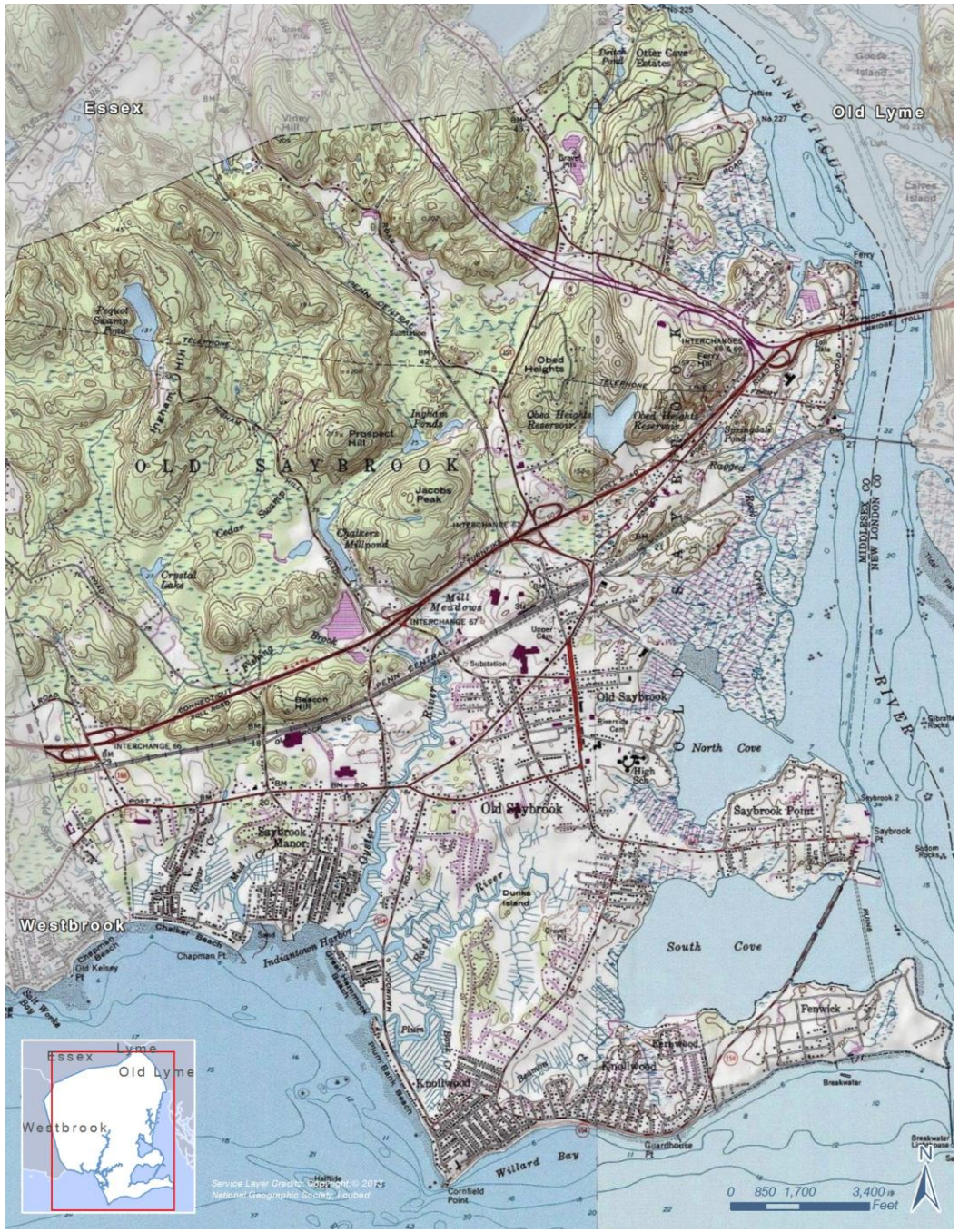
Creating Coastal Resilience

A 360 Degree GeoDesign Approach

Daniel Boudreau, GISP
Geospatial Systems Lead
GZA GeoEnvironmental, Inc

Our Story…

Using the ArcGIS Platform to support GeoDesign for Coastal Resilience Planning, Design, Construction, Observation and Adaptation



Images source: Hartford Courant, 2012

STUDY APPROACH

- Industry-accepted "State-of-the-Science" sea level rise projections consistent with current State of Connecticut guidance.

- A "risk-based" approach, which defined coastal flood hazards in terms of probability of occurrence, consistent with methods currently being used by state and federal agencies.

- High resolution, hydrodynamic computer flood modeling supplementing flood hazard analyses performed by FEMA and the U.S. Army Corps of Engineers (USACE).

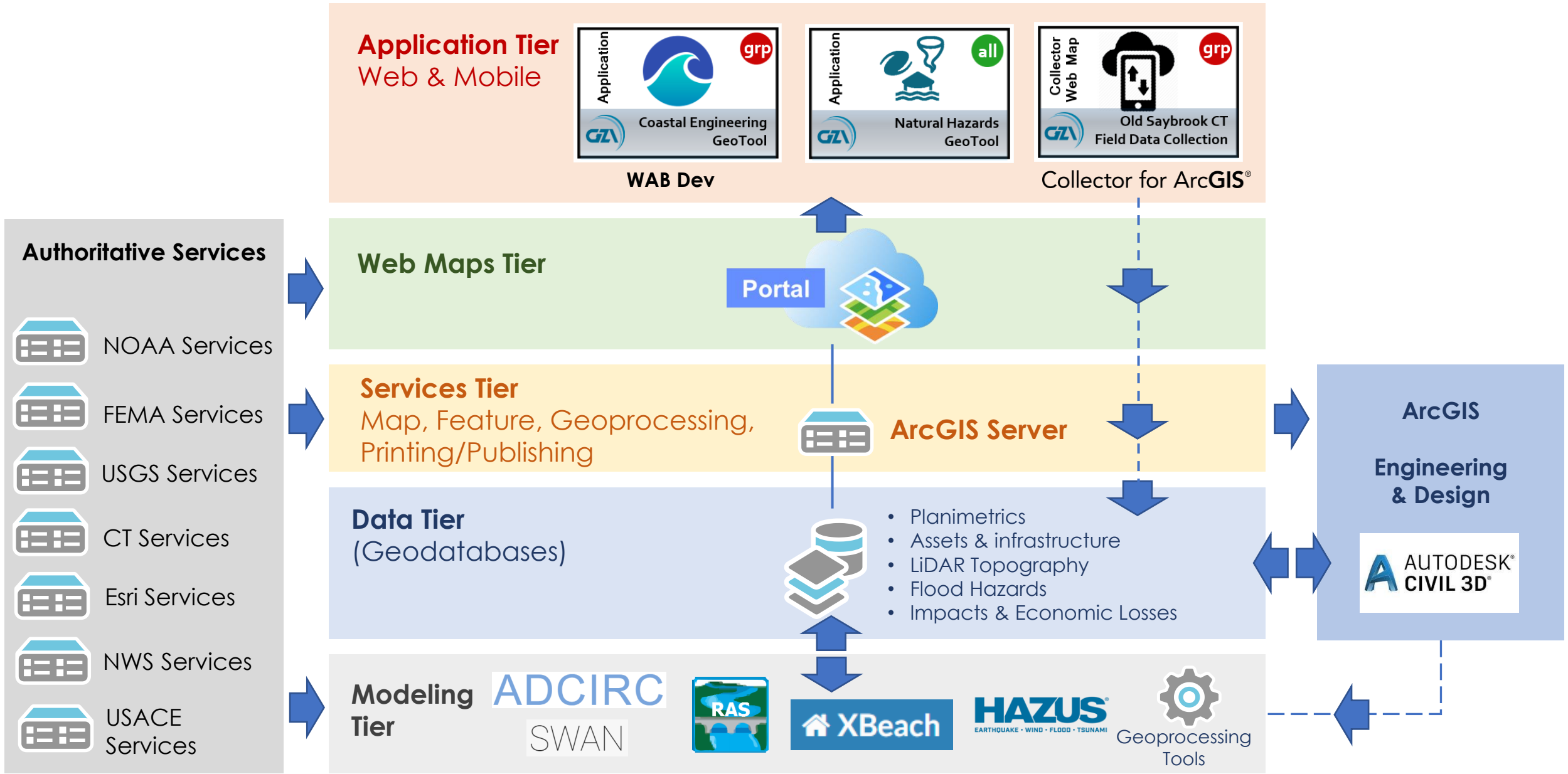
- Esri's ArcGIS Platform as a system of record, data integration platform, design support and system of engagement with the Town.

- Develop resilience and adaptation strategies, actions and measures consistent with Old Saybrook's current vision and plans for development.

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

ArcGIS 360 Degree Framework

ArcGIS Enterprise



STUDY METHODOLOGY

Step 1
Inventory and cataloguing of physical site setting and Town assets.

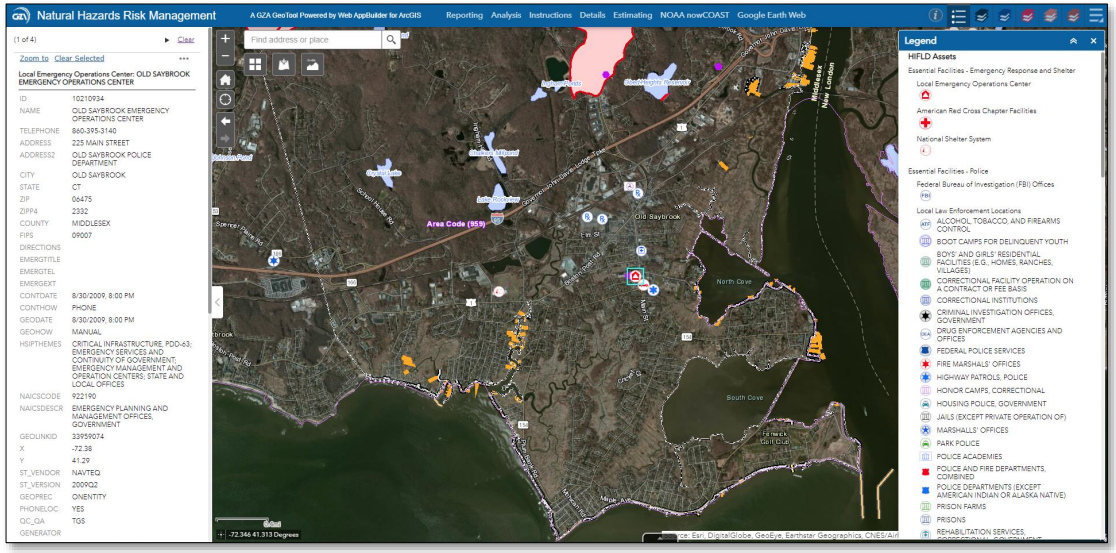
Step 2
Characterization of the Coastal Flood Hazards.

