

Creating Coastal Resilience

A 360 Degree GeoDesign Approach



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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

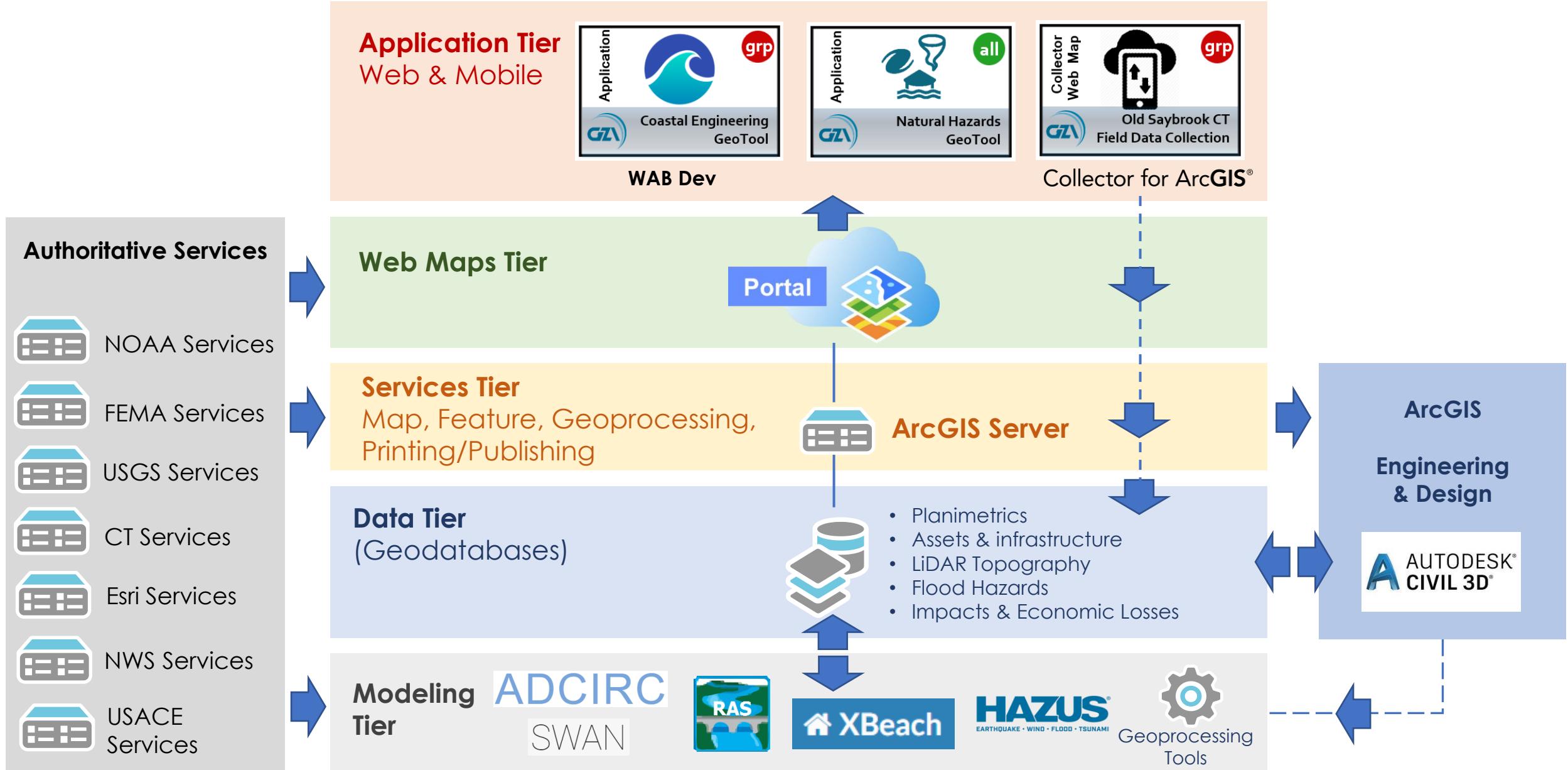
STUDY APPROACH

- 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



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

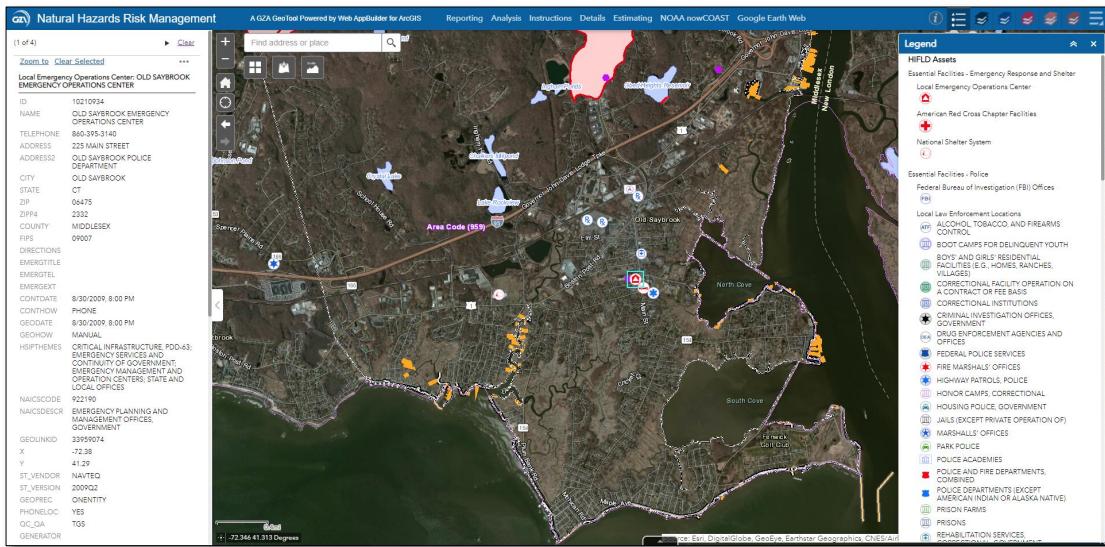
Identification of Coastal Resilience and Adaptation Strategies, Actions and Measures.

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

Natural Hazards Risk Management A GZA GeoTool Powered by Web AppBuilder for ArcGIS

(1 of 4) [Clear](#)

[Zoom to](#) [Clear Selected](#) [...](#)

Local Emergency Operations Center: OLD SAYBROOK
EMERGENCY OPERATIONS CENTER

ID	10210934
NAME	OLD SAYBROOK EMERGENCY OPERATIONS CENTER
TELEPHONE	860-395-3140
ADDRESS	225 MAIN STREET
ADDRESS2	OLD SAYBROOK POLICE DEPARTMENT
CITY	OLD SAYBROOK
STATE	CT
ZIP	06475
ZIPP4	2332
COUNTY	MIDDLESEX
FIPS	09007
DIRECTIONS	
EMERGTITLE	
EMERGTEL	
EMERGEXT	
CONTDATE	8/30/2009, 8:00 PM
CONTHOW	PHONE
GEODEATE	8/30/2009, 8:00 PM
GEOWHOW	MANUAL
HSIPTHEMES	CRITICAL INFRASTRUCTURE, PDD-63; EMERGENCY SERVICES AND CONTINUITY OF GOVERNMENT; EMERGENCY MANAGEMENT AND OPERATION CENTERS; STATE AND LOCAL OFFICES
NAICSCODE	922190
NAICSDESCR	EMERGENCY PLANNING AND MANAGEMENT OFFICES, GOVERNMENT
GEOLINKID	33959074
X	-72.38
Y	41.29
ST_VENDOR	NAVTEQ
ST_VERSION	2009Q2
GEOPREC	ONENTITY
