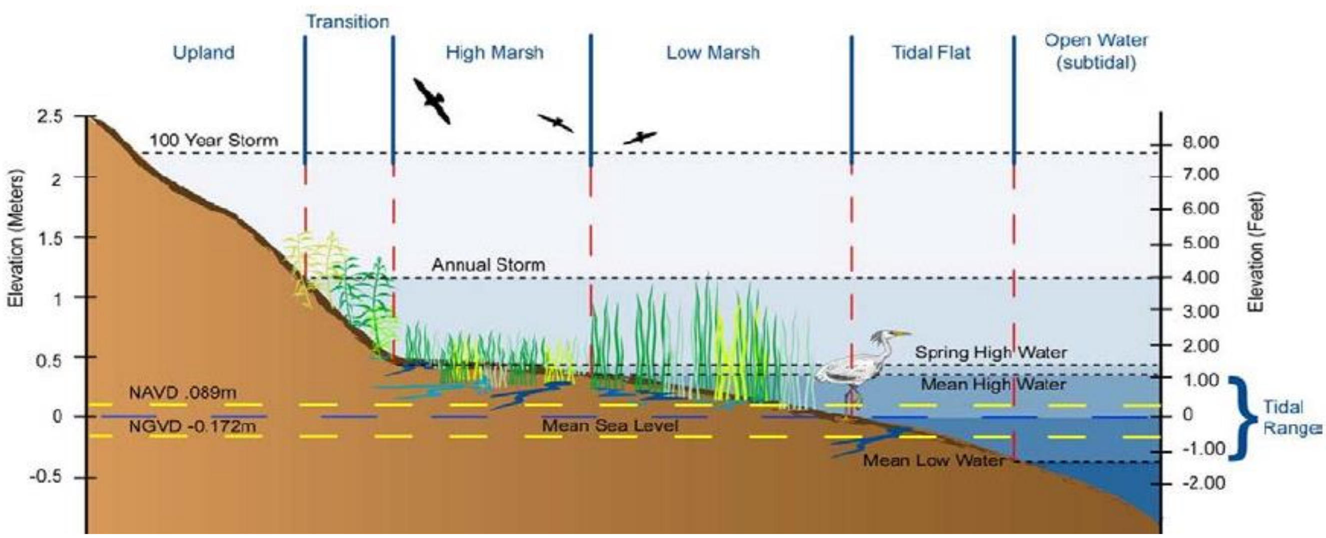


Figure 4-55: Relationship between Tides, Wetlands and Reference Elevations for Typical Connecticut Estuarine Marsh Profiles

As shown on the figure, tidal marshes are typically categorized into two distinct zones: the lower or intertidal marsh and the upper or high marsh. In saline tidal marshes, the low marsh is normally covered and exposed daily by the tide. It is predominantly covered by the tall form of Smooth Cordgrass **(**Spartina alterniflora**).** The high marsh is covered by water only sporadically and is characterized by Short Smooth Cordgrass, Spike Grass and Saltmeadow Rush (Juncus gerardii). Saline marshes support a highly specialized set of life adapted for saline conditions.

SLAMM simulations were run in the study from the date of the initial wetland cover layer to 2100. Maps and numerical data were output for the years 2025, 2055, 2085, and 2100. The following table shows SLR rates relative to the base year of 2002 used in the four scenarios applied to the Connecticut SLAMM model.

Scenario	**2025** (meters/feet)	**2055** (meters/feet)	**2085** (meters/feet)	**2100** (meters/feet)
Global Climate Model Maximum	0.13/0.4	0.31/1.0	0.58/1.9	0.72/2.4
1 m by 2100	0.13/0.4	0.43/1.4	0.81/2.7	1.0/3.3
Rapid Ice Melt Minimum	0.13/0.4	0.48/1.6	1.0/3.3	1.3/4.3
Rapid Ice Melt Maximum	0.25/0.8	0.74/2.4	1.4/4.6	1.72/5.6

Table 4-17: Sea Level Rise under Different Climate Change Scenarios Relative to the Base Year of 2002 assumed in SLAMM Simulations (from "Application of SLAMM to Coastal Connecticut", Final Report, 2015)

The "Old Saybrook Coastal Community Resilience Study" provides a detailed discussion of sea level rise projections applicable to Old Saybrook. Historic sea level rise in Long Island Sound has been on the order of 2.56 mm/yr to 2.85 mm/yr. The following table and figure summarize relative sea level rise projections utilized by NOAA and the US Army Corps of Engineers (USACE) for the New London NOAA tide gage. Projected sea level rise for 2025 ranges from 0.3 to 0.5 foot; 2055 ranges from 0.2 to 2.2 feet; 2085 ranges from 0.4 to 4.8 feet; and 2100 ranges by 0.5 to 6.5 feet.

The SLAMM Global Climate Change Model Maximum sea level rise scenario is slightly higher than the USACE Intermediate projection. The USACE Intermediate projection has "possible to certain" chance of occurrence by 2100. The SLAMM Rapid Ice Melt Maximum sea level rise scenario is slightly lower than the USACE High projection. The USACE High RSLC projection has a "very low to moderate" chance of occurrence.

The wetland boundary elevation (WBE) in SLAMM defines the boundary between coastal wetlands and dry lands (including non-tidal wetlands). Generally, the elevation defining the upland boundary of coastal wetlands (from dry lands and non-coastal wetlands) is approximated by the elevation inundated once every 30 days, during spring high water. For Connecticut, however, this boundary was determined in the study using the mean higher, high water (MHHW) elevation taken from a 5 year analysis of NOAA tide gauge data.

In tidal marshes, increasing inundation can lead to additional deposition of inorganic sediment that can help tidal wetlands keep pace with rising sea levels (original source Reed 1995). It is also observed that salt marshes will often grow more rapidly at lower elevations allowing for further inorganic sediment trapping (original source Morris et al. 2002). SLAMM considers such feedback loops in its modelling of marsh surface elevation change.

8461490, New London, CT
NOAA's Published Rate: 0.00738 feet/yr
All values are expressed in feet relative to NAVD88

Year	USACE Low NOAA Low	USACE Int NOAA Int Low	NOAA Int High	USACE High	NOAA High
2002	-0.2	-0.2	-0.2	-0.2	-0.2
2005	-0.2	-0.2	-0.2	-0.1	-0.1
2010	-0.2	-0.1	-0.1	-0.0	-0.0
2015	-0.1	-0.1	0.0	0.1	0.1
2020	-0.1	-0.0	0.1	0.2	0.3
2025	-0.1	0.0	0.3	0.3	0.5
2030	-0.0	0.1	0.4	0.5	0.7
2035	0.0	0.2	0.5	0.7	1.0
2040	0.1	0.3	0.7	0.9	1.2
2045	0.1	0.3	0.9	1.1	1.5
2050	0.1	0.4	1.1	1.4	1.8
2055	0.2	0.5	1.3	1.6	2.2
2060	0.2	0.6	1.5	1.9	2.6
2065	0.2	0.7	1.8	2.2	3.0
2070	0.3	0.8	2.0	2.5	3.4
2075	0.3	0.9	2.3	2.9	3.8
2080	0.4	1.0	2.6	3.2	4.3
2085	0.4	1.2	2.9	3.6	4.8
2090	0.4	1.3	3.2	4.0	5.3
2095	0.5	1.4	3.5	4.4	5.9
2100	0.5	1.5	3.8	4.8	6.5

Print Table

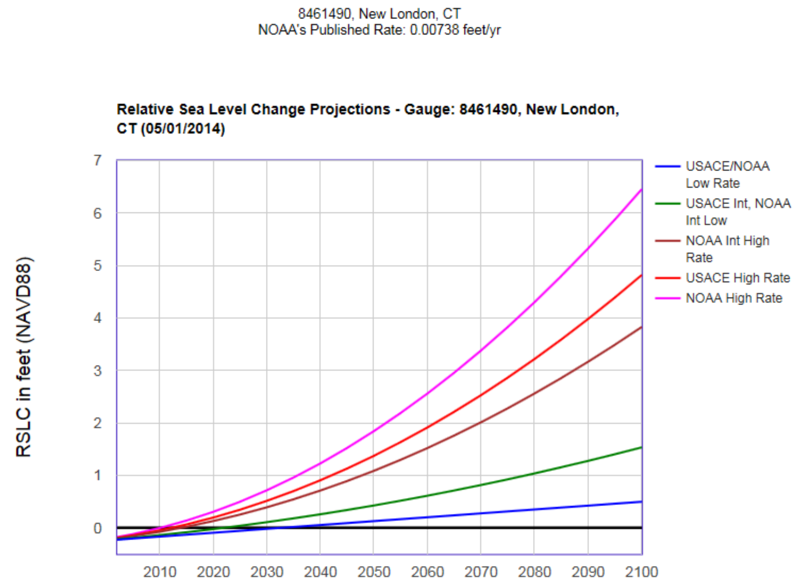
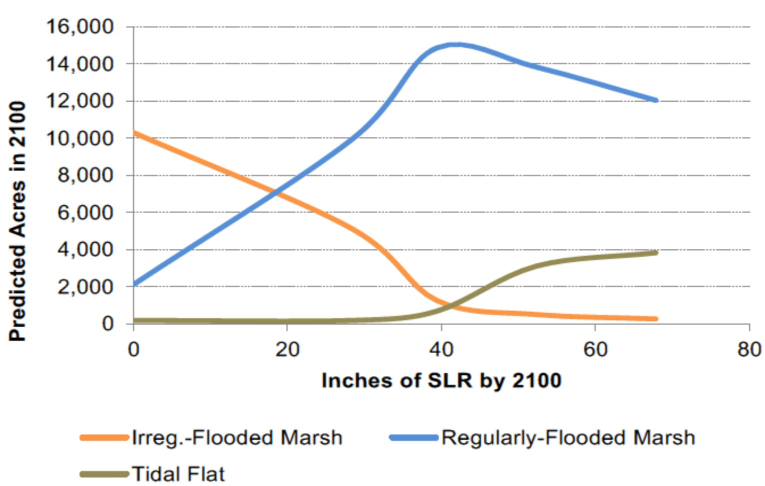


Table 4-18 and Figure 4-56: US Army Corps of Engineers Relative Sea Level Rise Change (RSLC) Projections (2002 to 2100)

The following figure shows the relationship between salt marsh types as SLR increases for the entire coastal Connecticut. Similar to Old Saybrook, irregularly-flooded (high) marsh currently dominates the Connecticut intertidal landscape. However, as relative sea level rise increases, more frequent inundation will increase the salinity in these marshes and lower their elevation relative to the tides, converting them to the regularly-flooded or low marsh. The predicted year 2100 marshes will little resemble the 2010 high marsh-low marsh complex compositions. As shown in **Figure 4-57**, under the 1 meter (40 inches) SLR by 2100 scenario, low marsh also begins to decline when SLR exceeds 40 inches as it is largely replaced with non-vegetated tidal flats or open water.

Figure 4-57: Relationship between Marsh Transformation and Sea Level Rise



One trend noted throughout the SLAMM study area is that as the tide range decreases from west to east along Connecticut's coast, marshes are predicted to be more vulnerable to SLR along this geographic gradient (e.g., Old Saybrook). This is because intertidal marsh is generally restricted to elevations between mean low water to spring high tide. A greater tidal range in the west, therefore, provides a greater vertical elevation range capable of supporting marsh vegetation than regions to the east with a smaller tide range. Applying a uniform relative sea level rise rate throughout Long Island Sound, and assuming that other factors affecting marsh sustainability (e.g., available upland marsh migration areas, marsh crab herbivory, etc.) are held constant, will result in a greater proportion of existing marsh conversions in eastern Long Island Sound.

Similarly, the long-term sustainability of a marsh is affected by the position of its platform, or surface, within its tidal frame. For example, two marshes with similar tidal ranges but different initial marsh surface elevations can respond differently under the same relative sea level rise scenario. Higher elevation marshes are described as having more 'elevation capital' and are therefore able to withstand additional sea level rise before converting to a tidal flat or open water or 'drowning.'

Figure 4-58 presents the SLAMM model 2010 Initial Land Cover map and indicates the current status of the marshes and tidal wetlands within Old Saybrook. Most of the tidal marshes are characterized as irregularly-flooded marsh (High Marsh), with sections of the marshes inundated tidally. High Marshes are general located between the MHHW elevation and the 1-year return period flood.

Figures 4-59 through **4-60** presents the SLAMM model results for Global Climate Change Model Maximum sea level rise scenario. Under this scenario, significant changes to the marshes do not begin to occur until the year 2085, corresponding to about < 2 feet of relative sea level rise. At this amount of sea level rise, portions of the irregular flooded marsh (High Marsh) converts to regularly flooded marsh (Low Marsh). This process continues through 2100 (about 2.5 feet relative sea level rise) with increased percentage of the marsh converting to regularly flooded marsh (Low Marsh). At this point about half of Old Saybrook's marshes are Low Marsh.

Figures 4-61 through **4-62** presents the SLAMM model results for Rapid Ice Melt maximum sea level rise scenario. 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.

Comparison between these two sets of figures illustrates that the effect of sea level rise is not just a function of the 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 the SLAMM Global Climate Change Model Maximum sea level rise scenario, results in more significant marsh transformation since the rate of sea level rise under the former scenario is occurring faster than the natural marsh accretion rates.