Step 3
Assessment of the Vulnerability of Town Infrastructure, Neighborhoods, Buildings, and Natural Resources.

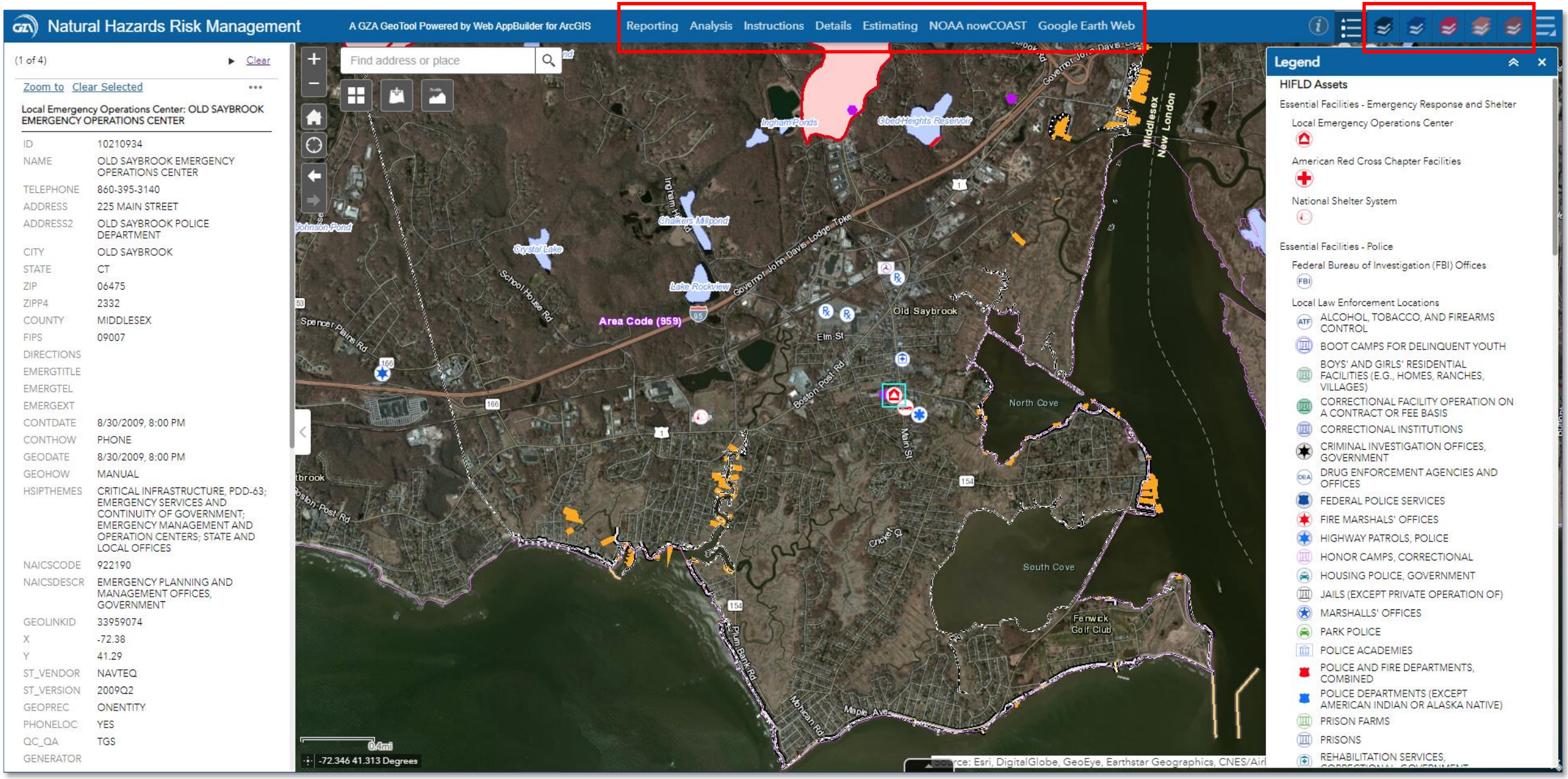
Step 4
Identification of Coastal Resilience and Adaptation Strategies, Actions and Measures.

Step 5
Outreach to the Public and Town Professionals.

Step 6
Identification of steps to implement resilience and adaptation strategies.



SITE SETTING AND ASSET INVENTORY



FLOOD HAZARD CHARACTERIZATION - FEMA

Natural Hazards Risk Management | A GZA GeoTool Powered by Web AppBuilder for ArcGIS | Reporting | Analysis | Instructions | Details | Estimating | NOAA nowCOAST | Google Earth Web

Find address or place

Spencer Plains Rd
School House Rd
166
TOWN OF WESTBROOK
090070
Boston Post Rd
0.4mi
-72.377 41.318 Degrees

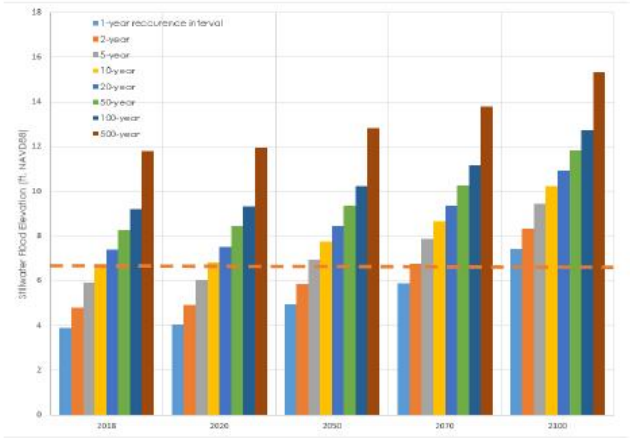
Old Saybrook Coastal Resilience and Adaptation Study

COASTAL FLOOD HAZARDS

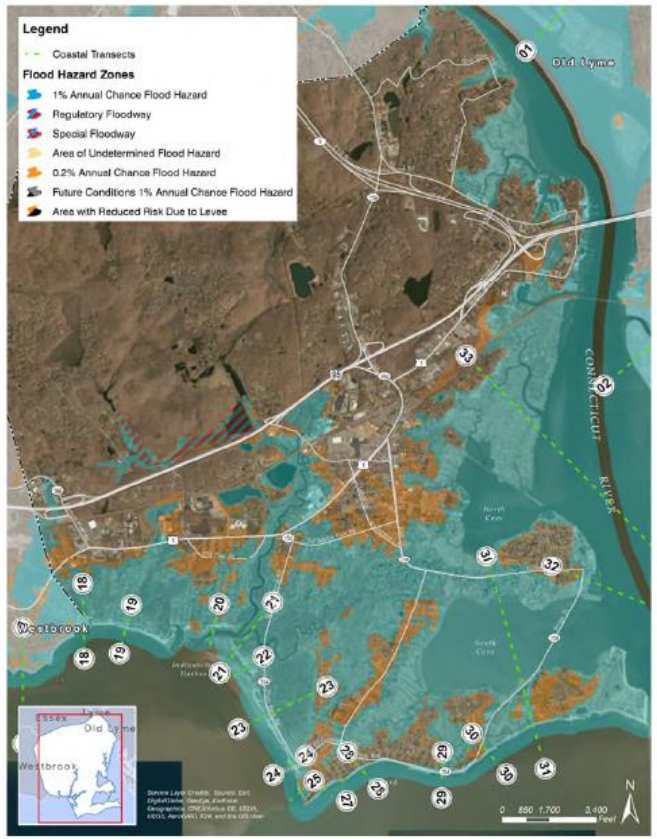
As detailed in **Attachment 2**, the extent and elevation of different probability flood events at Old Saybrook were evaluated using available sources (including FEMA, NOAA and NACCS). GZA supplemented these by performing numerical computer storm surge and wave simulations.