Figure 4-58: SLAMM Initial Land Cover

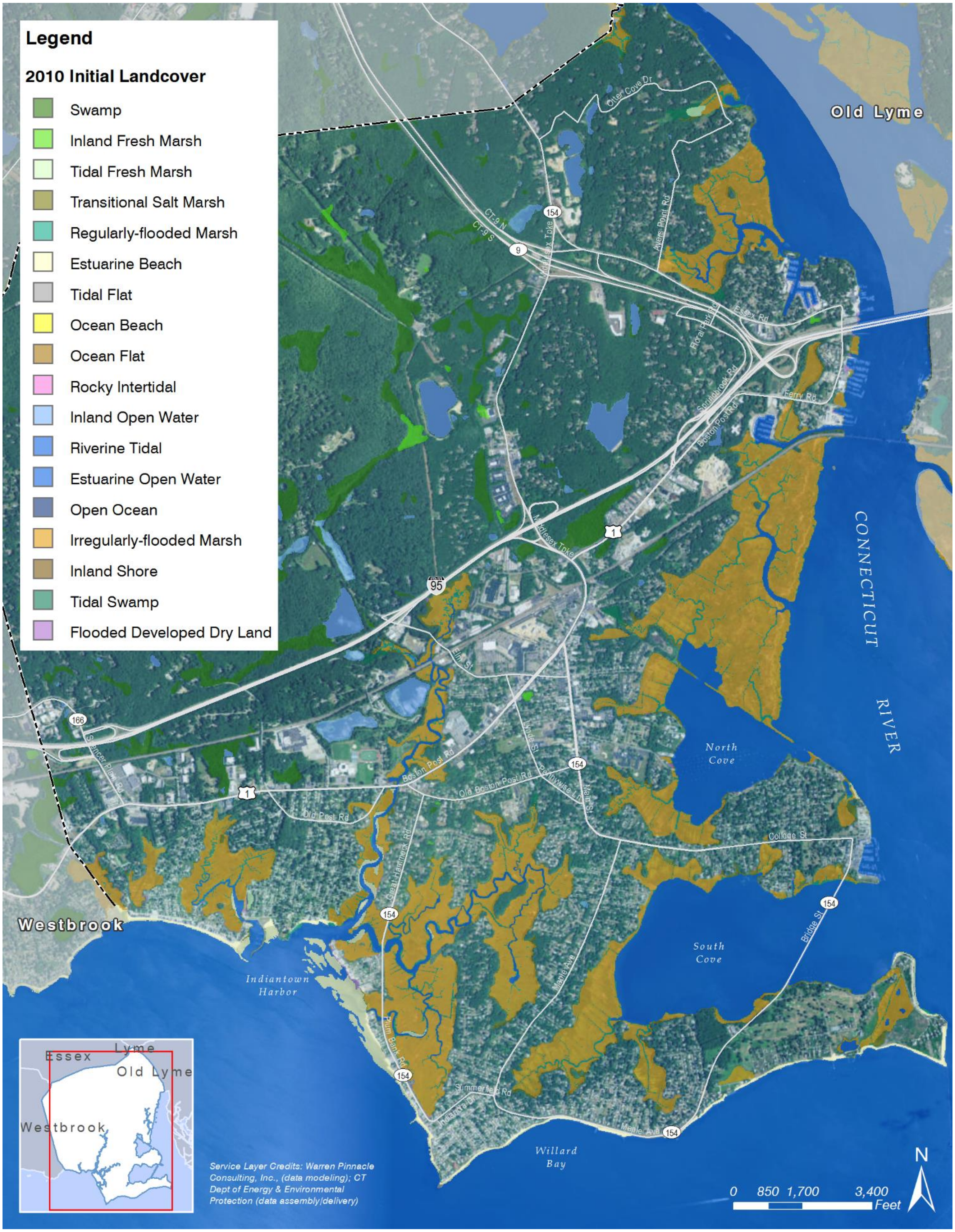


Figure 4-59: SLAMM 2025 Model Maximum Sea Level Rise

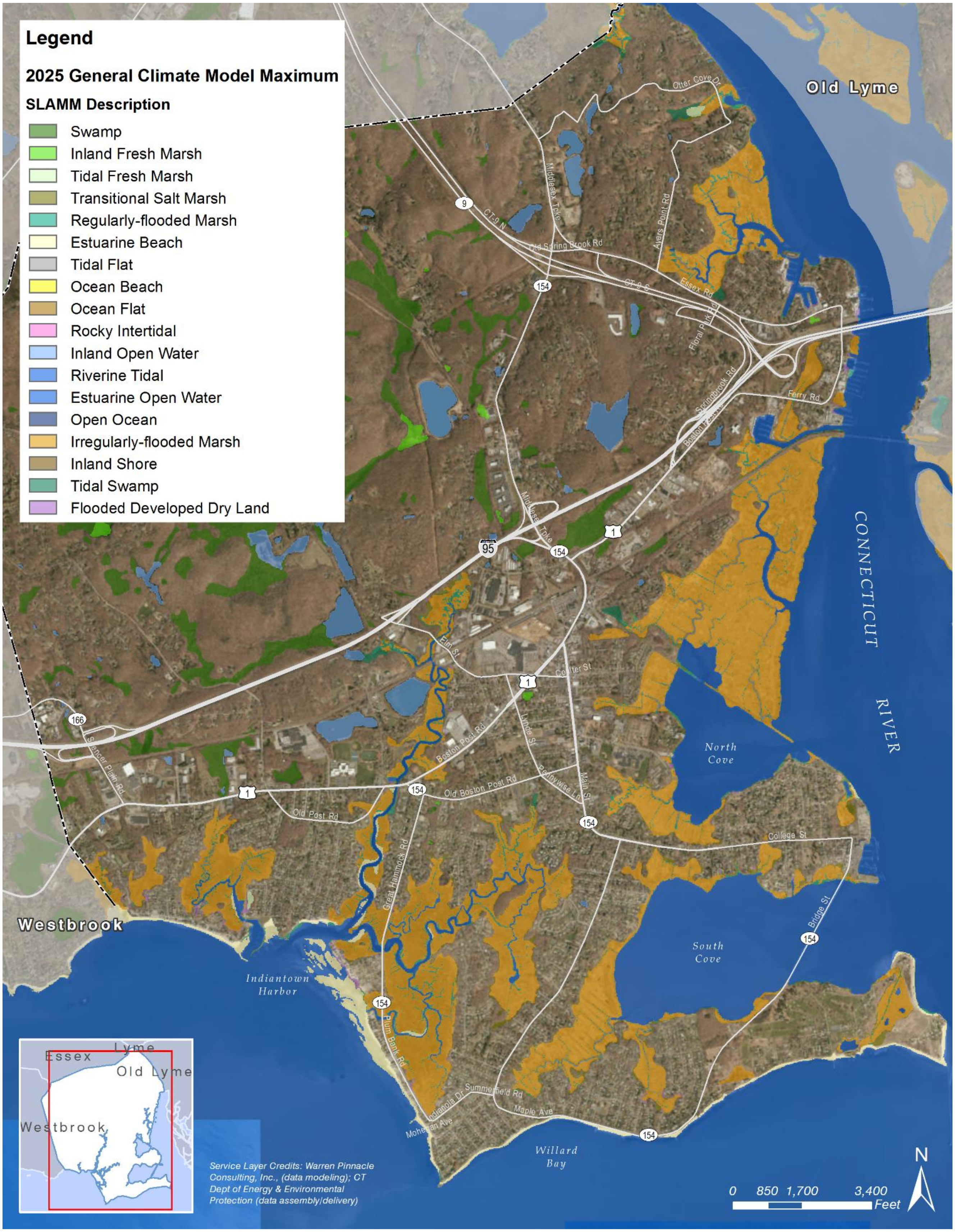


Figure 4-60: SLAMM 2055 Model Maximum Sea Level Rise

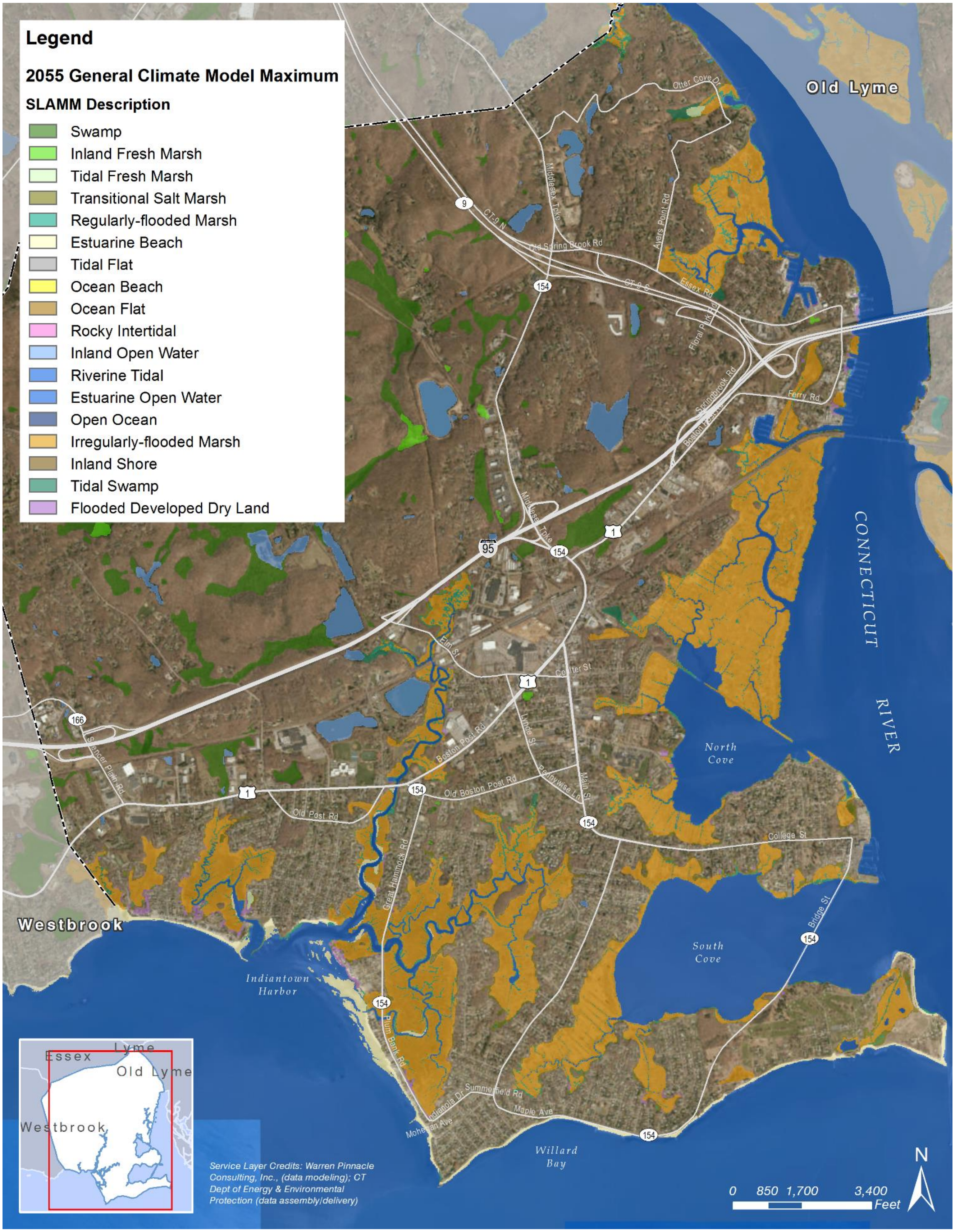


Figure 4-61: SLAMM 2085 Model Maximum Sea Level Rise

Figure 4-62: SLAMM 2100 Model Maximum Sea Level Rise

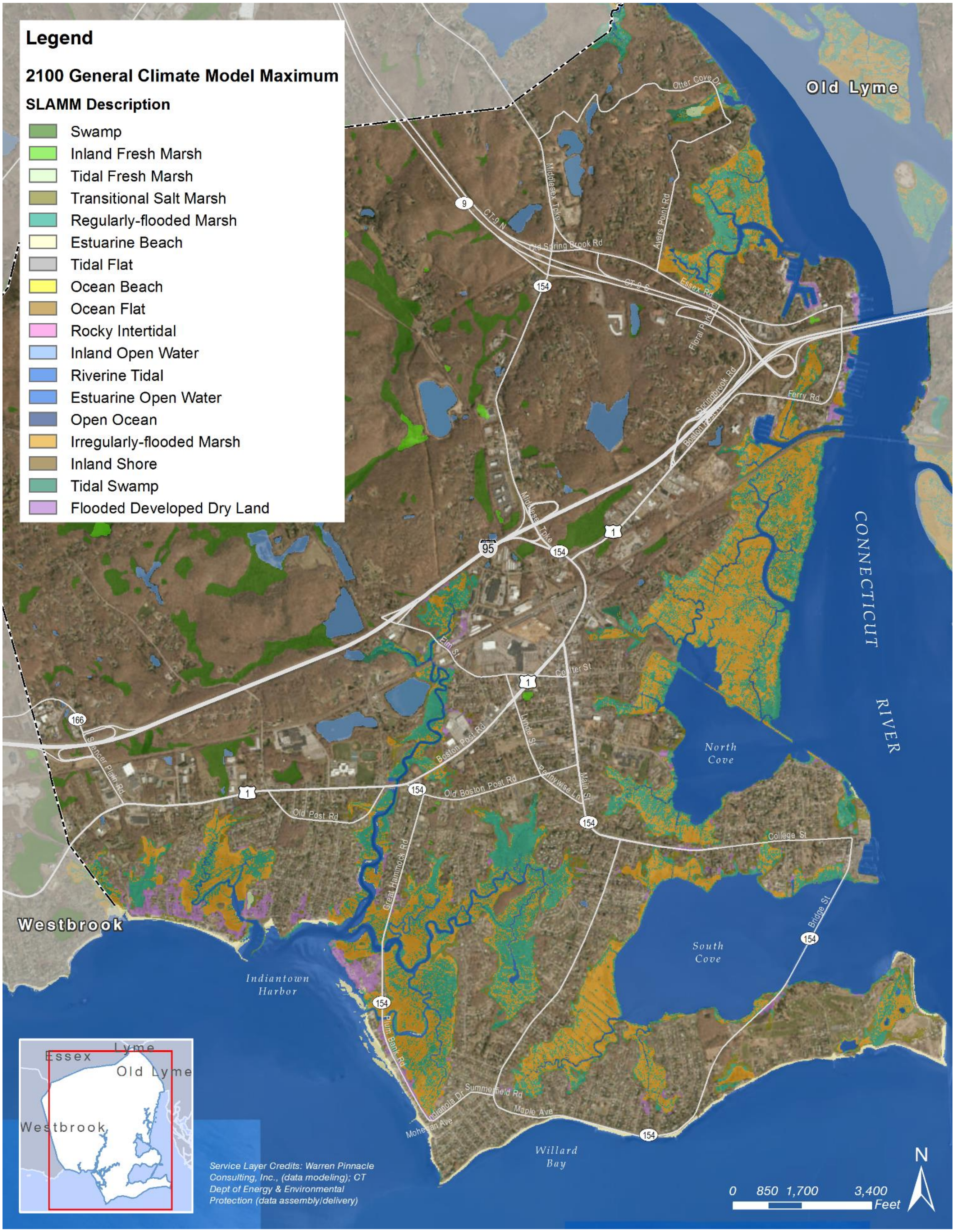


Figure 4-63: SLAMM 2025 Rapid Ice Melt Sea Level Rise

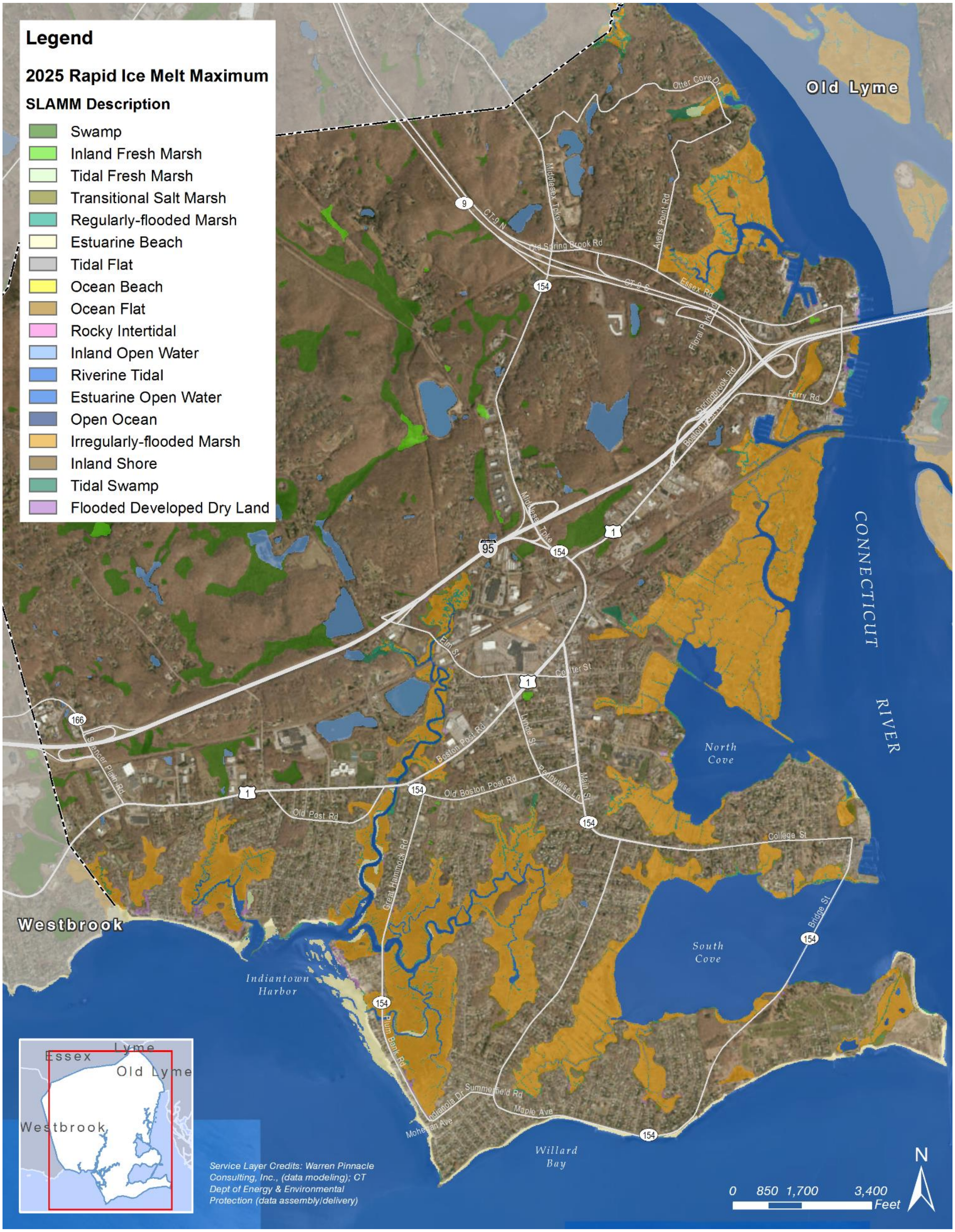


Figure 4-64: SLAMM 2055 Rapid Ice Melt Sea Level Rise

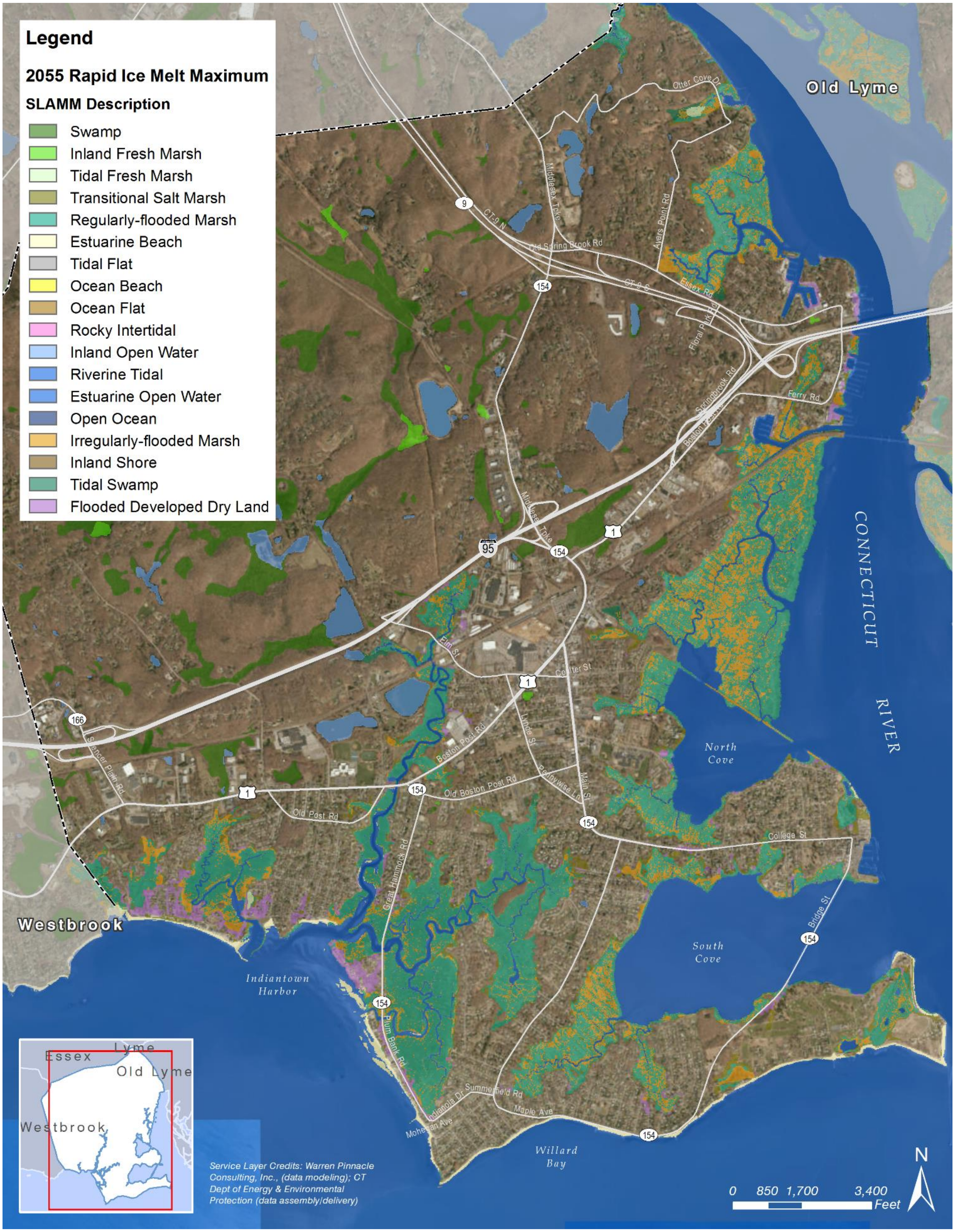


Figure 4-65: SLAMM 2085 Rapid Ice Melt Sea Level Rise

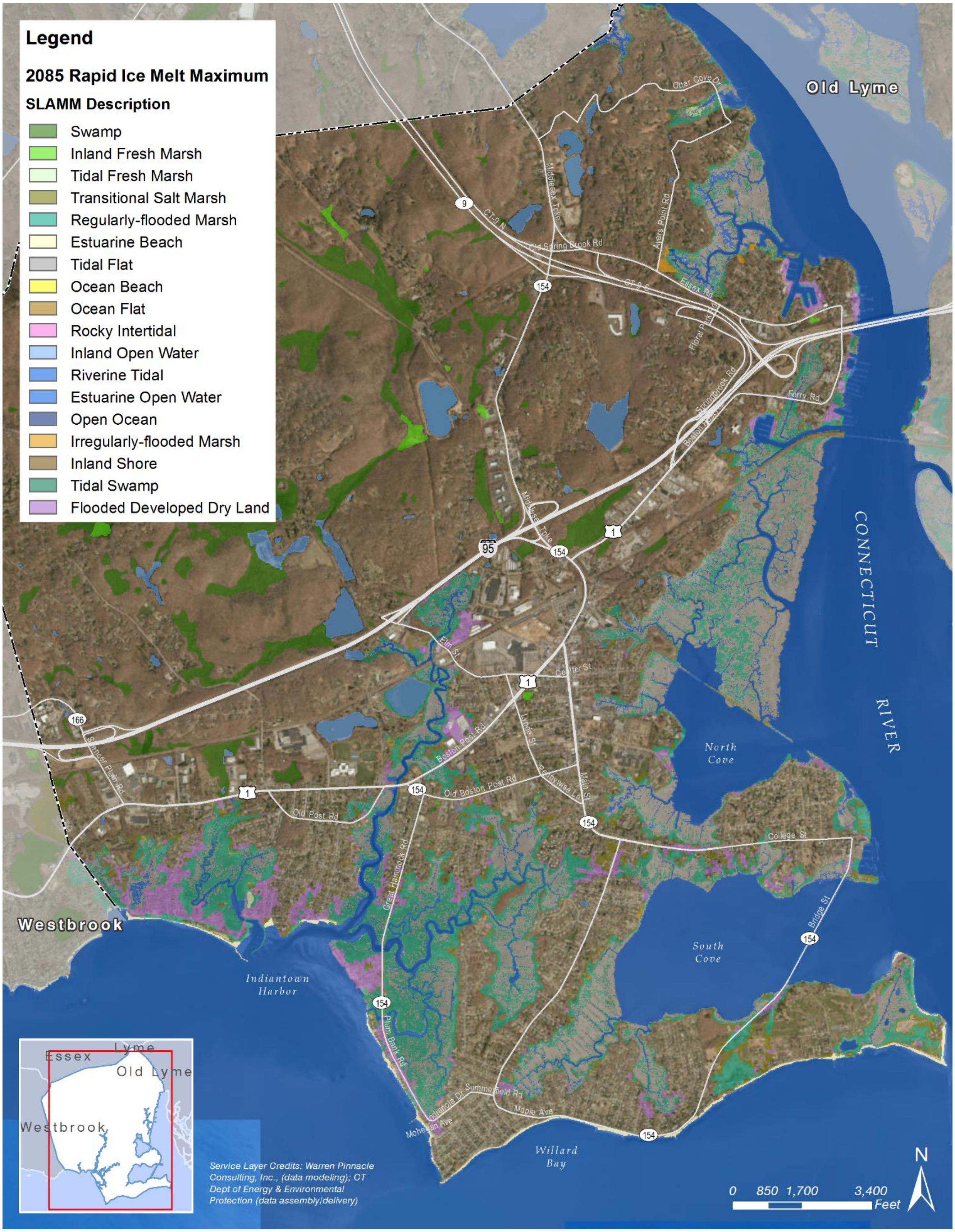
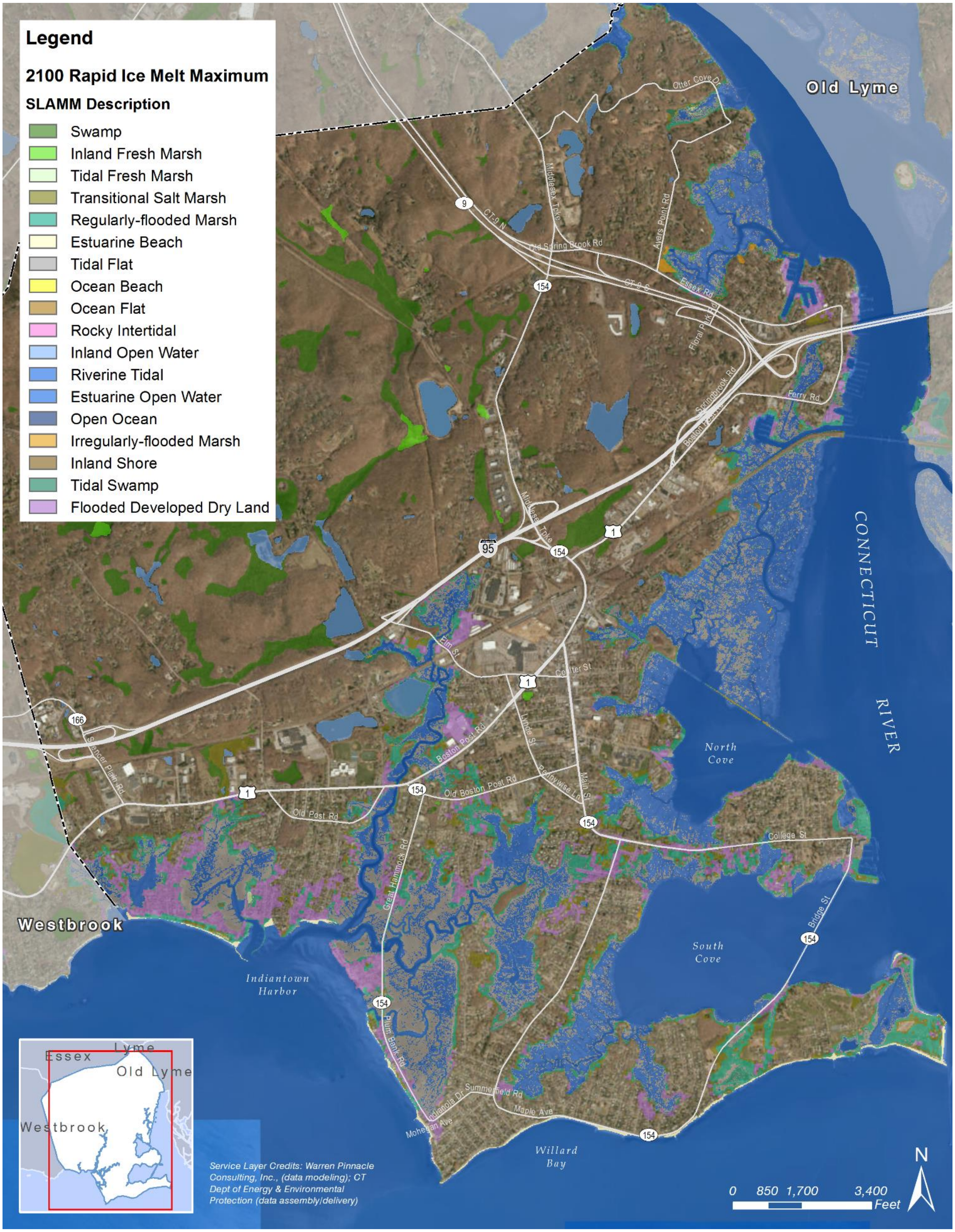


Figure 4-66: SLAMM 2100 Rapid Ice Melt Sea Level Rise



MARSH ADVANCEMENT

Most of the existing tidal marshes are bordered by developed property, which will restrict their lateral expansion. During 2013 and 2014, The Nature Conservancy (TNC) completed a study "A Salt Marsh Advancement Zone Assessment and presents an assessment (on a parcel basis) of upland migration of marsh with sea level rise. This study predates the SLAMM modeling presented above although used a similar methodology. Some difference in model results between the two analyses should be anticipated.

This TNC study provides a detailed assessment of projected marsh advancement and identifies specific parcels as opportunities for land acquisition. The detailed results of this report are not repeated here and the reader is referred to the study documents.

Natural Resources - Beaches

Attachment 4: Vulnerability and Risk

Natural Resources – Beaches

Old Saybrook's southern shoreline includes 14 beaches:

- Chalker Beach
- BelAire Manor Beach
- Indiantown Baby Beach & Marina (Red Bird Trail)
- Indiantown Shetucket Trail Beach (Shetucket Trail)
- Saybrook Manor Beach (Hartford Avenue)
- Saybrook Manor Beach (Middletown Avenue)
- Saybrook Manor Beach (8 Bayside Avenue)
- Saybrook Manor Beach (2 Bayside Avenue)
- Saybrook Manor Cove Beach (14 Bayside Avenue)
- Harvey's Beach
- Town Beach (Plum Bank)
- Cornfield Point Assoc. Beach
- Knollwood Beach Association Beach
- Fenwood Beach

Compared to the rest of the Atlantic seaboard, Long Island Sound is a relatively low energy system. The Old Saybrook coastline is located in a shoreline district characterized by the USACE as District E – Glacial Drift and Beaches. Areas of Old Saybrook consisting of glacial moraine deposits (e.g., Cornfield Point) are more resistant to erosion. About 8 miles of the Old Saybrook shoreline is potentially erodible, of which about 2 miles has been significantly affected by erosion. Typical of the Connecticut coast, Old Saybrook's beach consist of barrier spits and pocket beaches. Beach shoreline protection in the forms of groins and jetties and beach nourishment has been constructed at most of the beaches in Old Saybrook. Areas that have been historically affected by shoreline erosion include: Chalker Beach, Chapman Beach, Westbrook, Plum Beach and Great Hammock Beach.

The Connecticut shoreline, at any point in time, reflects the effects of both longshore sediment transport and cross-shore (on-shore - offshore) sediment transport. Longshore transport is primarily a function of the direction of the prevailing waves and tidal currents. Wave direction along the Connecticut Long Island Sound shoreline, in turn, is mostly a function of local wind direction (except areas to the east of Old Saybrook where the coast is also exposed to swells from the Atlantic Ocean). As a result, sediment transport and beach shoreline change are highly variable and localized. Along the Connecticut shoreline, the net longshore transport is generally east to west, but varies locally due to the irregular shoreline.

The Connecticut River is a significant source of sand that nourishes the beaches. Near the mouth of the Connecticut River, strong tidal currents can act to supplement weak, wave-induced littoral drift and can play a dominant role in the erosion process. Jetties and groins are built to trap longshore littoral drift, and these structures are numerous along Old Saybrook's shoreline.

Cross-shore sediment transport resulting in beach erosion is typically episodic and due to extreme flood conditions (storm surge and waves) associated with hurricanes and Nor-Easters. Given the predominance of Nor'easters in the Fall, Winter and Spring, cross shore beach erosion often occurs during that time of year, contributing to a seasonable effect of eroded beaches during the Winter and built-up beaches in the Summer. Tropical storms and hurricanes occur predominantly between June and November; although rare these storms can cause significant beach erosion.

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. A Geographic Information System (GIS) time series analysis was conducted using maps of the Connecticut shoreline from several different time periods between 1870 and 2006 to provide a high-level, quantifiable assessment of Connecticut shoreline trends from both a statewide and a localized perspective.

For each type of geographic area (by town and by shoreline district), the Connecticut shoreline change project data are presented as tables of values as well as charts. The tables provide numeric values of the minimum and maximum values for the change metrics (Net Shoreline Movement, End Point Rate, and Linear Regression Rate) as well as associated averages and uncertainty ranges. The charts provide a visual display of the actual change values along an axis representing the coast with common or unique places or landforms identified for context. In this way, users can see the progression and magnitude changes moving across the entire Connecticut coastline.

The causes of shoreline change can vary, but generally include:

- changes due to naturally-occurring trends given the specific physical characteristics of the area;
- changes due to a variety of man-made influences such as building structures that impede or restrict sediment transport, filling of wetlands, adding sand to nourish beaches, etc.; and
- a combination of both.

SHORELINE CHANGE STATISTICS

Shoreline "rate of change statistics" reflect a cumulative summary of the processes that altered the shoreline for the time period analyzed. **Figures 4-67 and 4-68** present the shoreline change statistics for the long-term and short term, respectively. The values calculated for Old Saybrook 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

Long-Term (1880 to 2006):

- Net Shoreline Movement:
  - Minimum: -67.5 meters
  - Maximum: 212.9 meters
  - Average: -4.3 meters
- End Point Rate (average): -0.03 meter/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

Long-Term (1880 to 2006):

- Net Shoreline Movement:
  - Minimum: -26.4 meter
  - Maximum: 258.3 meter
  - Average: 12.0 meter
- End Point Rate (average): 0.10 meter/year

The longterm effects of sea level rise on the beaches will be increased erosion and migration of barrier beaches and spits landward. The barrier beaches typically erode from the Long Island Sound side and will either: 1) wash overland and remain intact; or 2) break up and disappear (leaving open water and a shoreline at the current marsh boundary. Climate change may also have long term effects on the flow (and bedload sediment) of the Connecticut River, which in turn could affect long term beach shoreline change. Climate change can also result in long term changes to prevailing wind direction and velocity, which in turn would affect shoreline change.

Attachment 4: Vulnerability and Risk

In general, the beaches of Old Saybrook (consistent with almost all of Connecticut's beaches) are moving landward due to gradual sea level rise and the net effect of storms. 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.

The following presents a more detailed look at beach shoreline change in Old Saybrook.