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

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



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



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

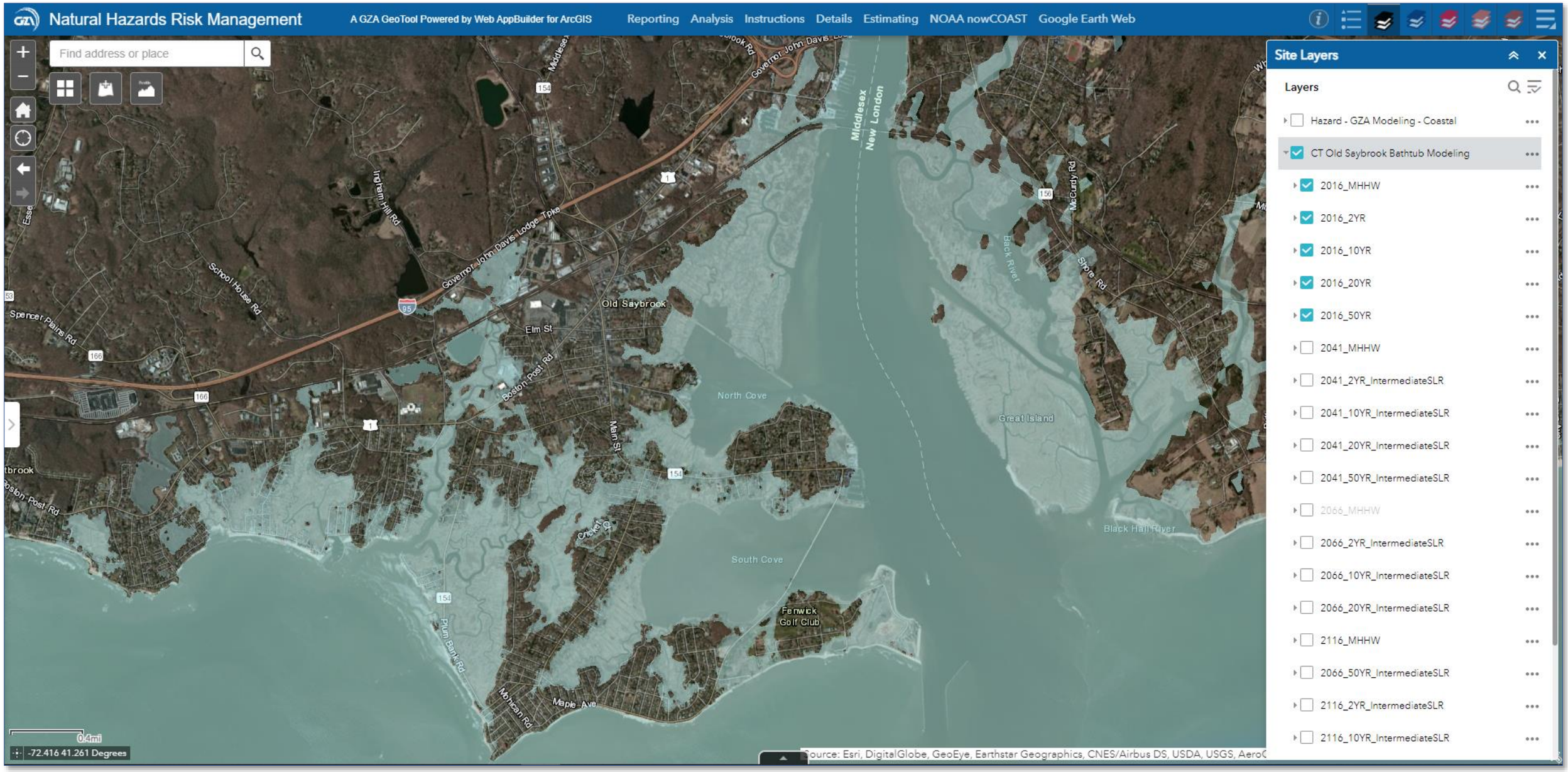
Severe Weather Hazards

Layers

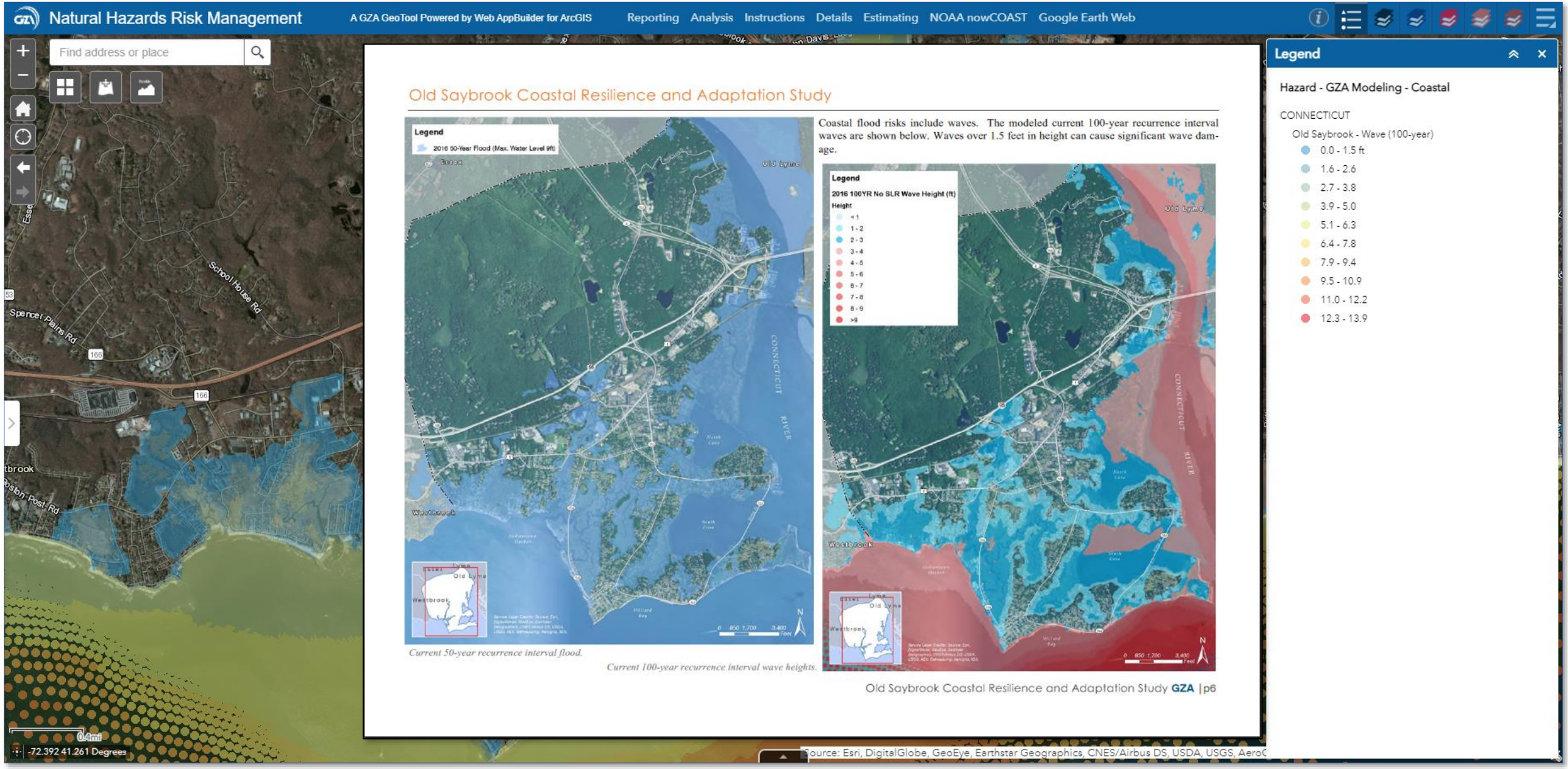
- CT Old Saybrook Risk Analysis
- CT Old Saybrook Bathtub Modeling
- Hazard - FEMA Preliminary Changes Since Last FIRM
- Hazard - FEMA Preliminary NFHL
- Hazard - FEMA National Flood Hazard Layer (NFHL)
  - NFHL Availability
  - LOMRs
  - LOMAs
  - FIRM Panels
  - Base Index
  - PLSS
  - Topographic Low Confidence Areas
  - River Mile Markers
  - Datum Conversion Points
  - Coastal Gages
  - Gages
  - Nodes
  - High Water Marks
  - Station Start Points
  - Cross-Sections

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroG

FLOOD HAZARD CHARACTERIZATION – INUNDATION MODELING



FLOOD HAZARD CHARACTERIZATION – WAVE MODELING



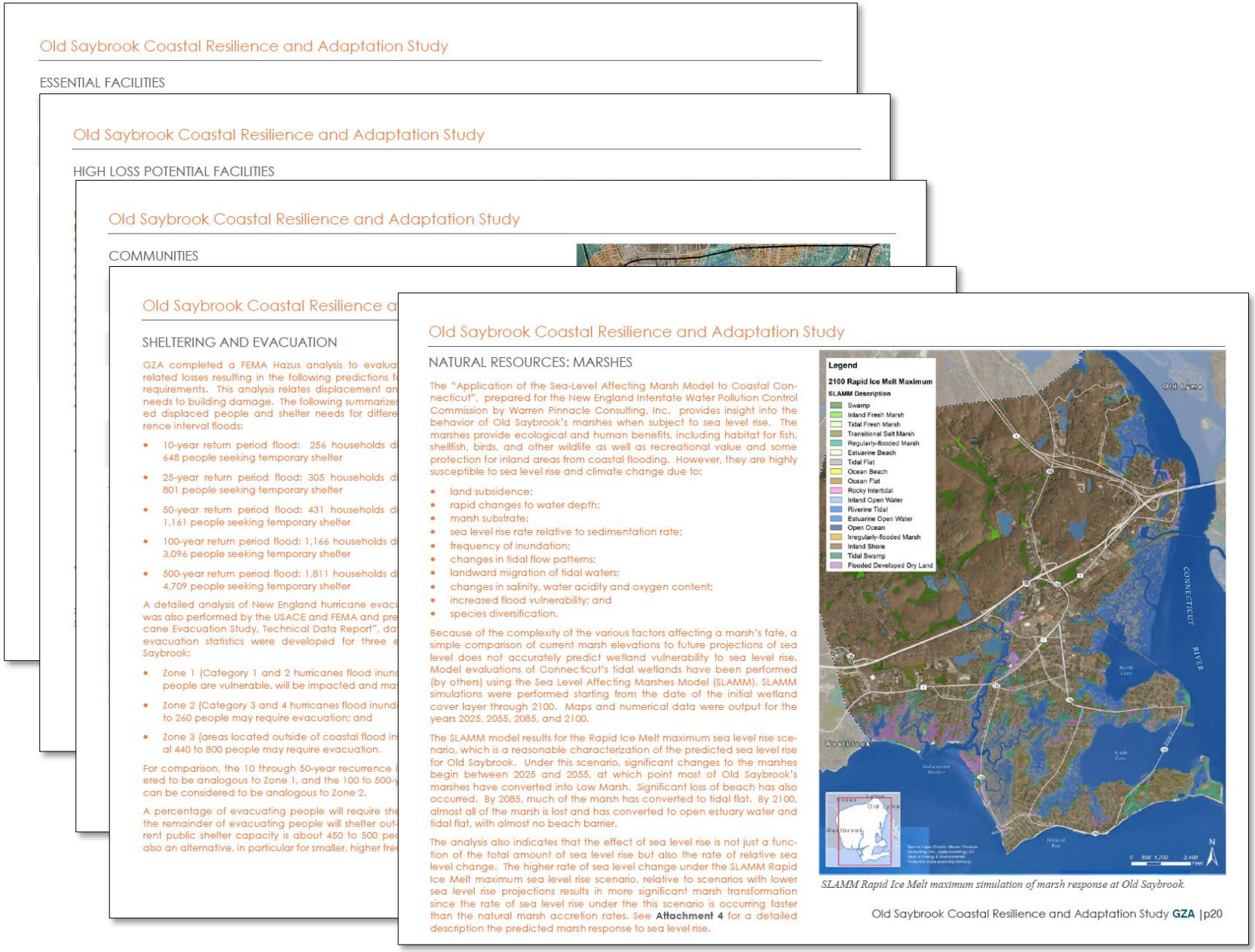
FLOOD HAZARD RISK

Assets
- Essential Facilities
- Lifeline Facilities
- High Potential Loss Facilities