Figure 4-67: Long Term Shoreline Change (meters/year)

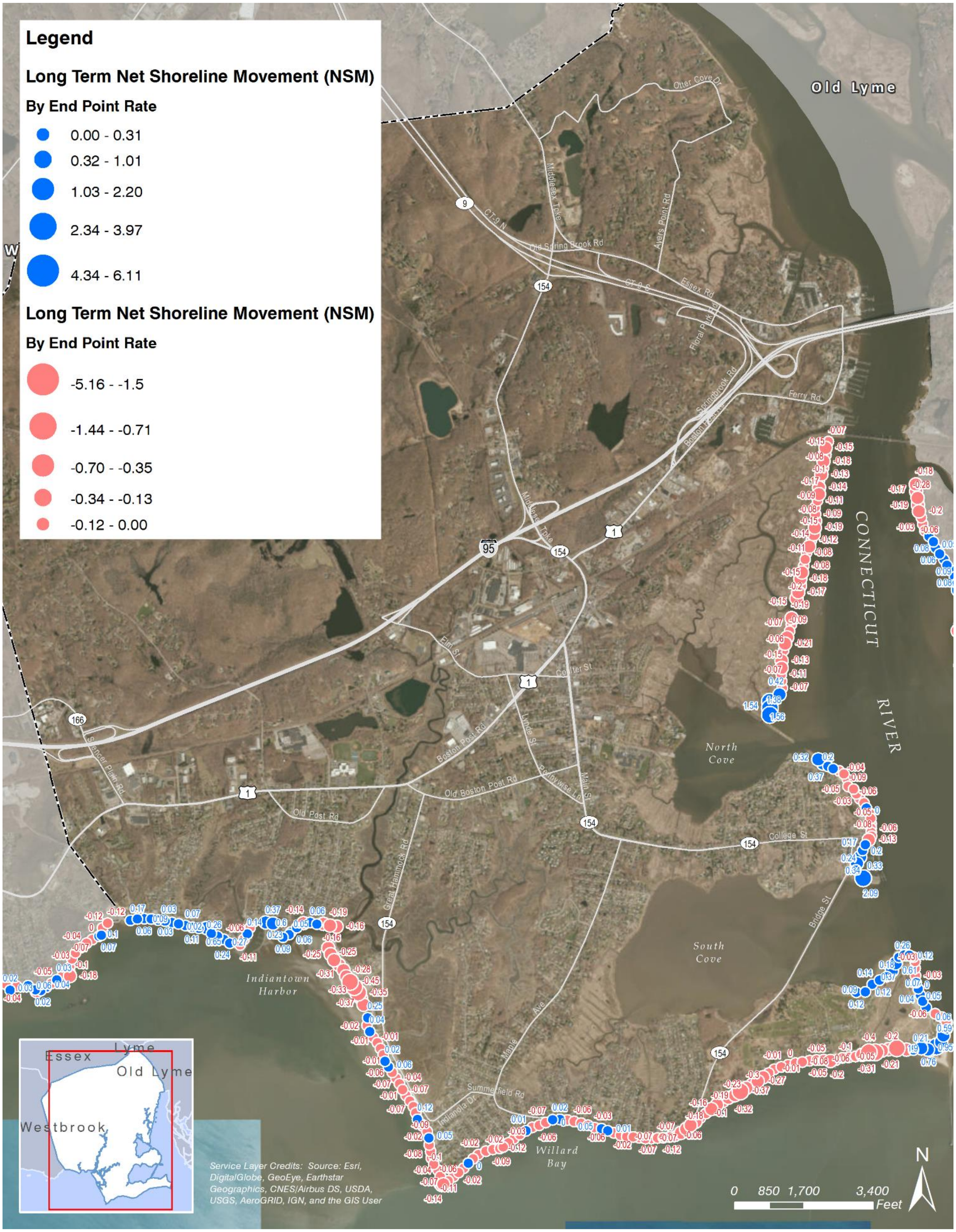
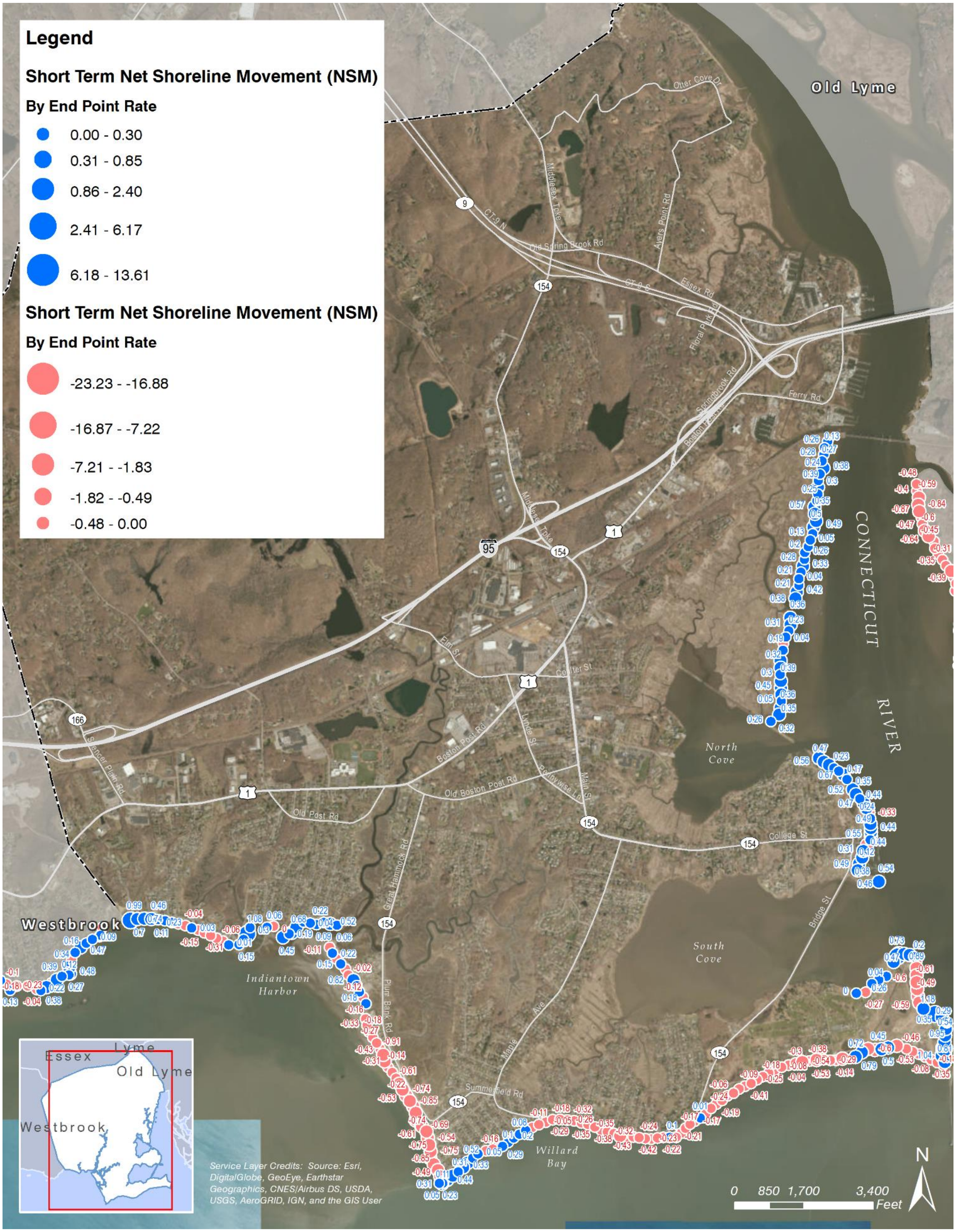


Figure 4-68: Short Term Shoreline Change (meters/year)



DETAILED REVIEW OF BEACH SHORELINE CHANGE

Figure 3-71 shows the NOAA navigation chart for the area, with bathymetry shown as depth below mean lower low water (MLLW).

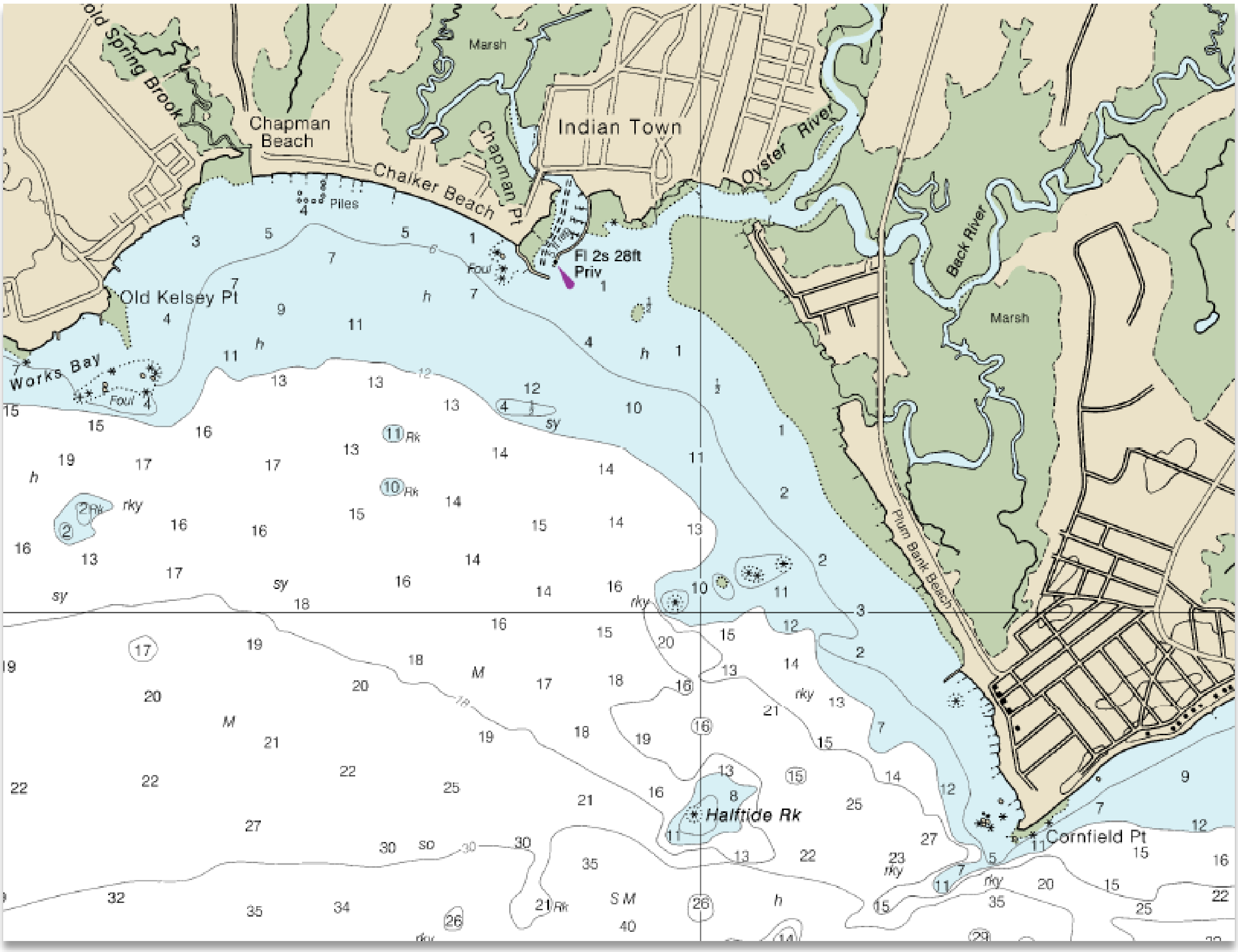
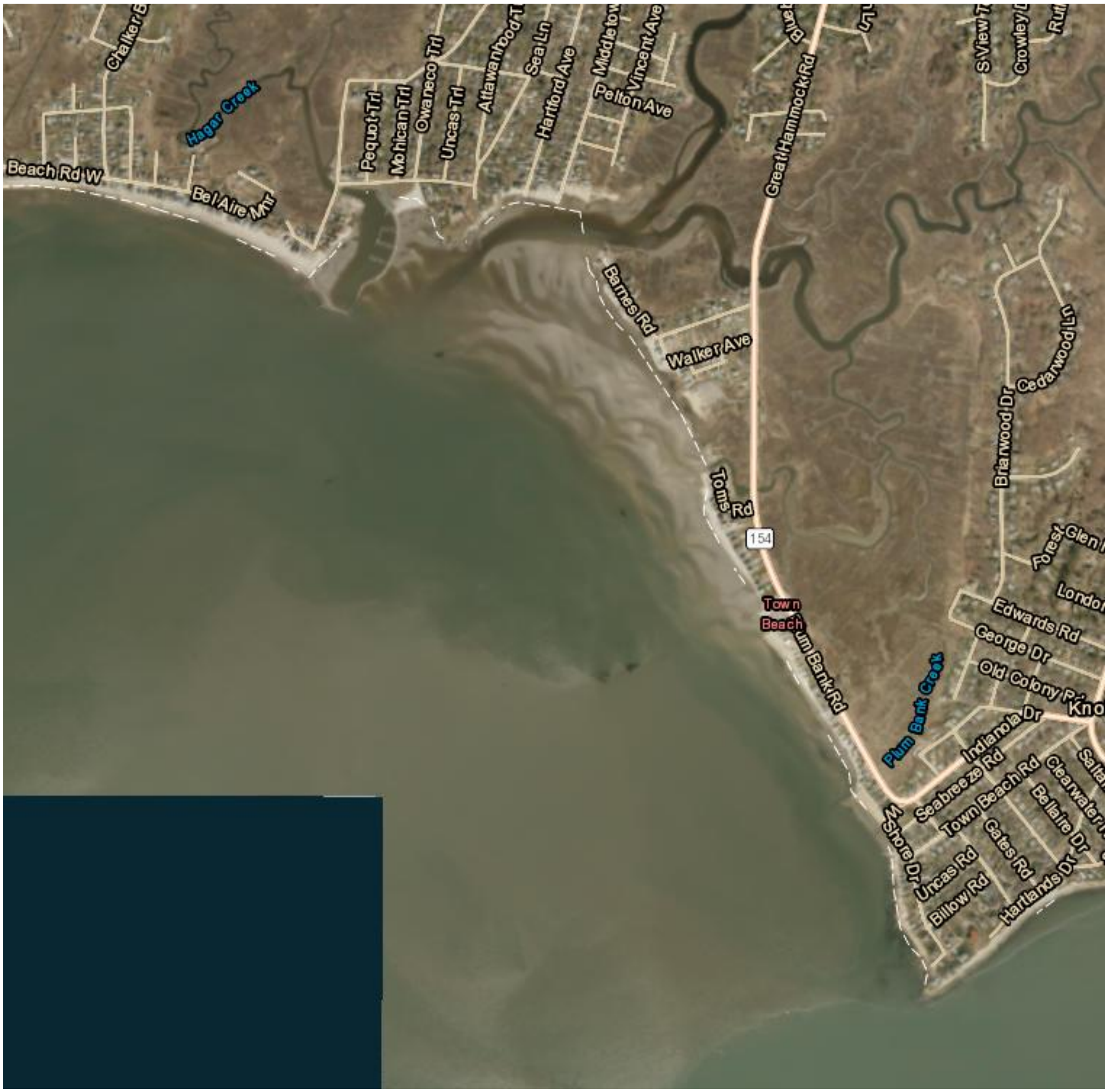


Figure 4-69: NOAA Navigation Chart

The NOAA navigation plot identifies some key feature of this stretch of shoreline. From Chalker Beach to Indian Town Beach, the shoreline faces south-southwest. The shoreline from Indian Town to Cornfield Point faces west-southwest. Around Indian Town and to the east of Indian Town, sediment transport is influenced by both coastal wave action and the effects of flow from Oyster River. There is a large area of tidal flat along the southwest-facing shore, south of Oyster River. As indicated above by shallow water depths, shallow deposits of sediment extend seaward about 800 feet from the shore and tidal flats. The shoreline has numerous shoreline structures, including small to large groins and the jetties at the inlet with Hager Creek. The nearshore topography is also characterized by shallow rock outcrops, in particular outcrops around Cornfield Point, Halftide Rock, the large set of outcrops that extend approximately perpendicular to the shore across from the Town Beach (Plum Bank Beach). The deeper water close to Cornfield Point (as well as wave transformation due to Cornfield Point) supports larger waves in the area between Cornfield Point and Plum Island Beach.

Figure 4-70 is a recent aerial photograph of this stretch of shoreline. The extent of shallow and nearshore suspended sediment is observable in this photograph. In particular, the influence of the rock outcrops (located perpendicular to the shoreline, across from the Town Beach) on wave attenuation and sediment distribution is apparent on sediment transport.

Figure 4-70: Aerial Photograph Showing Suspended Sediment Distribution



Figures 4-71 and **4-77** present aerial photographs and short-term (1983 – 2006) shoreline change statistics for the shoreline from Chalker Beach to Cornfield Point. For comparison, in Connecticut, erosion rates of about 1 foot per year or less are considered minor. Erosion rates on the order of 1 to 2 feet per year are considered moderate and erosion rates greater than 2 feet per year are considered severe.