Geographic Areas
- Neighborhoods
- Commercial and Industrial Districts
- Historic Districts

Systems
- Economic Factors
- Shelter and Evacuation Requirements
- Stormwater Infrastructure
- Transportation Infrastructure

Natural Resources
- Marshes
- Beaches



FLOOD HAZARD RISK – ROADWAY IMPACTS

Natural Hazards Risk Management | A GZA GeoTool Powered by Web AppBuilder for ArcGIS | Reporting | Analysis | Instructions | Details | Estimating | NOAA nowCOAST | Google Earth Web

Find address or place

Old Saybrook Coastal Resilience and Adaptation Study

ROADS, BRIDGES AND CULVERTS

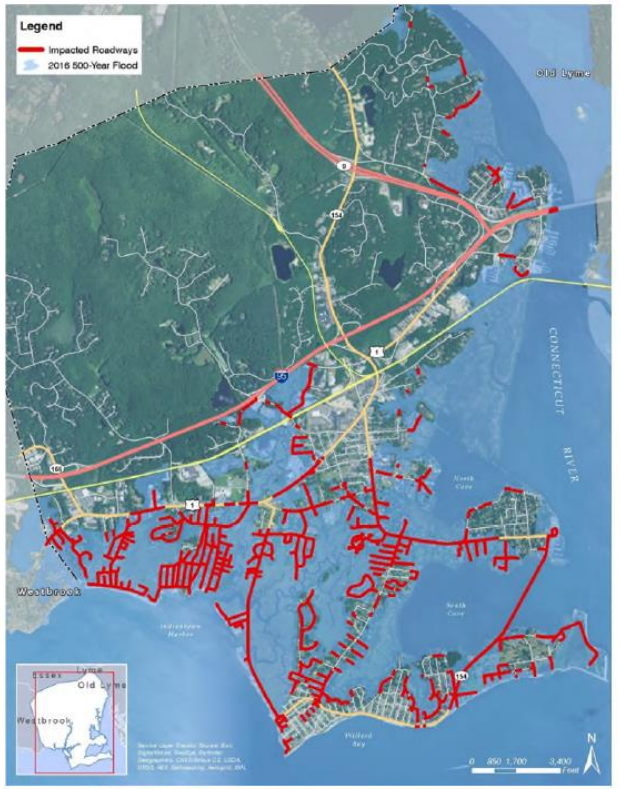
	2-yr	10-yr	20-yr	50-yr	100-yr	500-yr
State (%)	2.9	7.4	9.6	11.3	13.1	16.9
State (miles)	1	2.4	3.2	3.7	4.3	5.6
Municipal (%)	3	8.5	12.4	16.2	20.6	32.3
Municipal (miles)	2.6	7.4	10.7	14.0	17.9	28.0
Private (%)	3.6	10.5	15	23.7	50.4	71.4
Private (miles)	0.1	0.3	0.4	0.7	1.5	2.1
Total (miles)	+/-4	+/-10	+/-14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

Vulnerability Profile of Old Saybrook Roads

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

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

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



Inundated roads during the 500-year recurrence interval flood

Legend

CT Old Saybrook Risk Analysis

Transportation Infrastructure

- Impacted Roadways 2016 2-Year Flood
- Impacted Roadways 2016 10-Year Flood
- Impacted Roadways 2016 20-Year Flood
- Impacted Roadways 2016 50-Year Flood
- Impacted Roadways 2016 100-Year Flood
- Impacted Roadways 2016 500-Year Flood

CT_Old_Saybrook_Modeling

2016 500yr

- 10.8 - 12.1
- 12.2 - 12.5
- 12.6 - 12.8
- 12.9 - 13.2
- 13.3 - 13.6
- 13.7 - 14.0
- 14.1 - 14.6
- 14.7 - 15.5

HIFLD Assets

Essential Facilities - Emergency Response and Shelter

- Local Emergency Operations Center
- American Red Cross Chapter Facilities
- National Shelter System

Essential Facilities - Police

- Federal Bureau of Investigation (FBI) Offices

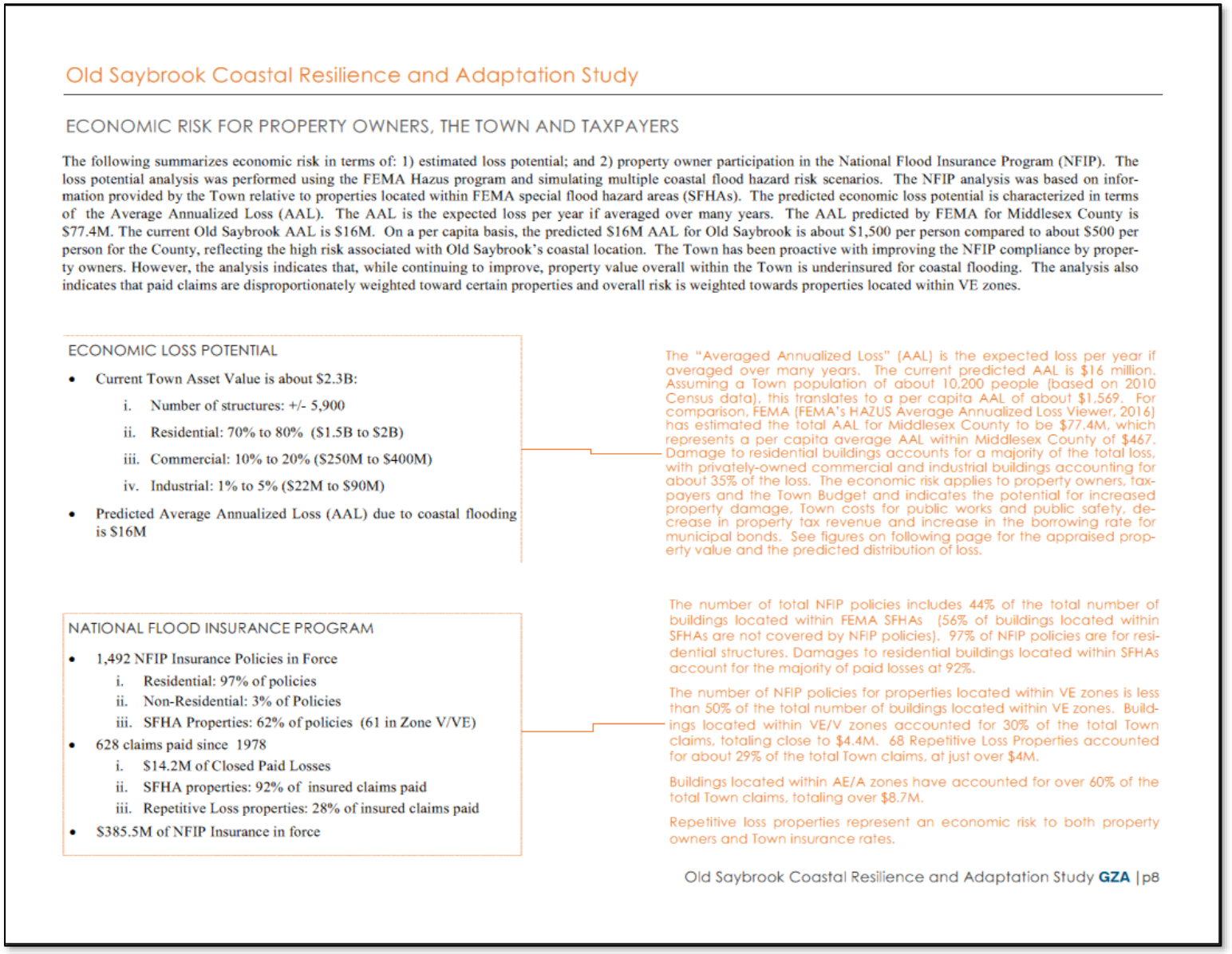
-72.382 41.301 Degrees

Tsri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community | USDA FSA, Ma

FLOOD HAZARD RISK

Loss Characterization (FEMA HAZUS-MH)

- Financial projections of economic loss due to business disruption and damage
- Loss estimation for damage to buildings and infrastructure
- Claims that can be made through National Flood Insurance Program



Old Saybrook Coastal Resilience and Adaptation Study

ECONOMIC RISK FOR PROPERTY OWNERS, THE TOWN AND TAXPAYERS

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

ECONOMIC LOSS POTENTIAL

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

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

NATIONAL FLOOD INSURANCE PROGRAM

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

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

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

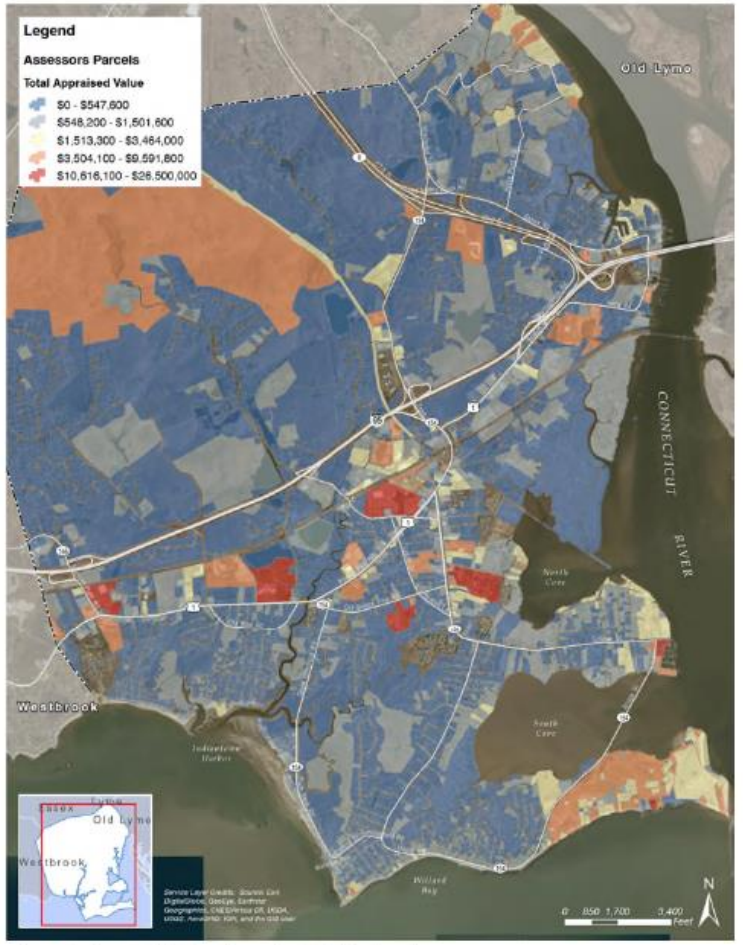
Buildings located within AE/A zones have accounted for over 60% of the total Town claims, totaling over $8.7M.

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

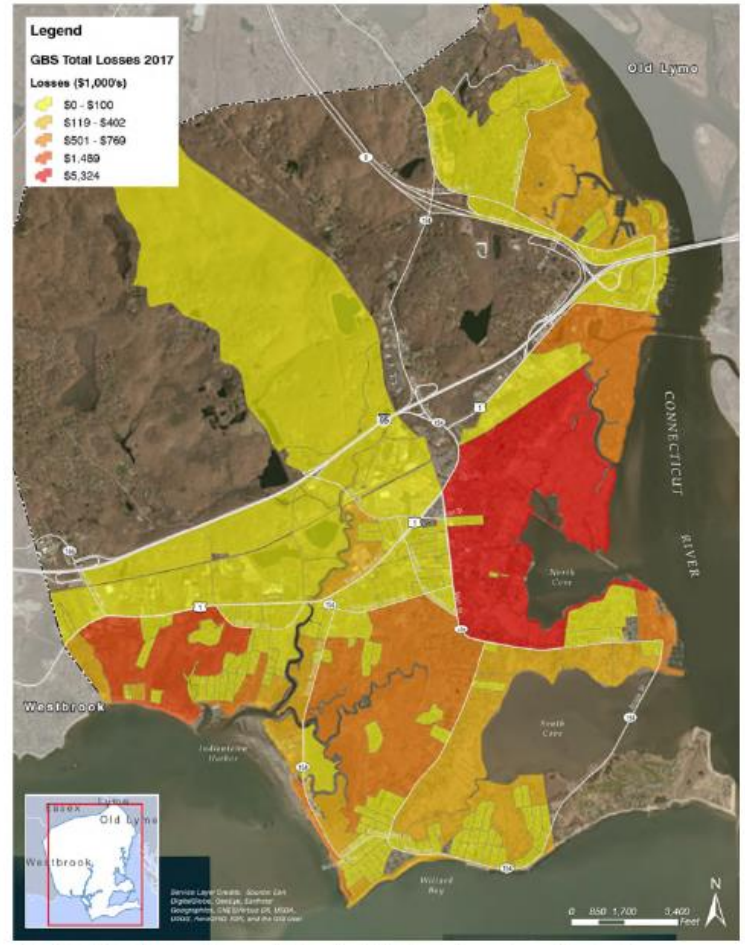
FLOOD HAZARD RISK

Loss Characterization (FEMA HAZUS-MH)

- Financial projections of economic loss due to business disruption and damage
- Loss estimation for damage to buildings and infrastructure
- Claims that can be made through National Flood Insurance Program
- HAZUS-MH results integrated with project Geodatabase and published as a discrete Map Service



Property Appraisal Values throughout Old Saybrook



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

ADAPTATION STRATEGIES, ACTIONS AND MEASURES

Adaptation Alternative A: Strategic Realignment

Section diagram 1-1'

Section diagram 2-2'

Strategy

Retreat programs favor removing or relocating structures further back from the shoreline rather than repeatedly repairing storm damaged structures and hardening the shoreline.

A Strategic Realignment approach typically involves establishing thresholds to trigger demolition or relocation of structures threatened by coastal risks, including erosion and sea level rise. This approach is frequently coupled with several other planning and regulatory techniques, such as identifying high-risk areas and instituting relocation assistance and/or buy-back programs to help with relocation costs or compensate property owners when their property becomes unusable.

Managed Retreat

what	Create natural coastal area that provides protective functions, long term solution, and habitat
why	Town of Old Saybrook, Property owners
initiator	Ecosystems, habitat creation
who benefits	Diminished emergency services along corridor, property loss, space for relocation
issues	

Removal and relocation

what	Eliminate threats from sea level rise by moving threatened structures and infrastructure
why	Town of Old Saybrook, Property owners
initiator	Ecosystems, habitat creation
who benefits	Potential buy-back assistance costs, loss of tax revenue, finding upland area for relocation
issues	

Chalker Beach Map

Relocation

FLOOD DIRECTIONS

Risk level

500-year emergency flood, 13.7 feet

100-year regulatory flood, 10.3 feet

10-year nuisance flood, 7 feet

500y

100y

10y

FLOOD DIRECTION

Illustration (2-2')

Flood risk

Most of Chalker Beach will be effected by even a 10-year flood. With a 100-year flood, the entire neighborhood will be underwater, with flooding coming from multiple directions.

FLOOD DIRECTION

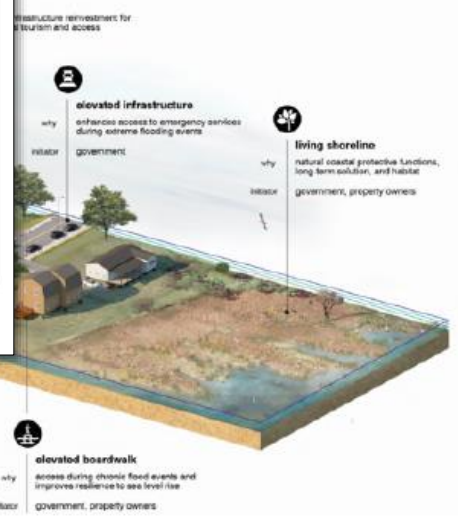
Illustration (1'-1)

Beach Community Workshop

Old Saybrook Community Coastal Resilience Study
Community Workshop

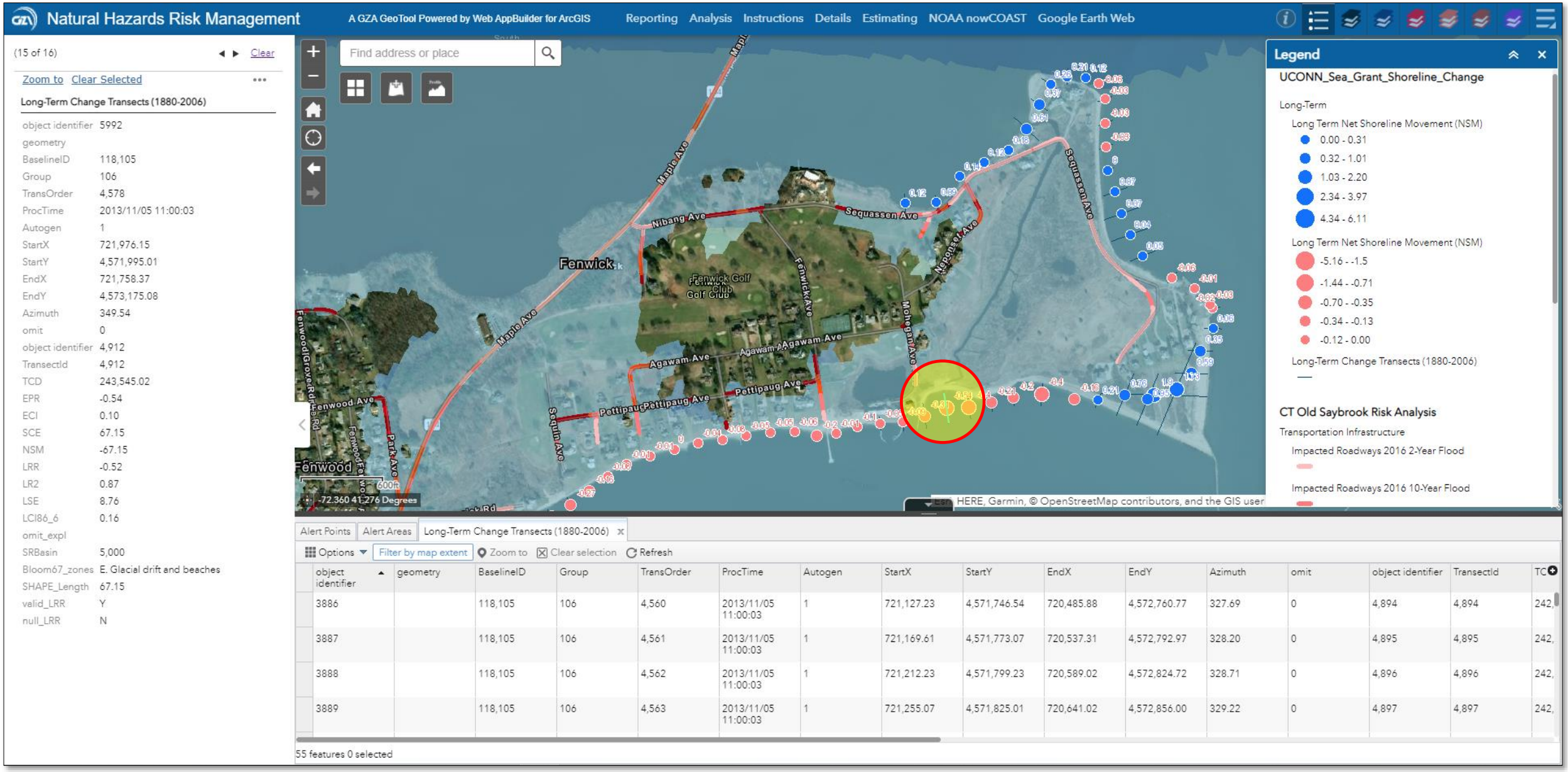
GZA Stantec

Figure 5-2: Adaptation Strategy A - Strategic Realignment



Representation of a long-term resilience and adaptation strategy for Old Saybrook., above. Function shown below.