Figure 4-71: Aerial Photograph and Short-Term Shoreline Change - Chalker Beach to Bel Aire Manor Beach

This stretch of shoreline is characterized by artificial fill placed within the marsh and estuarine beach deposits, with the beach characterized as a barrier spit. The shoreline is fortified with groins and sea walls. The upland ground surface elevation is about 4 to 6 feet NAVD88.

The calculated shoreline change rate along Beach Road, which indicates (on average) accretion, has likely been affected by repairs and modifications made to the groins during the period of record (around 1984). While the average shoreline change rates indicate accretion; minor to moderate erosion is expected to be the representative long term beach state. The shoreline change along Bel Aire Manor Road has been erosion. The observed net longshore sediment transport direction is locally variable, with a slight westward component.

Figure 4-72: Aerial Photograph and Short-Term Shoreline Change – Indiantown Beach to Old Saybrook Manor Beach

This stretch of shoreline is characterized by artificial fill placed within the marsh. The shoreline is fortified with groins, revetments and sea walls. This stretch of shoreline also includes the man-made inlet to Hager Creek, including the inlet jetties and dredged harbor/inlet channel. The upland ground surface elevation is about 4 to 6 feet NAVD88, and gets lower to the east and north to about Elevation 2 feet NAVD88 along Plum Bank Road. The nearshore area is characterized as dynamic tidal flat and estuarine beach. Sediment transport here is affected by both longshore currents and flow from Oyster River to the north.

The observed shoreline change is minor, with average change rates indicating accretion. The observed net longshore sediment transport direction is mixed and locally variable.

Figure 4-73: Aerial Photograph and Short-Term Shoreline Change – South of Oyster River

This stretch of shoreline is characterized by man-made fill placed within the marsh. The shoreline is fortified with groins, revetments and sea walls. The upland ground surface elevation is about 4 to 6 feet NAVD88, and gets lower to the east and north to about Elevation 2 feet NAVD88 along Plum Bank Road. The nearshore area is characterized as dynamic tidal flat and estuarine beach. Sediment transport here is affected by both longshore currents and flow from Oyster River to the north.

The observed shoreline change is minor. The observed net longshore sediment transport direction is mixed and locally variable.

Figure 4-74: Aerial Photograph and Short-Term Shoreline Change – Vicinity of Plum Bank Creek

This stretch of shoreline is characterized as a barrier spit (beach), marsh and man-made fill (to the north) and includes the mouth of Plum Bank Creek. The developed part of the shoreline is fortified with groins. For the most part, this shoreline consists of a low lying barrier spit, with the beach separating the marsh from Long Island Sound. The beach elevation high is about 10 feet NAVD88, and gets lower to the east to about Elevation 2 feet NAVD88 along Plum Bank Road. The nearshore area is characterized as dynamic tidal flat and estuarine beach.

The observed shoreline change in the vicinity of Plum Bank Creek is moderate erosion (average rates of about 1 to 1.5 feet per year. The observed shoreline change is typical of barrier spits which tend to erode and migrate landward into the marsh. Flow into and out of Plum Bank Creek prevents beach formation along the northern portion of shoreline shown here. This condition is also affected by the presence of the sea wall and groin/jetty at the creek mouth.

The observed net longshore sediment transport is to the north-northeast.

Figure 4-75: Aerial Photograph and Short-Term Shoreline Change – Town Beach

The observed shoreline change from the area of the Town Beach south to Cornfield Point is moderately to severely eroding (average rates of about 1.5 to 3 feet per year, with lessor rates to the immediate south of the Town Beach groins and a greater rate to the immediate north of the Town Beach north groin). Sediment is generally accreting to the south of the southern Town Beach groin and eroding north of the northern groin. North of the Town Beach, the average shoreline change is erosion at the rate of about 0.5 foot to 1.6 feet per year). The tidal flats expand in this area relative to the shoreline to the south. The observed shoreline change is typical of barrier spits which tend to erode and migrate into the marsh.

The observed net longshore sediment transport is to the north-northeast). Extensive rock outcrops are present across from the Town Beach, trending approximately east-west perpendicular to the beach, which have some impact on longshore sediment transport.

Figure 4-76: Aerial Photograph and Short-Term Shoreline Change – South of Town Beach

This stretch of shoreline is characterized as a barrier spit (beach). The shoreline is fortified with groins. For the most part, this shoreline consists of a low-lying barrier spit, with the beach separating the marsh from Long Island Sound. The beach elevation high is about 5 feet NAVD88, and gets lower to the east to about Elevation 2 feet NAVD88 along Plum Bank Road. This section also represents the southern extent of tidal flats, with a small section of tidal flat present. The shoreline change transects indicate that the current shoreline is located about midway between the observed extremes over the period of analysis (1983 to 2006). That is, during this period, the shoreline has been in a more eroded condition than currently observed and that both accretion and erosion has occurred, with the average shoreline change condition at a rate of about 1.5 to 2.5 feet per year. The observed direction of longshore sediment transport is to the north-northwest.

Figure 4-77: Aerial Photograph and Short-Term Shoreline Change – Near Cornfield Point

This stretch of shoreline is characterized predominantly as glacial moraine bluff. The topography ranges from Mean Sea Level at the beach to about Elevation 10 to 12 feet NAVD88 in the bordering upland areas. The shoreline is also fortified with revetments and groins, as well as natural rock outcrops. The shoreline change transects indicate that the current shoreline is located about midway between the observed extremes over the period of analysis (1983 to 2006). That is, during this period, the shoreline has been in a more eroded condition than currently observed and that both accretion and erosion has occurred, with the average shoreline change condition at a rate of about 1.5 to 2.5 feet per year. The observed direction of longshore sediment transport is to the north-northeast.

Figure 4-78: Aerial Photograph and Short-Term Shoreline Change – Cornfield Point to Fenwick

The shoreline from Cornfield Point to Fenwick is characterized by moraine and glacial drift bluffs. The elevation of the upland areas are generally 15 to 20 feet NAVD88. The shoreline is fortified in certain areas with revetments (e.g., along Maple Avenue Route 154) and the beaches are primarily pocket beaches between natural promontories and groins. The beaches range from medium grained sand to gravel with cobbles, typical of glacial drift and moraine bluff material sources.

As shown of **Figure 4-78**, the average shoreline change rates indicate minor to moderate erosion and accretion (less than 0.5 foot per year to 1.5 feet per year). The direction of longshore sediment transport is variable locally but generally is to the east-northeast. Areas with beaches are generally eroding. Areas with revetments (such as along Maple Avenue) have eroded to the base of the revetment.

CONCLUSIONS AND RECOMMENDATIONS

Old Saybrook beaches include: 1) barrier spits, separating the marsh from Long Island Sound, from Chalker Beach to just north of Cornfield Point; and 2) pocket beaches between shoreline structures and natural promontories, from Cornfield Point to Old Saybrook Point. The shoreline has been heavily fortified by hard shoreline structures including groins, revetments and seawalls.

Both types of shoreline identified above general face south-southwest and are exposed to long fetches and Long Island Sound waves. The prevailing wind and wave direction, affecting longshore sediment transport, is from the southwest. The direction of longshore sediment transport from Cornfield Point to Indian Town is typically to the north-northeast. The direction of sediment transport from Indian Town to Chalker Beach (including Chalker Beach), varies locally. The direction of sediment transport along the shoreline from Cornfield Point to Old Saybrook Point varies locally but is generally to the east-northeast.

Shoreline change along the Town's Long Island Sound shorelines is due to both: 1) long-term erosion (with localized areas of beach accretion); and 2) episodic erosion due to coastal storms (with combined flood and waves). Due to the increased storm and wave activity during the Fall and Winter, beach profiles may change seasonally from an eroded "winter" beach to a fuller "summer" beach; however, this seasonal effect is less prominent along Long Island Sound compared to beaches that are directly exposed to the Atlantic Ocean.

The morphology of the shoreline extending from Chalker Beach (including Chalker Beach) to just north of Cornfield Point consists predominantly of barrier spits (beaches) and marsh. The barrier spits are separated by river and creek inlet channels, creating large areas of shallow sediment and tidal flat in the vicinity of these features. Certain portions of this stretch of shoreline also include artificial fill placed within former marsh. Barrier spit and marsh morphologies are, by nature, very dynamic. Absent man-made structures, the natural morphological change consists of: 1) migration of the barriers spits inland over the marsh; 2) dynamic movement of the river and creek inlets; and 3) dynamic movement of shallow sediment areas/tidal flats.

This type of shoreline is generally characterized by erosion and dynamic movement of sediment. Sea level rise will accelerate the natural landward movement of the barrier spits. The shoreline, however, has been heavily modified by: 1) construction of hard shoreline structures, in particular groins designed to interrupt longshore transport; 2) development with roads and houses; and 3) placement of artificial fill. Although these structures affect the natural coastal processes, they do not, on net, prevent the natural tendency of the shoreline toward dynamic movement change and often increase erosion. The groins have been successful in trapping sand locally, but overall they drastically impact the natural longshore sediment transport. In addition, the overall availability of sediment is diminished within Long Island Sound.

The net, long term effect for the Old Saybrook shoreline including Chalker Beach to just north of Cornfield Point is long term, moderate (1 to 2 feet per year) erosion of the beaches with highly impactful, episodic erosion associated with coastal storm flooding and wave action. Sea level rise will amplify and accelerate shoreline change. Inadequate sediment supply to replace alongshore and offshore transport will require beach nourishment to mitigate erosion. The morphology of the shoreline extending from Cornfield Point to Old Saybrook Point consists of glacial moraine and drift bluffs. Major sections of shoreline are fortified with revetments. The average shoreline change rates indicate minor to moderate erosion and accretion (less than 0.5 foot per year to 1.5 feet per year). Under a natural setting, the glacial drift deposits provide a source of beach sediment. Under a developed setting, such as the Old Saybrook shoreline, revetments and seawalls: 1) eliminate this sediment source; and 2) create wave reflection and erosion, such that the shoreline erodes to the base of the revetment or sea wall.

Appendix A

Wastewater Treatment Coastal Flood Risk Memorandum

FINAL Memorandum -

Old Saybrook Wastewater Management District

This memorandum presents coastal flood information relevant to the Old Saybrook Wastewater Management District, including tides, sea level rise and storm surge and waves. This information is presented for planning purposes. Additional analyses, including detailed numerical modeling, are recommended for design once additional system details are available. This memorandum has also been included as part of GZA Old Saybrook Coastal Resilience Study report.

Background

Town residents and businesses are currently serviced exclusively by on-site septic systems. The Town established a Decentralized Wastewater Management District (WWMD) in August, 2009 for the purpose of protecting the public health and the environment through improvements to the treatment of wastewater (per Article II of Chapter 173). Decentralized wastewater management approaches seek to deal with wastewater needs closer to the source of wastewater generation using smaller, dispersed (decentralized) treatment and disposal/recharge methods. This keeps the wastewater management more local than sewer approaches which tend to centralize treatment and discharge. Enhancing the existing on-site wastewater systems through the use of a Decentralized Wastewater Management Program (DWMP) proactively upgrades certain on-site systems and increases the extent of management of these systems.

The Town adopted: 1) WWMD boundaries that include approximately 1900 lots located within 15 neighborhood focus areas; and 2) Upgrade Program Standards for improvements. The areas were selected primarily based on physical characteristics such as density of houses, proximity to water bodies and marshes and shallow depth to groundwater.

The Upgrade Program Standards specify the types of improvements required for existing septic systems as part of the DWMP. The type of upgrades required for a given lot are, generally, based on the adequacy of the current septic system to meet current Public Health Code (PHC) requirements with a few modifications to enhance protection of the environment. Upgrades may be similar to conventional septic systems or they may include advanced treatment systems. Newer code-compliant septic systems typically will not need to make any modifications. Advanced Treatment (NI) systems will be required on 400 to 500 properties, for two main reasons: 1) where lots are very small and cannot accommodate the leaching area required by the PHC for the number of bedrooms and the soil characteristics on a given lot (the DEEP has agreed that properties with two-thirds or more of the required leaching area may remain if depth to groundwater is adequate); and 2) all waterfront lots. For purposes of this program, waterfront means any lot that abuts a surface water body (e.g., river or Long Island Sound), but does not include lots abutting marshes or other wetlands.

The Town has applied a phased approach to the implementation of improvements to existing on-site septic upgrades with an estimated nine-year expected build-out. The 15 neighborhood focus areas located within the WWMD include:

- Chalker Beach
- Meadow Brook
- Indiantown
- Saybrook Manor
- Great Hammock Beach
- Plum Bank
- Oyster River East
- Cornfield Point
- Cornfield Point Park
- Fenwood
- Saybrook Acres
- Maple Avenue North

- Saybrook Point
- Ingham Hill
- Thompson

As of 2016, the program is in the 2nd Phase with over 500 on-site septic systems installed and over 800 designated "Upgrade Compliant" that include on-site septic systems in 10 of the 15 focus areas.
(Reference https://www.oswpca.org/).

The Town is in the process of conducting a study “Old Saybrook Wastewater Pollution Control Authority [WPCA]) Draft Study” (2016-17) to evaluate the use of a Community System to improve the remaining 800 systems. These 800 properties are located in 5 focus areas all of which include high numbers of residential properties located on Long Island Sound that will be the most vulnerable to future saltwater intrusion as sea levels rise from groundwater infiltration. The focus areas include:

- Chalker Beach
- Great Hammock Beach
- Indiantown
- Plum Bank
- Saybrook Manor

The study will include a cost and feasibility evaluation of following three options:

1. On-site Repairs
2. Community System(s) with dispersal of wastewater into the ground
3. Community System(s) with dispersal of wastewater into the Connecticut River

The locations of the neighborhood focus areas and the potential effluent disposal areas are shown in Attachment 1 (figures prepared by Wright-Pierce). Community systems will require the use of sanitary residential piping, municipal underground piping, municipal pump stations and municipal disposal locations. Effluent disposal is currently planned to utilize leach fields.

Climate Change and Coastal Resilience Issues

Climate change and coastal resilience must be considered in evaluation of the existing systems as well as design and construction of the proposed new systems. Issues include:

- Flood vulnerability of alternative wastewater treatment and disposal systems.
- The effectiveness of, and limitations with, on-site septic systems, including municipal leach fields, located in areas with shallow groundwater and increasing groundwater elevations due to sea level rise, in particular in areas with small lots (prohibiting mounded leach fields).
- Groundwater and surface water quality impacts due to inadequately treated effluent (nitrogen, bacteria).
- Changes in water chemistry (i.e., pH, salt content, dissolved oxygen).
- Increased precipitation.
- Scour and erosion of beach communities, resulting in damage to utilities.

Coastal Flooding

To evaluate the coastal flood hazards affecting the WWMD, GZA performed:

1. a metocean analysis of observed wind, wave and water level data;
2. review of published flood hazard data including the Federal Emergency Management Agency (FEMA) effective Flood Insurance Rate Map (FIRM) and the FEMA Flood Insurance Study (FIS), the National Oceanic and Atmospheric Agency (NOAA), tide gage data and the U.S. Army Corps of Engineers (USACE) North Atlantic Coast Comprehensive Study (NACCS);

3. review of USACE and National Oceanic and Atmospheric Agency (NOAA) sea level rise projections; and
4. numerical hydrodynamic modeling of tides, storm surge and waves using the Advanced Circulation Model (ADCIRC) and the Simulating WAves Nearshore (SWAN) models.

The results of the coastal flooding analysis are presented in GZA's Old Saybrook resilience Study report. The following summarizes key findings relevant to the Wastewater Management District and effluent disposal areas.

Tides and Sea Level Rise

Projected sea level rise and tidal elevations in the vicinity of Old Saybrook were developed using data from the New London NOAA tide gage. The historical tide gage data indicate a mean sea level rise trend of 2.55 millimeters (mm) per year (about 0.1 inch per year) (with a 95% confidence interval of +/- 0.23 mm per year).

Over the most recent 25 years, the data indicates that the mean rate of sea level rise is increasing and the rate of sea level rise is predicted to increase further. The predicted sea level rise at New London (the closest NOAA tide station to Old Saybrook), between the years 2016 and 2116, are summarized in Table1, below:

Table 1 - Sea Level Rise Projections at Old Saybrook (using the USACE Sea Level Rise Calculator at New London, in feet)

Year	NOAA (LOW)	USACE (LOW)	NOAA (INT-LOW)	USACE (INT)	NOAA (INT-HIGH)	USACE (HIGH)	NOAA (HIGH)
2016	-	-	-	-	-	-	-
2041	0.07	0.07	0.29	0.29	0.78	1.00	1.35
2066	0.25	0.25	0.75	0.75	1.86	2.34	3.13
2116	0.62	0.62	2.01	2.01	5.09	6.42	8.60

These projections were developed using the USACE Sea Level Rise Calculator (version 2017.42) and are based on USACE 2013/NOAA 2012 projections. NOAA sea level rise projections were revised subsequent to completion of GZA's analysis. The 2017 NOAA projections are presented in Figure 1 and Table 2. Based on different emissions models, the USACE Intermediate projections are predicted (at this time) to have a high probability of occurrence (about 50 to 100 percent). The USACE High projections have a low to moderate probability of occurrence (about 1 to 17 percent). For mid-term risk (say, over the next 35 years), the USACE Intermediate projection is a reasonable "lower bound" for flood mitigation sea level rise planning and the USACE High is a reasonable "upper bound". However, recent observations and modeling of accelerated ice loss from Greenland and Antarctica indicate that the 2017 NOAA High to Extreme projections (or higher) are possible by the year 2117.

Figure 1 - NOAA 2017 Sea Level Rise Projections at New London, in feet relative to NAVD88

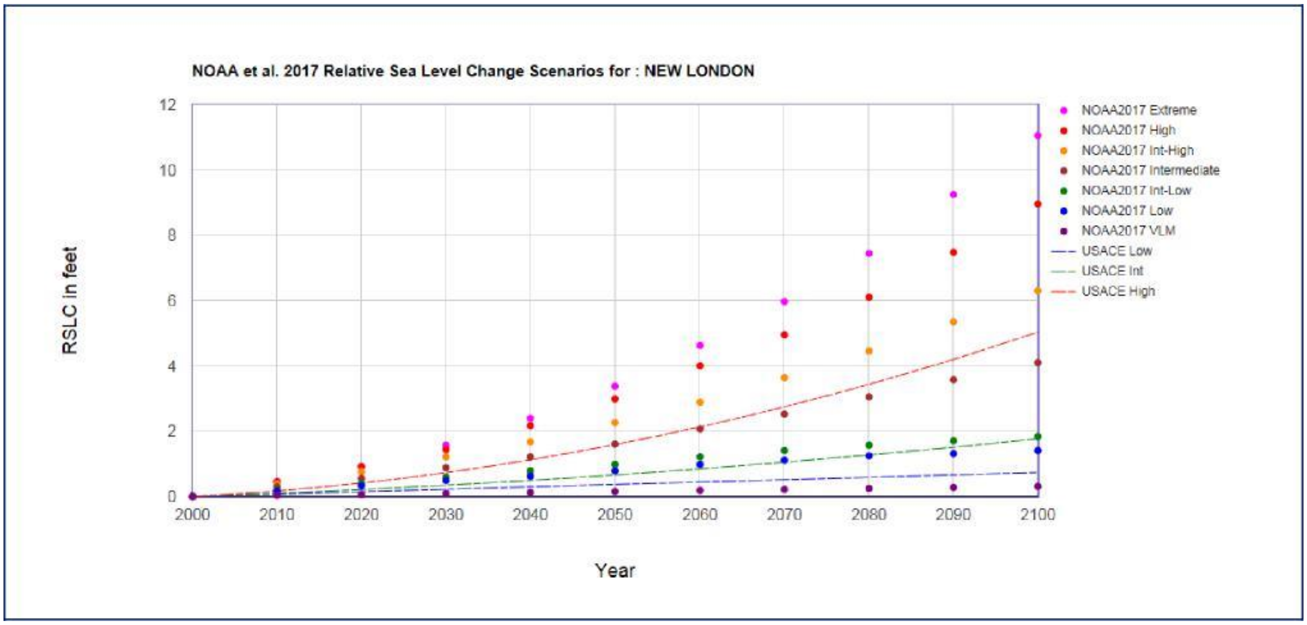


Table 2 - NOAA 2017 Sea Level Rise Projections at New London, in feet relative to NAVD88

Scenarios for NEW LONDON
NOAA2017 VLM: 0.00308 feet/yr
All values are expressed in feet

Year	NOAA2017 VLM	NOAA2017 Low	NOAA2017 Int-Low	NOAA2017 Intermediate	NOAA2017 Int-High	NOAA2017 High	NOAA2017 Extreme
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	0.03	0.16	0.20	0.30	0.39	0.46	0.46
2020	0.06	0.33	0.39	0.56	0.75	0.92	0.92
2030	0.09	0.49	0.59	0.89	1.21	1.44	1.57
2040	0.12	0.62	0.79	1.21	1.67	2.17	2.40
2050	0.15	0.79	0.98	1.61	2.26	2.99	3.38
2060	0.19	0.98	1.21	2.07	2.89	4.00	4.63
2070	0.22	1.12	1.41	2.53	3.64	4.95	5.97
2080	0.25	1.25	1.57	3.05	4.46	6.10	7.45
2090	0.28	1.31	1.71	3.58	5.35	7.48	9.25
2100	0.31	1.41	1.84	4.10	6.30	8.96	11.06

Assuming linear superposition of sea level rise on the current tides, the current and predicted changes to the tidal elevations at Old Saybrook due to sea level rise are presented in Table 3 for the years 2042, 2067 and 2117.

Table 3 - NOAA 2017 Sea Level Rise Projections at New London, in feet relative to NAVD88

Tidal Datums (ref. feet, NAVD88)	Current	2041			2066			2116		
		High SLR	Int SLR	Low SLR	High SLR	Int SLR	Low SLR	High SLR	Int SLR	Low SLR
MSL	-0.3	0.7	-0.01	-0.23	2.04	0.45	-0.05	6.12	1.71	0.32
MHW	0.92	1.92	1.21	0.99	3.26	1.67	1.17	7.34	2.93	1.54
MHHW	1.21	2.21	1.5	1.28	3.55	1.96	1.46	7.63	3.22	1.83
HAT	2.04	3.04	2.33	2.11	4.38	2.79	2.29	8.46	4.05	2.66
MLW	-1.65	-0.65	-1.36	-1.58	0.69	-0.9	-1.4	4.77	0.36	-1.03
MLLW	-1.84	-0.84	-1.55	-1.77	0.5	-1.09	-1.59	4.58	0.17	-1.22

Extreme Coastal Flood Events

Extreme coastal flooding, including storm surge and waves, were also evaluated including the effects of sea level rise. Attachment 2 presents the typical predicted nearshore 100-year and 500-year return period flood elevations in the vicinity of Old Saybrook (2017 through 2117) and the modeled 100-year and 500-year flood elevations at the five Community System neighborhood focus areas (2016 through 2116).

The modeled significant wave heights and wave crest elevation (feet NAVD88) at the five Community System neighborhood focus areas are also presented for the 100-year and 500-year return period flood events during 2016.

Coastal Flood Vulnerability

Figure 2 presents the limits of flood inundation during the Mean Higher High Water (MHHW) tide during the years 2016 through 2116. Figure 3 presents the flood hazard zones based on the effective FEMA Flood Insurance Rate Maps. Figure 4 presents the limits of flood inundation (floodplain) during the 500-year return period flood during the years 2016 through 2116. Attachment 2 presents predicted and modeled stillwater flood elevations, wave heights and wave crest elevations.

The stillwater flood elevation refers to the water flood elevation in the absence of waves. The wave crest elevation refers to the maximum water level associated due to both stillwater and wave height. Wave heights greater than 3 feet are associated with significant structure damage and storm-related beach erosion and scour. Wave heights between 1.5 and 3.0 feet can also result in some building damage and moderate beach storm-related beach erosion.

Wastewater system planning for flooding and sea level rise typically utilizes a risk-informed approach. TR-16 “Guides for Wastewater Treatment Works” (2016 revisions) include the following criteria:

- Watertight manholes should be used when located within the 100-year return period floodplain. Alternatively, raise manholes above the 100-year flood level.
- New treatment plants and pump stations should: 1) provide for uninterrupted operation of all units during the 100-year return period flood; and 2) be placed above, or protected against, the structural, process and electrical equipment damage that might occur in an event that results in a water elevation above the 100-year return period flood.
- Critical equipment should be protected against damage up to a water surface elevation of 3 feet above the 100-year return period flood elevation and non-critical equipment should be protected against damage up to a water elevation of 2 feet above the 100-year return period flood elevation.
- Certain agencies may also require, as a minimum, that flood protection be required to the 500-year return period flood, if greater.

ASCE 24-14 “Flood Resistant Design and Construction” also provides flood protection criteria for critical public utilities (considered Flood Design Class 4):

- Coastal High Hazard Areas and Coastal A Zones Bottom of Lowest Supporting Horizontal Structural Member): Base Flood Elevation plus 2 feet or the 500-year flood
- A-Zone (Elevation of Top of Lowest Floor): Base Flood Elevation plus 2 feet or the 500-year flood

To apply these criteria to Old Saybrook for the current sea level conditions:

- Use the 100-year wave crest elevations (presented in Attachment 2 where Base Flood Elevations are referred to in regulation and guidance.
- Use the 500-year stillwater elevations presented in Attachment 2.

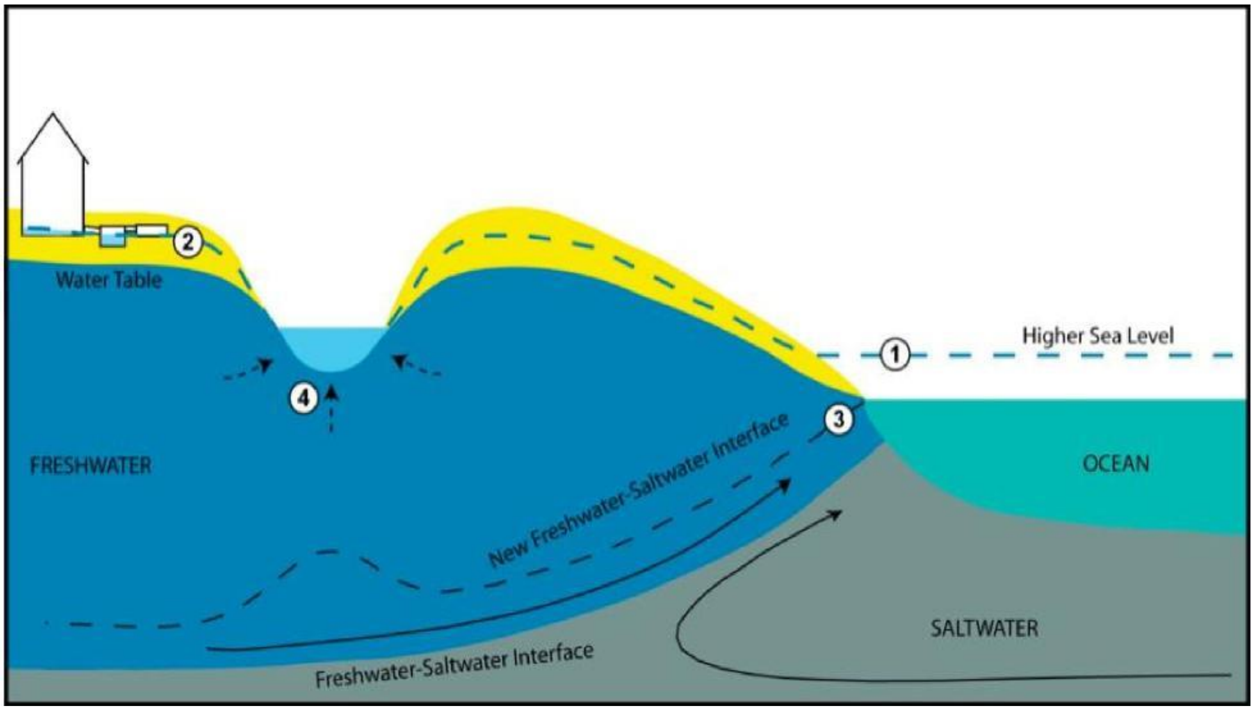
In general, all of the Wastewater Management Districts are located with coastal floodplains (see Figures 3 and 4). The effluent discharge sites currently under consideration are impacted as follows:

- Site 29 - Gardella Property (Mulchaey Rd):
    - Located within effective FEMA 100-year and 500-year flood hazard zones
    - Located just outside GZA modeled 100-year and 500-year flood limits
- Site 31 - Spencer Plain Rd:
    - Located outside effective FEMA 100-year and 500-year flood hazard zones
    - Located outside GZA modeled 100-year and 500-year flood limits
- Sites 36 and 42 - On Ingham Hill Rd D:
    - Located outside effective FEMA 100-year and 500-year flood hazard zones
    - Located outside GZA modeled 100-year and 500-year flood limits
- Site 38 - Roam Tree Road:
    - Located outside effective FEMA 100-year and 500-year flood hazard zones
    - Located outside GZA modeled 100-year and 500-year flood limits
- Sites 1 and 2 (High School and Donnelly Property:
    - Portions located within effective FEMA 500-year return period flood hazard zone
    - Portions located within GZA modeled 500-year flood limits
    - The parking lot at the Old Saybrook High School is flooded but the buildings and the effluent site locations # 1 and 2 remain unflooded.
- Site 18 Fenwick Golf Course:

- Portions located within effective FEMA 100-year and 500-year return period flood hazard zone
- Portions located within GZA modeled 100-year and 500-year flood limits

Predicted Effects of Sea Level Rise on Groundwater Elevations

A rise in sea-level can affect ground-water elevations and flow in coastal aquifers such as those at Old Saybrook. An increase in the elevation of the water table (see dashed–blue line in the figure, below) may result in flooding and compromise on-site, subsurface septic systems. A rise in sea level may also result in an upward and landward shift in the position of the freshwater-saltwater interface. Where streams are present, an increase in the water-table elevation also may increase ground-water discharge to streams and result in local changes in the underlying freshwater-saltwater interface.



The approximate depth to groundwater at the Wastewater Treatment Districts is summarized in the table below (from 2009 study).

Old Saybrook Wastewater Facilities Plan
Summary of Study Area Characteristics
Table 4-1

Study Area	Current No. of Dev Properties	From 1998 Phase I - Refinement of Study Areas Report No. of Properties	No. of Dev Properties	Total Acreage	Typ Lot Size, ac	% Seasonal	Ave Depth to GW	Est WW Flow, gpd	Fut WW Flow, gpd
Chalker Beach	247	263	252	82	0.25	60	1.58	48,500	49,000
Indiantown	178	233	184	78	0.20	46	2.84	35,200	36,000
Saybrook Manor	240	300	252	115	0.15	30	4.22	47,500	48,000
Great Hammock Beach	79	96	80	17	0.16	88	4.15	15,400	16,000
Plum Bank (2)	77		80					13,700	14,000
Cornfield Point	305	361	319	65	0.15	38	14.44	59,500	60,000
Cornfield Park	98	98	98	25	0.20	38	1.05	18,900	19,000
Maple Ave. North	197	253	202	96	0.25	6	6.82	37,900	39,000
Saybrook Point	35	38	35	15	0.40	11	13.68	6,700	7,000
Fenwood	116	117	116	40	0.25	2	10.68	22,300	23,000
Saybrook Acres	104	107	168	58	0.30	0	6.20	20,200	21,000
Oyster River East	79	91	78	57	0.04	33	6.28	15,000	16,000
Meadowood	73	79	74	53	0.30	25	4.44	13,900	15,000
Ingham Hill	23	20	19	13	0.20	0	4.81	3,500	4,000
Thompson	47	62	52	30	0.40	12	3.48	10,000	11,000
Totals (3)	1898	2118	2009	744				368,200	378,000

Notes: 1. The number of developed properties differs between current and 1998 counts due to refinements in study area limits.
2. Plum Bank was a late addition/breakout in the 1998 report, and not all the data were developed at that time
3. Totals for no. of properties and total acreages do not include Plum Bank.

A 2002 well survey (2009 study) indicates the following additional groundwater depth data. Note that Table 1 of Appendix B of the 2002 well survey report was not available to GZA.

Study Area	Mean Depth to Groundwater	Depth to Groundwater Maximum	Depth to Groundwater Minimum
Meadowood	2.71	2.72	2.70
Oyster River East	6.75	10.44	4.44
Saybrook Acres	5.16	6.84	4.26
Cornfield Park	10.09	13.91	7.89
Cornfield Point	15.86	19.22	11.83
Maple Ave North	6.57	11.28	3.35
Saybrook Point	18.25	19.50	17.00
Ingham Hill	NA	4.72	NA
Fenwood	12.97	15.85	9.87
Thompson	3.15	3.20	3.10
Great Hammock	2.98	4.90	1.05
Plum Bank	3.10	3.93	2.27

Detailed groundwater modeling is required to predict changes to groundwater elevation and water quality. Recent USGS analyses at Cape Cod indicate that there is an approximately 1:3 ratio of groundwater rise to sea level rise. However, given the high permeability of the Old Saybrook low beach communities and close proximity to the shoreline, the low beach communities may experience groundwater increases between 1:1 and 1:3 ratios.

Based on the observed groundwater elevations and the predicted sea level rise, on-site septic systems are expected to be unusable at the low beach communities unless upgrades are made using a viable advanced treatment system.