SHORELINE CHANGE



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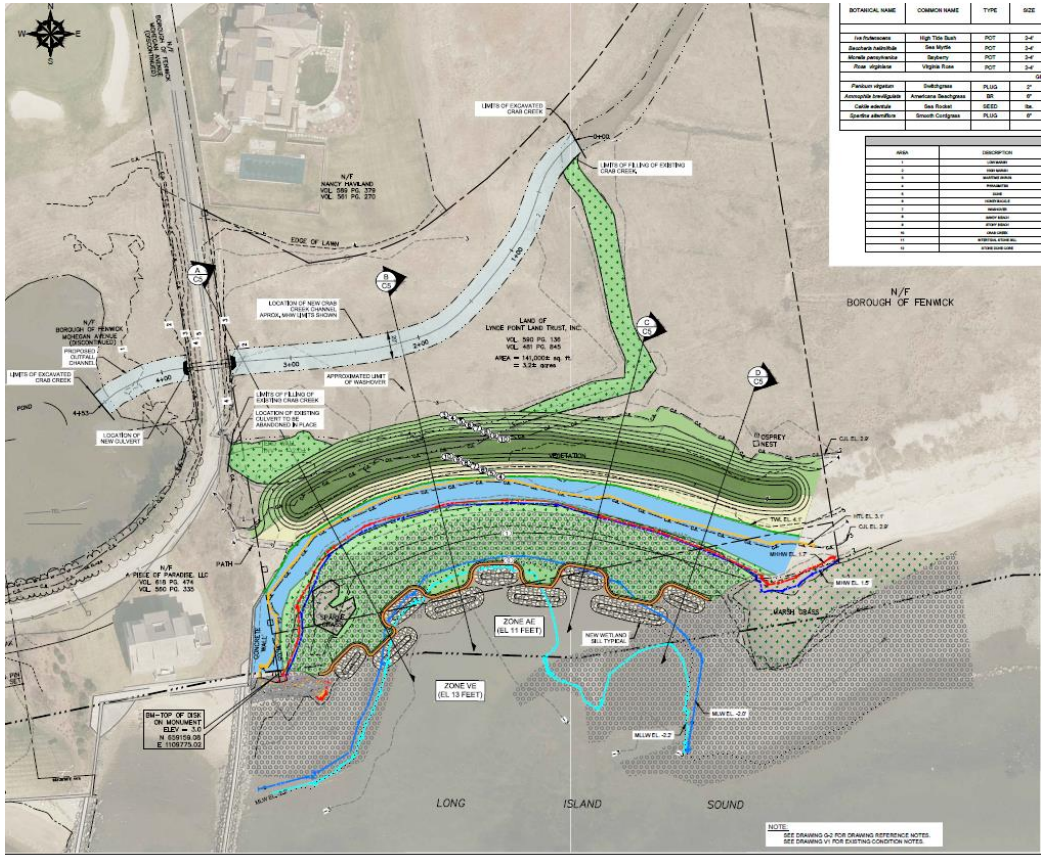
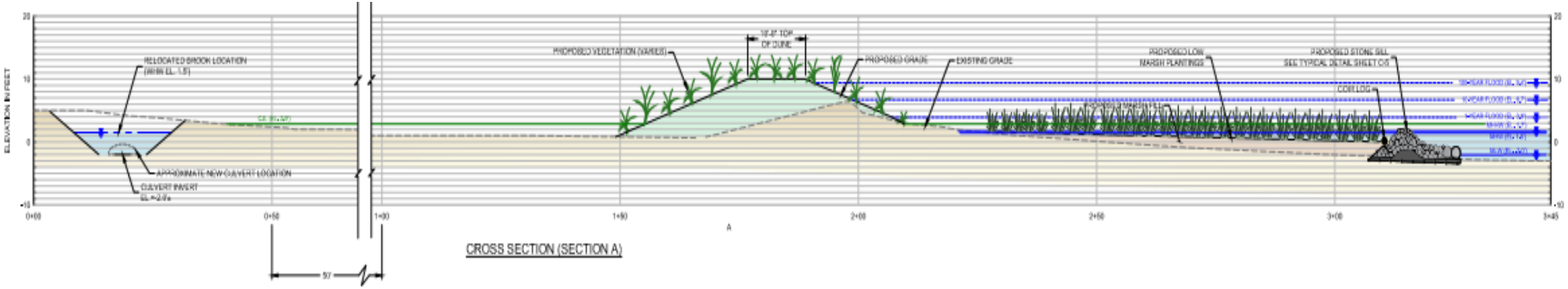
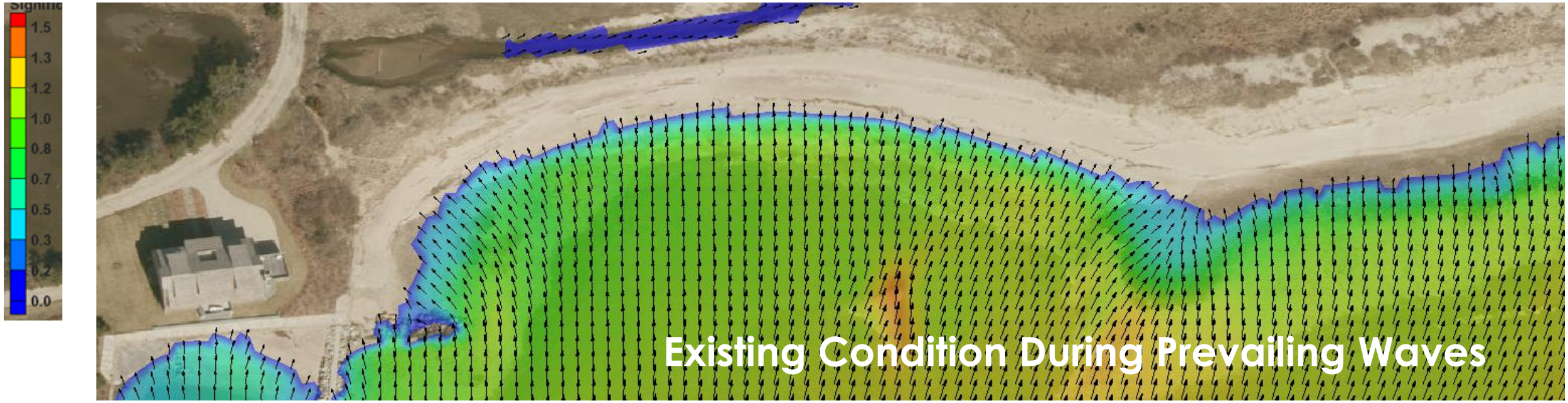
3887		118,105	106	4,561	2013/11/05 11:00:03	1	721,169.61	4,571,773.07	720,537.31	4,572,792.97	328.20	0	4,895	4,895	242,
3888		118,105	106	4,562	2013/11/05 11:00:03	1	721,212.23	4,571,799.23	720,589.02	4,572,824.72	328.71	0	4,896	4,896	242,
3889		118,105	106	4,563	2013/11/05 11:00:03	1	721,255.07	4,571,825.01	720,641.02	4,572,856.00	329.22	0	4,897	4,897	242,

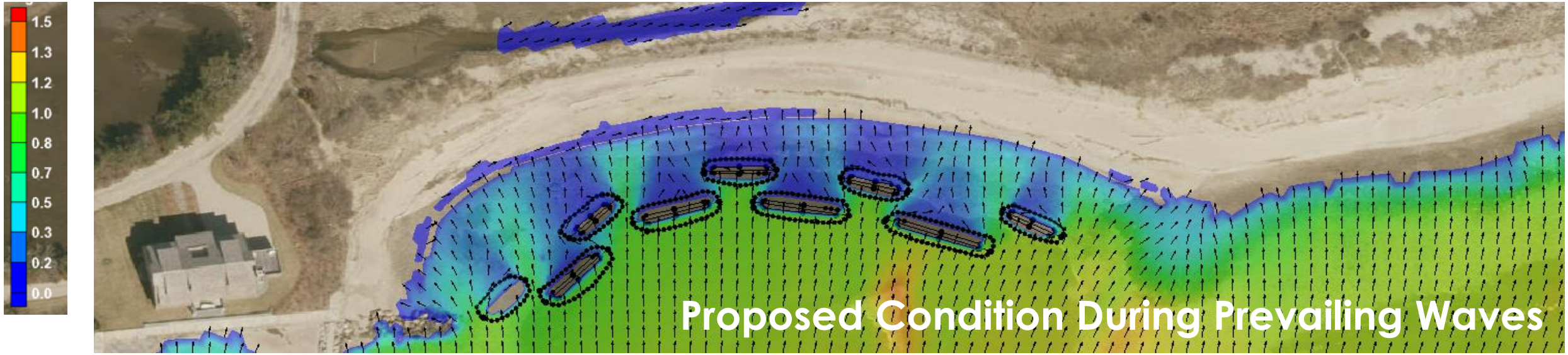
LIVING SHORELINE CONCEPT DESIGN





Living Shoreline Design Stress Analysis: Adverse Effects





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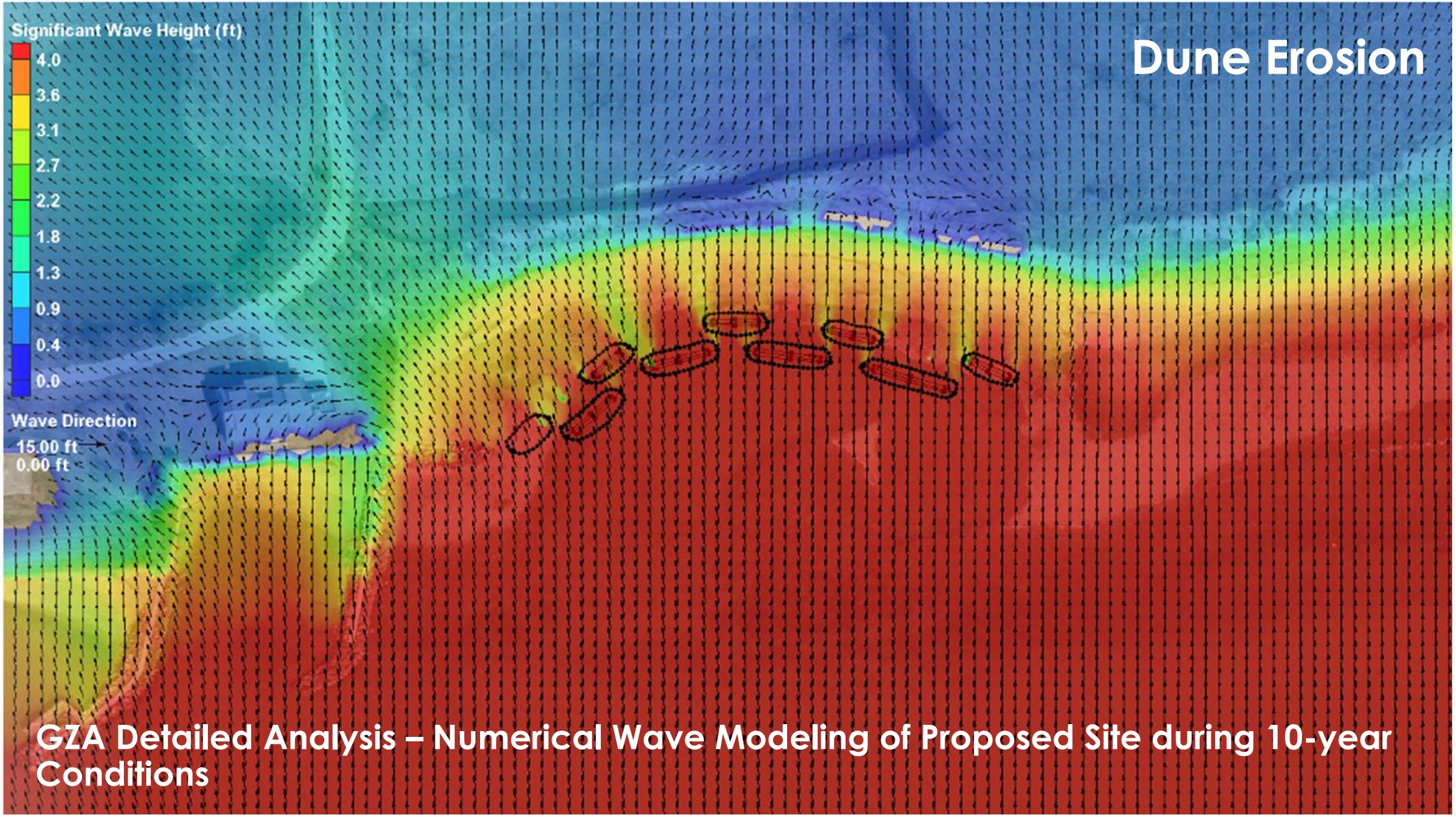
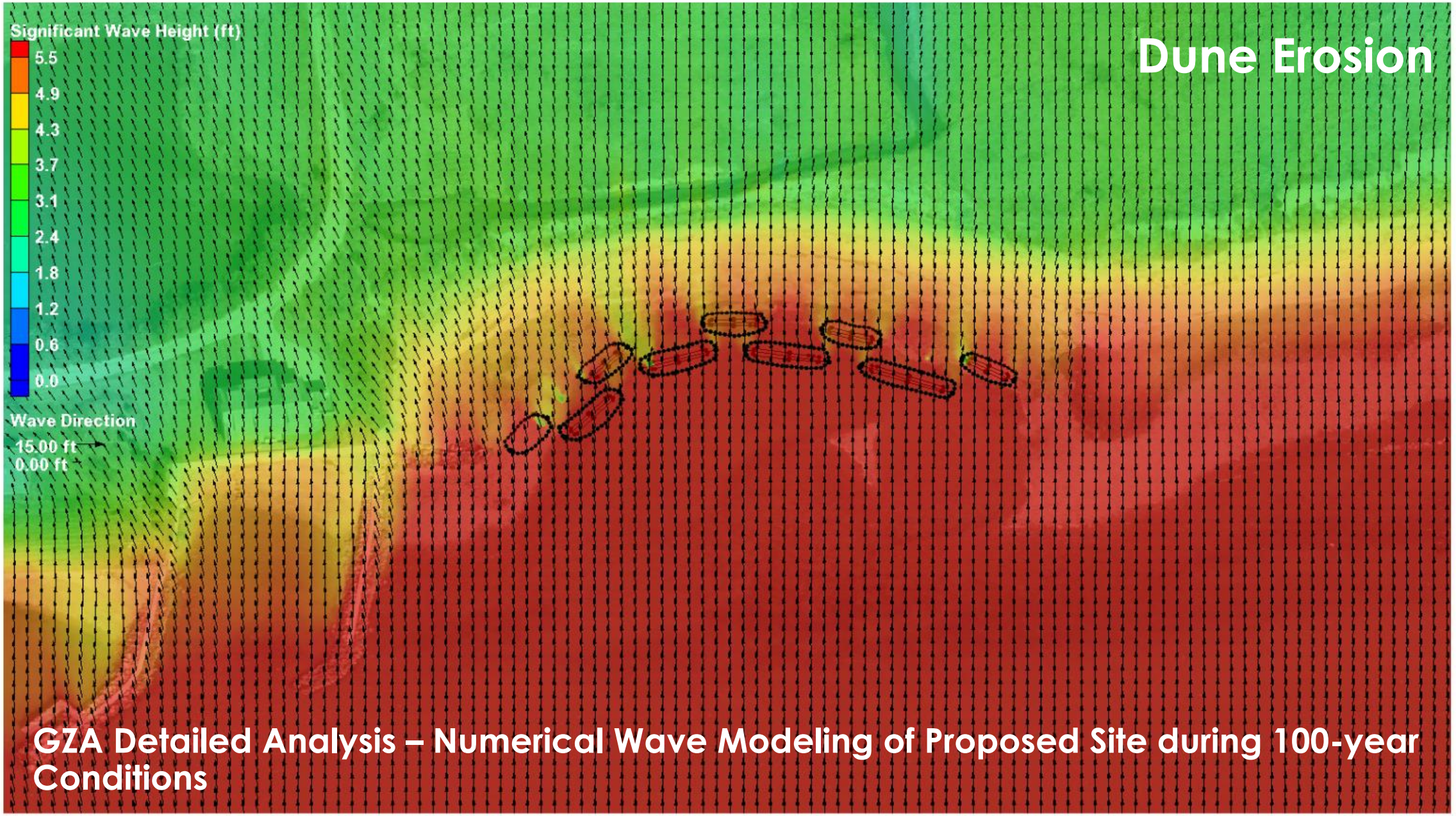
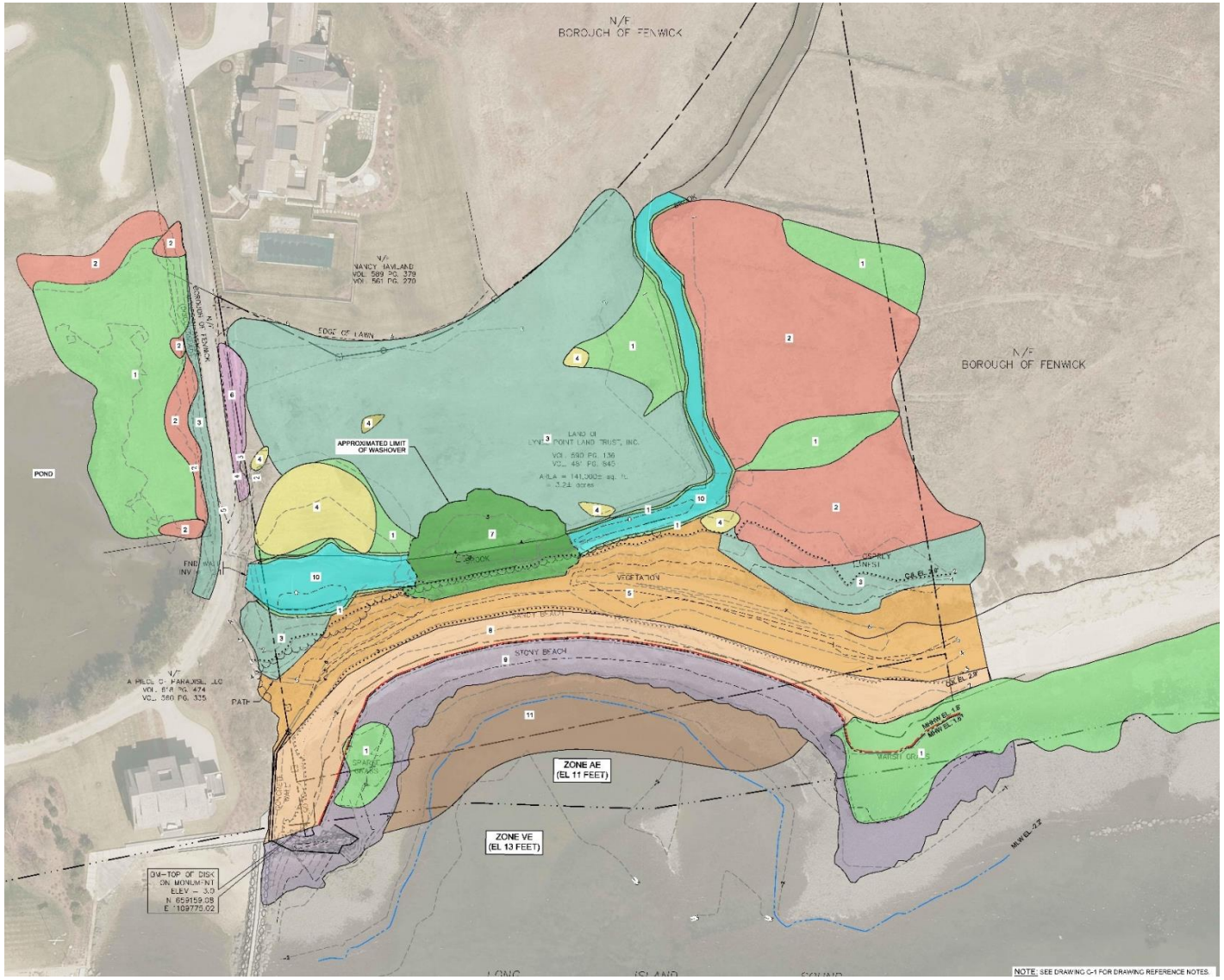