Predicted Beach Erosion and Scour

Beach erosion and scour, both chronic and episodic (coastal storm-related) can result in damage to underground piping, manholes, pump stations, etc. The low beach communities are most vulnerable to erosion and scour, in particular beach area located along Long Island Sound.

GZA has not performed detailed erosion and scour analyses. However, general conclusions are made relative to erosion and scour vulnerability:

- As shown on Figure 5, Plum Bank and portions of Great Hammock Beach and Indiantown beaches are chronically eroding, at an approximate rate of 0.1 to 0.9 meters per year.
- Significant storm-related scour should be anticipated during the 100-year and 500-year return period flood events. Wave heights on the order of 4 to 6 feet are predicted. These wave heights, along with storm surge, can result in lateral loss of beach on the order of 50 to 150 feet and vertical scour on the order of 5 to 10 feet.
- Existing shoreline protection is intermittent and, in general. Inadequate to resist 100-year and 500-year return period flood events. However, the presence of shoreline protection will affect the location and extent of beach erosion and scour.
- Sediment transport modeling should be performed during design to better predict scour and erosion.

Conclusions and Recommendations

Coastal flooding, including the effects of sea level rise, will affect the performance of wastewater treatment infrastructure and should be considered during design, construction and operation. Predictions of sea level rise and extreme flood conditions (including water levels and waves) are presented in this memorandum. Potential effects include:

- Coastal flood inundation as characterized by predicted stillwater elevations and wave crest elevations, including flood loads.
- Wave effects resulting in wave loads, scour and erosion, as characterized by wave heights.
- Damage, including corrosion, due to salt water and sea spray exposure.
- Increasing groundwater elevations due to sea level rise.
- Changes to water salinity related to inland migration of the freshwater/saltwater interface, due to sea level rise.
- Changes in water chemistry due to increased sea water acidity and reduced pH.

Wastewater system planning and design for flooding and sea level rise should utilize a risk-informed approach, as defined by regulation and industry design guidance:

- Critical equipment should be protected against damage up to a water surface elevation of 3 feet above the 100-year return period flood elevation and non-critical equipment should be protected against damage up to a water elevation of 2 feet above the 100-year return period flood elevation.
- Certain agencies may also require, as a minimum, that flood protection be required to the 500-year return period flood, if greater.

In general, all of the Community System neighborhood focus areas are located with coastal floodplains (see Figures 2 and 3). Most, but not all, of the effluent discharge sites currently under consideration are located outside coastal flood zones. To apply the flood protection criteria presented above, for the current sea level conditions:

- Use the 100-year wave crest elevations (presented in Attachment 2 where Base Flood Elevations are referred to in regulation and guidance.
- Use the 500-year stillwater elevations presented in Attachment 2.

Based on the observed groundwater elevations and the predicted sea level rise, on-site septic systems are expected to be unusable at the low beach communities unless mounded systems are used.

In general, the risk of scour and erosion is very high within the low beach communities and should be a design consideration of all wastewater treatment infrastructure. The location of underground piping and infrastructure should be away from the beach side and all piping should be designed to be structurally supported in the event of scour and resistant to flood loads (hydrostatic, hydrodynamic, wave and debris impact loads).

It is recommended that:

1. Future groundwater elevations and water chemistry be considered during planning and system design. Numerical modeling is recommended to better predict groundwater elevation and water chemistry changes. Groundwater elevations and water chemistry should also be monitored on an annual basis to identify future changes with sea level rise.
2. System design should take into account the current and future predicted flood inundation limits and elevations and be consistent with industry design guidance and regulations, including a design basis using current and future (over system design life) 100-year and 500-year return flood elevations and designated freeboard.
3. System design, including electrical components, should consider the effects of salt water and salt spray.
4. Systems should be designed to resist flood loads, including hydrostatic, hydrodynamic, wave and debris impact loads.
5. Locations of systems within the low beach communities should plan for long-term beach erosion.
6. Locations of systems within the low beach communities should plan for episodic, storm-related beach erosion and scour, and scour protection should be provided.