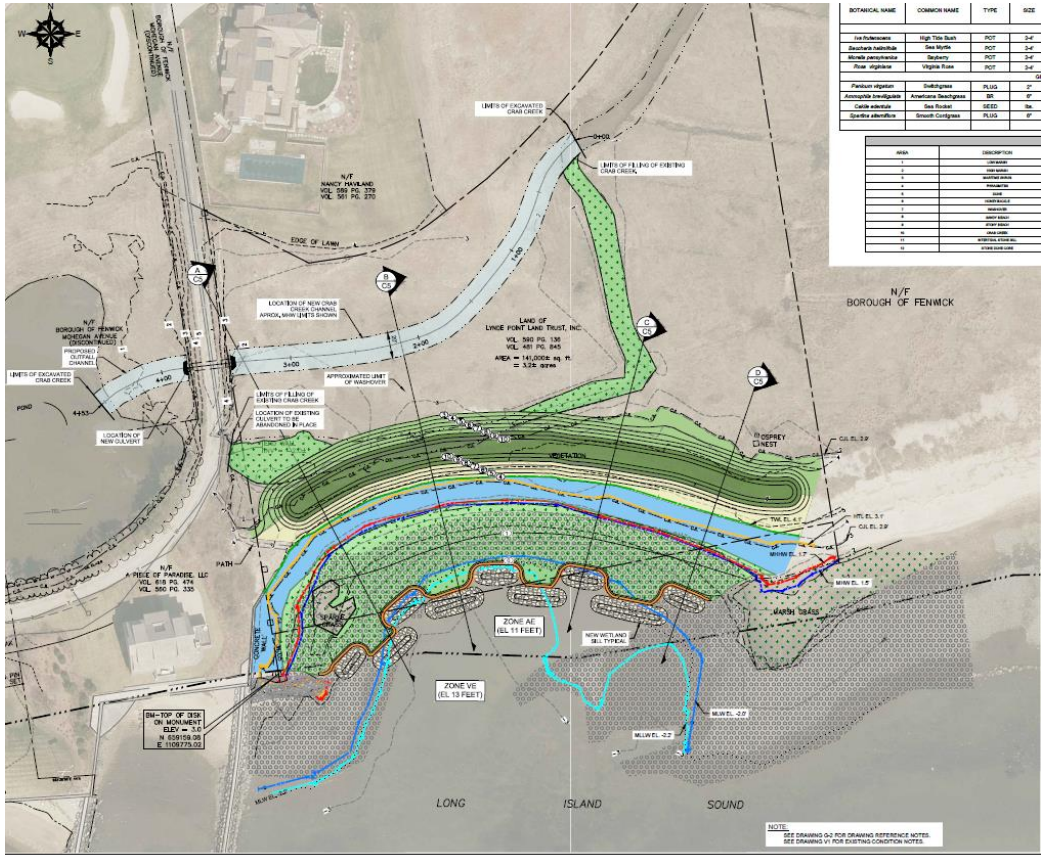
Living Shoreline Design Stress Analysis: Adverse Effects

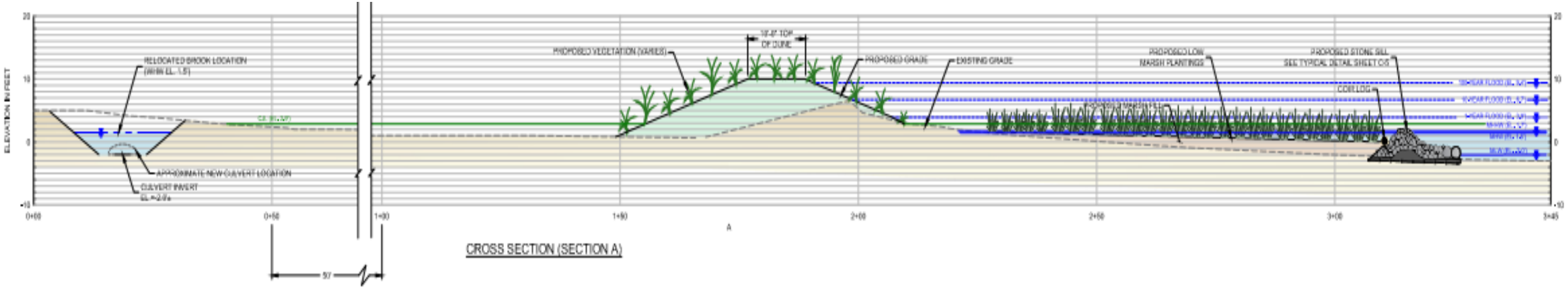


SITE CHARACTERIZATION: ECOLOGICAL

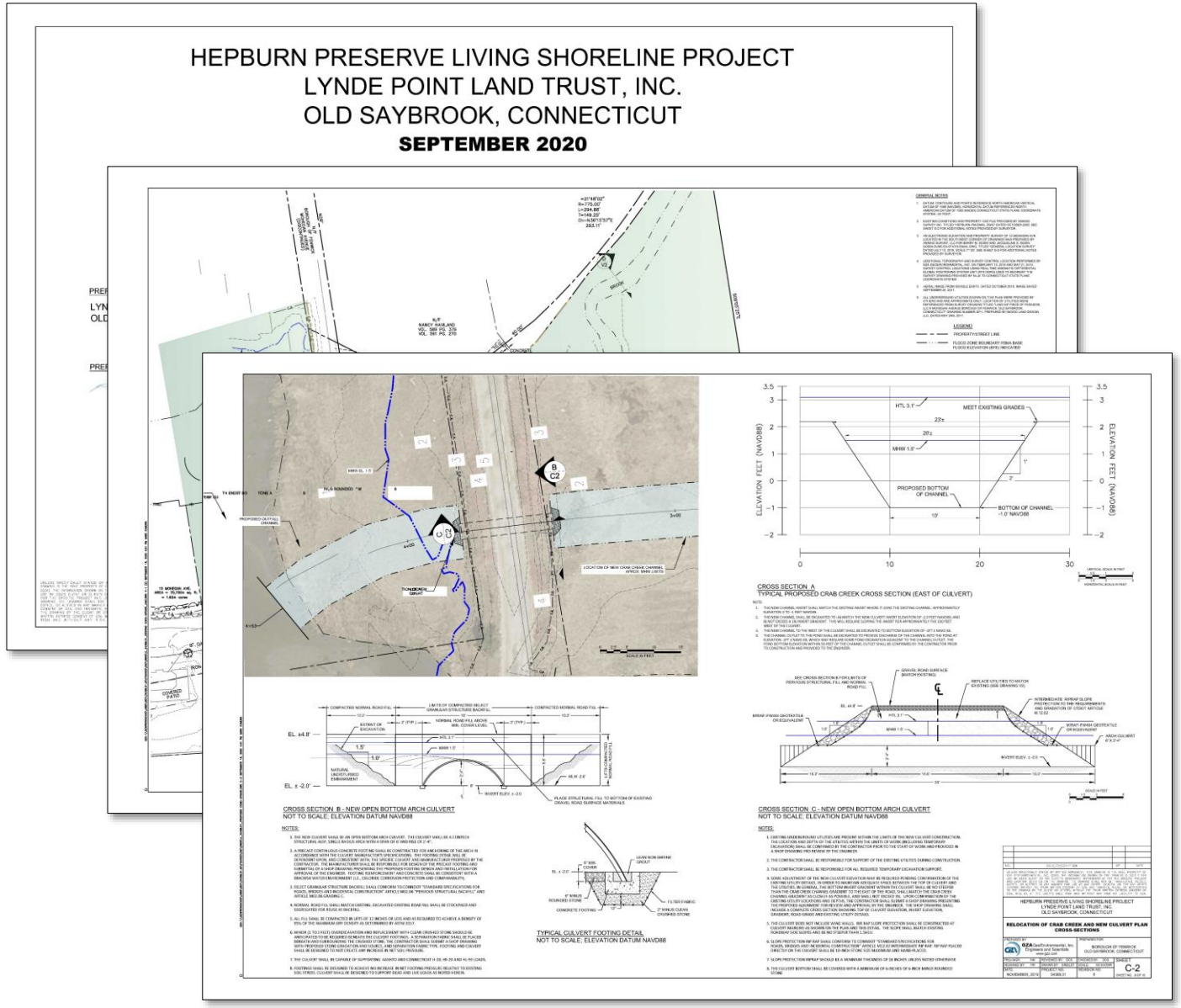


LIVING SHORELINE CONCEPT DESIGN





LIVING SHORELINE FINAL DESIGN AND CONSTRUCTION



THANK YOU

Daniel Boudreau, GISP
Geospatial Systems Lead
GZA GeoEnvironmental, Inc
daniel.boudreau@gza.com