Figure 2 - Predicted Mean Higher High Water, in feet relative to NAVD88

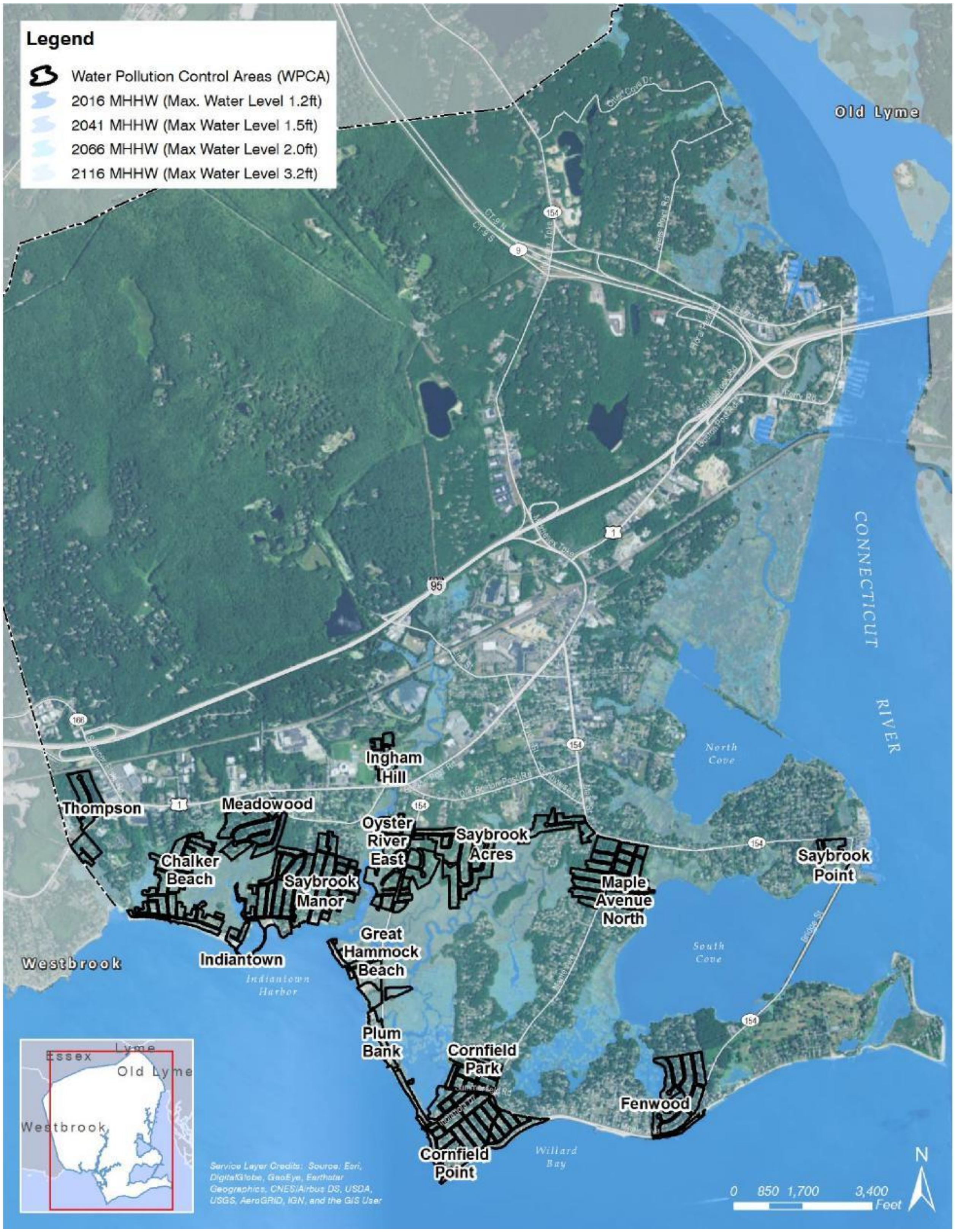


Figure 3 - Effective FEMA Floodplain

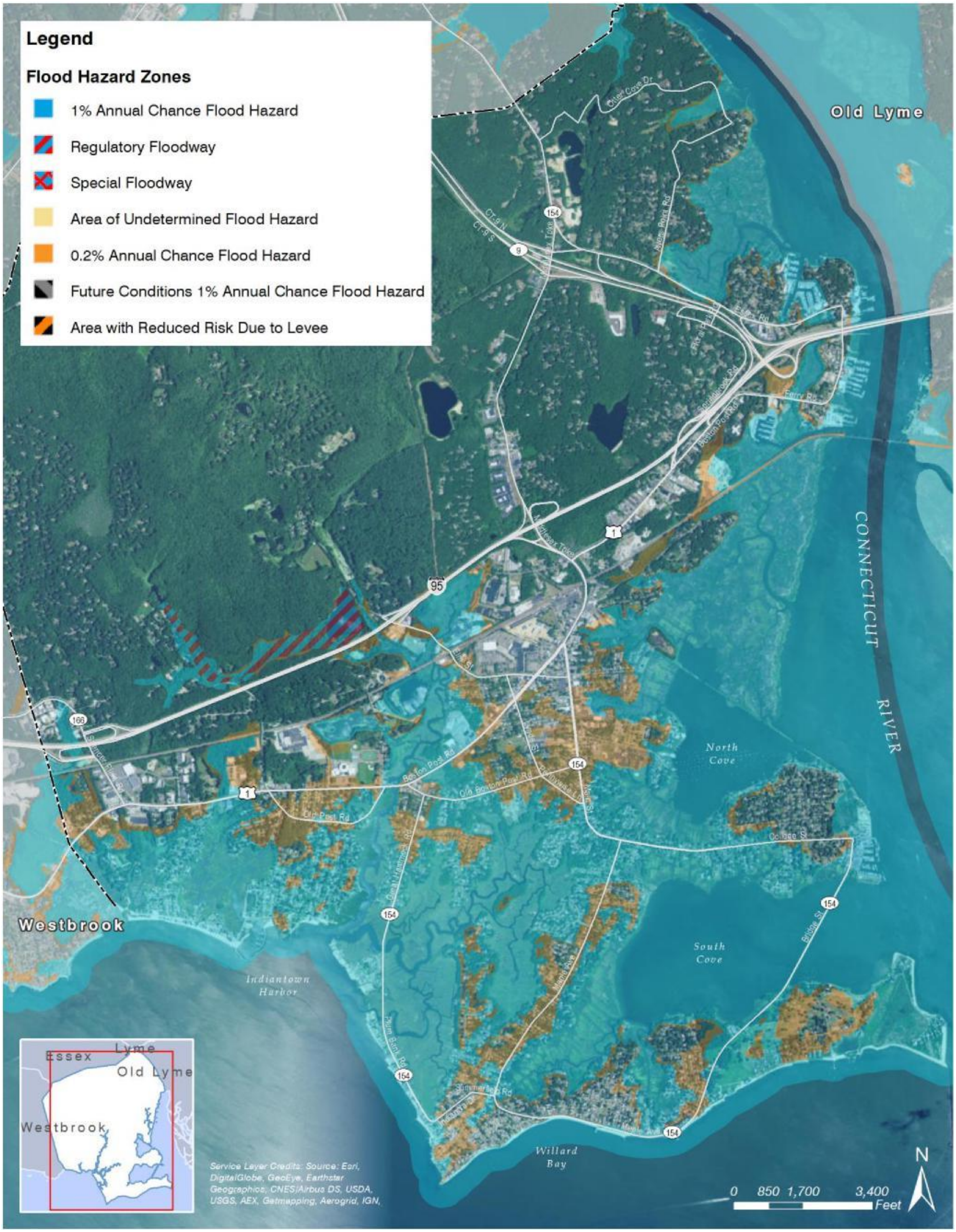


Figure 4 – Modeled 500-year return period flood limits

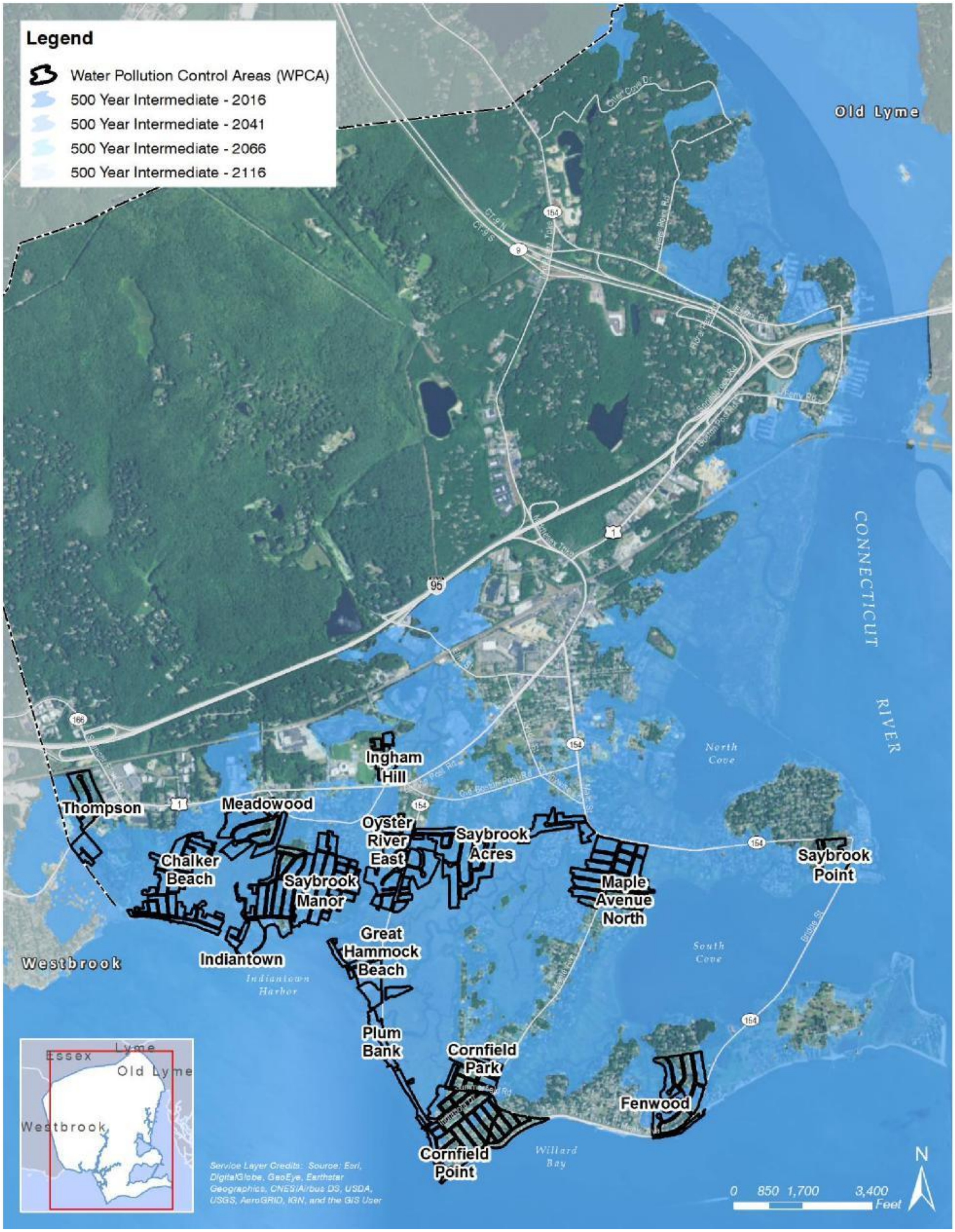
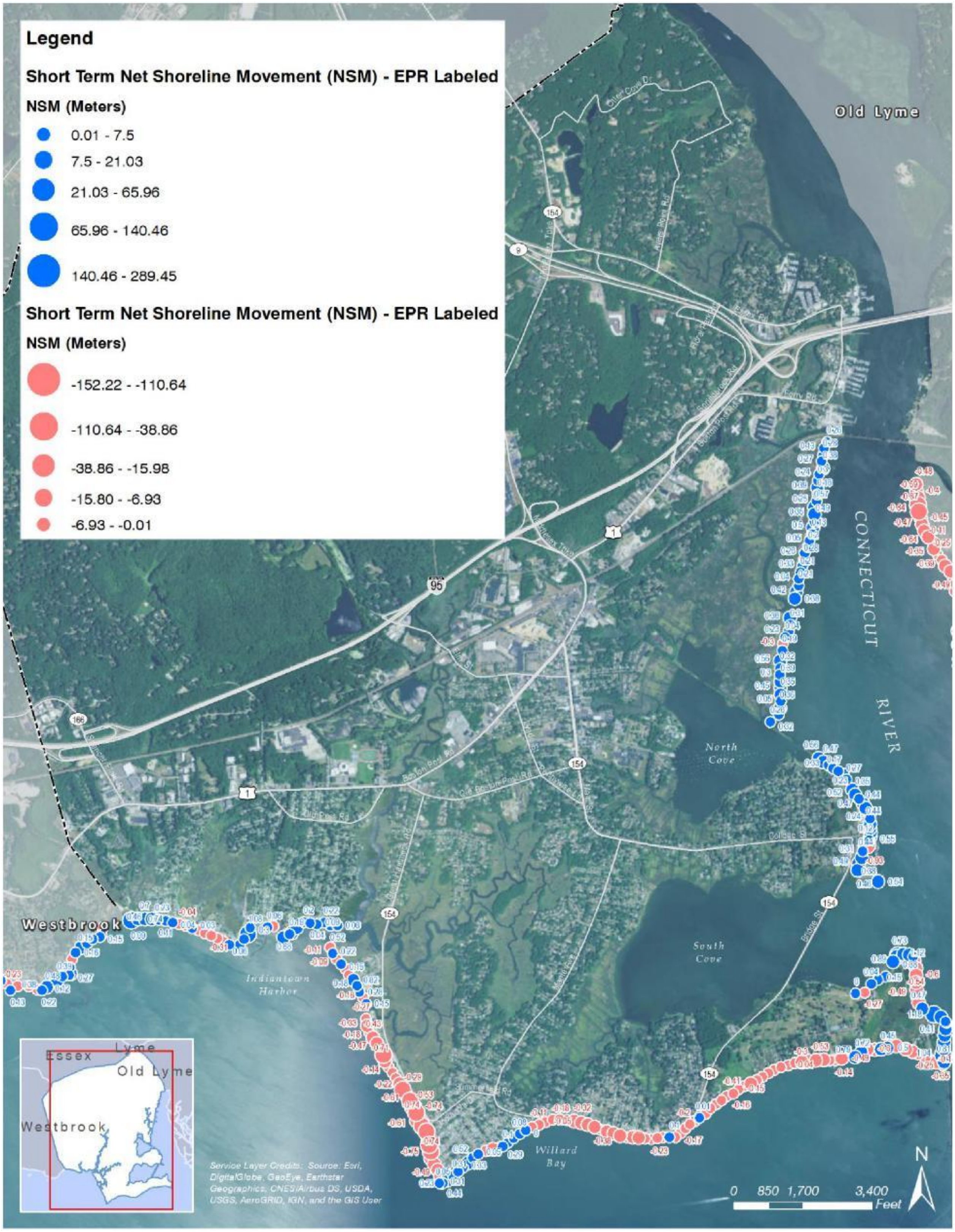
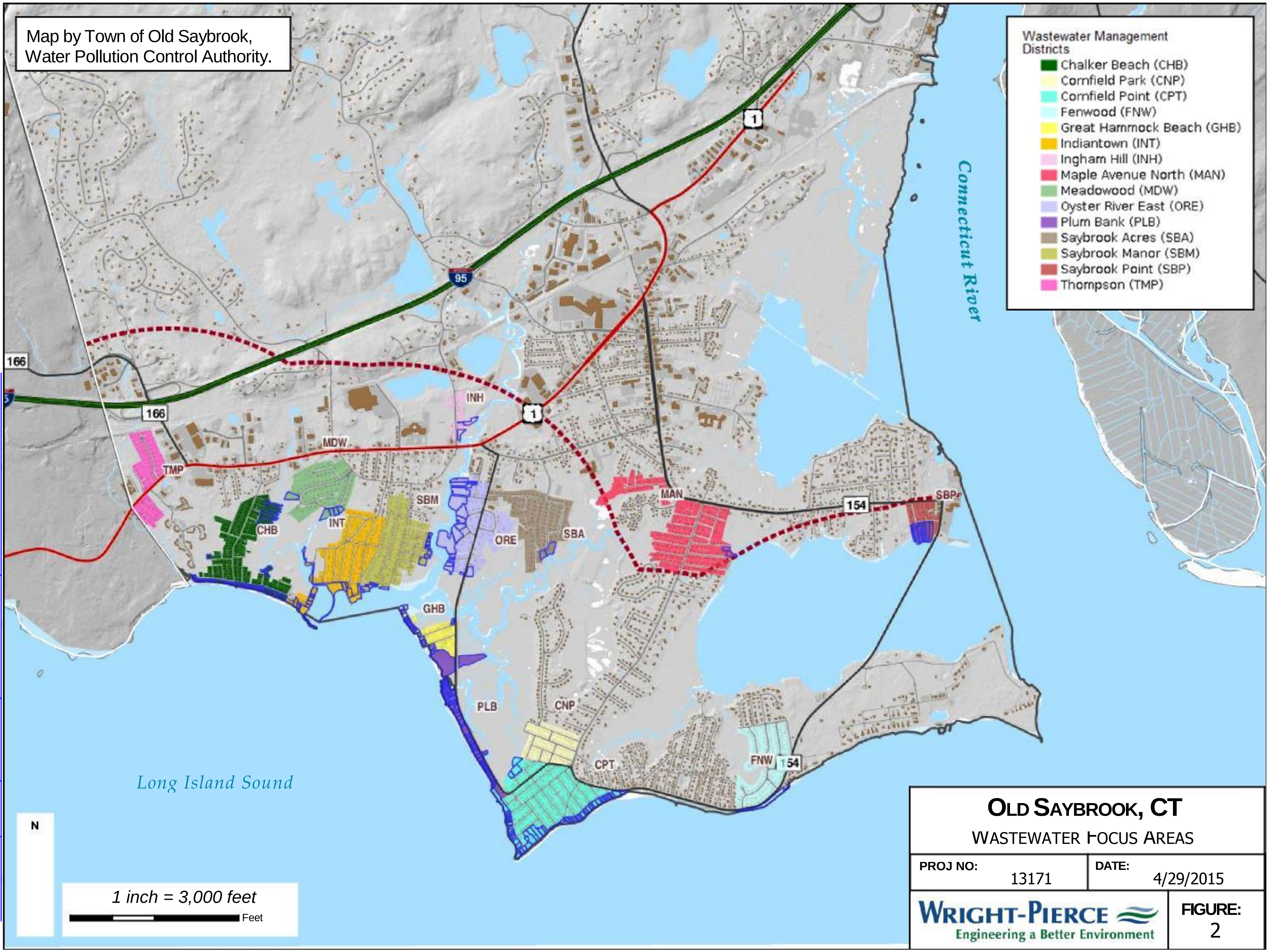


Figure 5 – Observed Shoreline Change



Attachment 1



OLD SAYBROOK, CT

WASTEWATER FOCUS AREAS

PROJ NO: 13171	DATE: 4/29/2015
WRIGHT-PIERCE Engineering a Better Environment	FIGURE: 2

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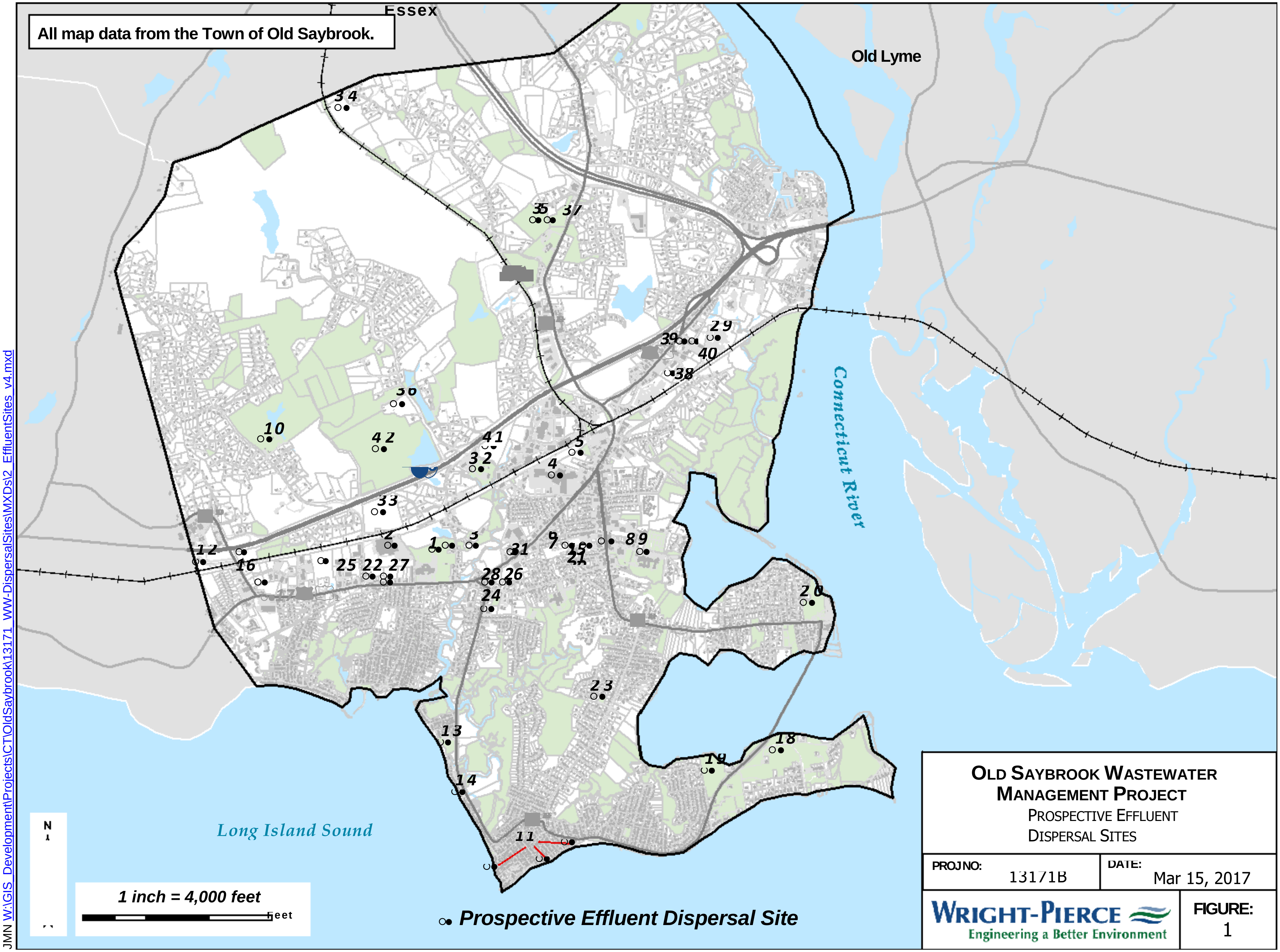

All map data from the Town of Old Saybrook.
Essex
Old Lyme
Connecticut River
Long Island Sound
1 inch = 4,000 feet
Feet
N
Prospective Effluent Dispersal Site
OLD SAYBROOK WASTEWATER MANAGEMENT PROJECT
PROSPECTIVE EFFLUENT DISPERSAL SITES
PROJ NO: 13171B
DATE: Mar 15, 2017
WRIGHT-PIERCE
Engineering a Better Environment
FIGURE: 1
JMN W:\GIS_Development\Projects\CT\OldSaybrook\13171_WW-DispersalSites\MXDs\2_EffluentSites_v4.mxd

Attachment 2

Table 2-1- Predicted Flood Stillwater Elevations in Vicinity of Old Saybrook, in feet relative to NAVD88

Return Period	1-yr	2-yr	5-yr	10-yr	20-yr	50-yr	100-yr	200-yr	500-yr	1,000-yr
2017:										
NOAA MEAN	2.3	3.5	4.4	5.0	5.6	6.6	7.5	8.4		
NOAA UB	2.3	3.7	4.7	5.7	6.7	8.6	10.3	12.6		
NOAA LB	2.3	3.3	4.1	4.5	5.0	5.7	6.2	6.8		
FEMA				5.5		7.7	9.2		15.3	
USACE MEAN	3.9	4.8	5.9	6.7	7.4	8.3	9.2	10.3	11.8	12.8
USACE UB	6.9	7.7	8.7	9.6	10.4	11.8	12.9	14.1	15.6	16.6
USACE LB	0.9	2.0	3.1	3.7	4.3	4.9	5.5	6.4	7.9	9.0
2042:										
USACE MEAN (LOW SLR)	4.0	4.9	6.0	6.8	7.5	8.4	9.3	10.4	11.9	12.9
USACE MEAN (INT SLR)	4.2	5.1	6.2	7.0	7.7	8.6	9.5	10.6	12.1	13.1
USACE MEAN (HIGH SLR)	4.9	5.8	6.9	7.7	8.4	9.3	10.2	11.3	12.8	13.8
2067:										
USACE MEAN (LOW SLR)	4.2	5.1	6.2	7.0	7.7	8.6	9.5	10.6	12.1	13.1
USACE MEAN (INT SLR)	4.7	5.6	6.7	7.5	8.2	9.1	10.0	11.1	12.6	13.6
USACE MEAN (HIGH SLR)	6.2	7.1	8.2	9.0	9.7	10.6	11.5	12.6	14.1	15.1
2117:										
USACE MEAN (LOW)	4.5	5.4	6.5	7.3	8.0	8.9	9.8	10.9	12.4	13.4
USACE MEAN (INT SLR)	5.9	6.8	7.9	8.7	9.4	10.3	11.2	12.3	13.8	14.8
USACE MEAN (HIGH SLR)	10.3	11.2	12.3	13.1	13.8	14.7	15.6	16.7	18.2	19.2

Table 2-2 Predicted Flood Stillwater Elevations at Coastal Wastewater Management Districts, in feet relative to NAVD88

Return Period	Existing Ground Elevation, feet NAVD88	100-yr	500-yr
2017:			
Chalker Beach	0 to 5 Beach 0 to 4 Marsh 5 to 10 Land	10.4 to 10.8	13.2 to 13.6
Indiantown	0 to 5 Beach 0 to 4 Marsh 5 to 10 Land	10.4 to 10.9	13.1 to 13.7
Saybrook Manor	0 to 5 Beach 0 to 4 Marsh 5 to 10 Land	10.4 to 10.9	13.2 to 13.7
Great Hammock	0 to 5 Beach 0 to 4 Marsh 0 to 6 Land	10.2 to 10.3	12.9 to 13.0
Plum Bank	0 to 5 Beach 0 to 4 Marsh 0 to 10 Land	9.9 to 10.2	12.7 to 13.0
2042 USACE Intermediate SLR Projection:			
Chalker Beach		10.6 to 11.1	13.4 to 13.8
Indiantown		10.6 to 11.2	13.3 to 13.9
Saybrook Manor		10.7 to 11.2	13.4 to 14.0
Great Hammock		10.5 to 10.6	13.2 to 13.3
Plum Bank		10.3 to 10.5	13.0 to 13.2
2067 USACE Intermediate SLR Projection:			
Chalker Beach		11.1 to 11.5	13.8 to 14.2
Indiantown		11.0 to 11.6	13.7 to 14.2
Saybrook Manor		11.1 to 11.5	13.9 to 14.3
Great Hammock		10.9 to 11.0	13.6 to 13.7

Plum Bank		10.6 to 10.9	13.5 to 13.6
2117 USACE Intermediate SLR Projection:			
Chalker Beach		12.2 to 12.6	14.5 to 14.9
Indiantown		12.2 to 12.7	14.4 to 14.9
Saybrook Manor		12.2 to 12.7	14.6 to 15.0
Great Hammock		12.1 to 12.1	14.3 to 14.4
Plum Bank		11.7 to 12.0	13.9 to 14.3

Table 2-3 - Predicted Significant Wave Height and Wave Crest Elevation at Coastal Wastewater Management Districts, in feet relative to NAVD88

	Significant Wave Height, feet		Approximate Wave Crest Elevation, feet	
Return Period	100-yr	500-yr	100-yr	500-yr
2017:				
Chalker Beach	4.0 to 4.5 Beach 2.0 to 3.0 Marsh 1.0 to 3.0 Land	5.0 to 6.0 Beach 3.5 to 4.0 Marsh 2.5 to 5.0 Land	14.0 13.0 14.0	18.0 16.5 17.0
Indiantown	4.0 to 4.5 Beach 2.0 to 2.5 Marsh 1.0 to 2.0 Land	5.0 to 5.5 Beach 2.5 to 4.0 Marsh 1.5 to 2.0 Land	14.0 13.0 12.0	17.0 16.5 15.0
Saybrook Manor	4.0 to 4.5 Beach 2.0 to 3.0 Marsh 1.0 to 3.0 Land	5.0 to 5.5 Beach 3.0 to 4.0 Marsh 1.0 to 4.0 Land	14.0 13.0 13.0	17.0 16.0 16.0
Great Hammock	3.0 to 4.0 Beach 2.0 to 3.0 Marsh 1.5 to 2.5 Land	4.5 to 5.0 Beach 3.0 to 4.0 Marsh 4.0 to 4.5 Land	14.0 13.0 13.0	17.0 16.0 16.5
Plum Bank	3.5 to 5.0 Beach 2.5 to 3.0 Marsh 1.5 to 3.0 Land	4.5 to 5.5 Beach 3.5 to 4.0 Marsh 2.0 to 4.0 Land	14.0 13.0 to 14.0 13.0 to 14.0	17.0 16.0 16.0