PHONELOC	YES
QC_QA	TGS
GENERATOR	

Reporting Analysis Instructions Details Estimating NOAA nowCOAST Google Earth Web

Find address or place

Legend

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
 - Local Law Enforcement Locations
 - ALCOHOL, TOBACCO, AND FIREARMS CONTROL
 - BOOT CAMPS FOR DELINQUENT YOUTH
 - BOYS' AND GIRLS' RESIDENTIAL FACILITIES (E.G., HOMES, RANCHES, VILLAGES)
 - CORRECTIONAL FACILITY OPERATION ON A CONTRACT OR FEE BASIS
 - CORRECTIONAL INSTITUTIONS
 - CRIMINAL INVESTIGATION OFFICES, GOVERNMENT
 - DEA DRUG ENFORCEMENT AGENCIES AND OFFICES
 - FEDERAL POLICE SERVICES
 - FIRE MARSHALS' OFFICES
 - HIGHWAY PATROLS, POLICE
 - HONOR CAMPS, CORRECTIONAL
 - HOUSING POLICE, GOVERNMENT
 - JAILS (EXCEPT PRIVATE OPERATION OF)
 - MARSHALS' OFFICES
 - PARK POLICE
 - POLICE ACADEMIES
 - POLICE AND FIRE DEPARTMENTS, COMBINED
 - POLICE DEPARTMENTS (EXCEPT AMERICAN INDIAN OR ALASKA NATIVE)
 - PRISON FARMS
 - PRISONS
 - REHABILITATION SERVICES, GOVERNMENT

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

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

Legend

- Coastal Transects
- Flood Hazard Zones
- 1% Annual Chance Flood Hazard
- Regulatory Floodway
- Special Floodway
- Area of Undetermined Flood Hazard
- 0.2% Annual Chance Flood Hazard
- Future Condition 1% Annual Chance Flood Hazard
- Area with Reduced Risk Due to Levee

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

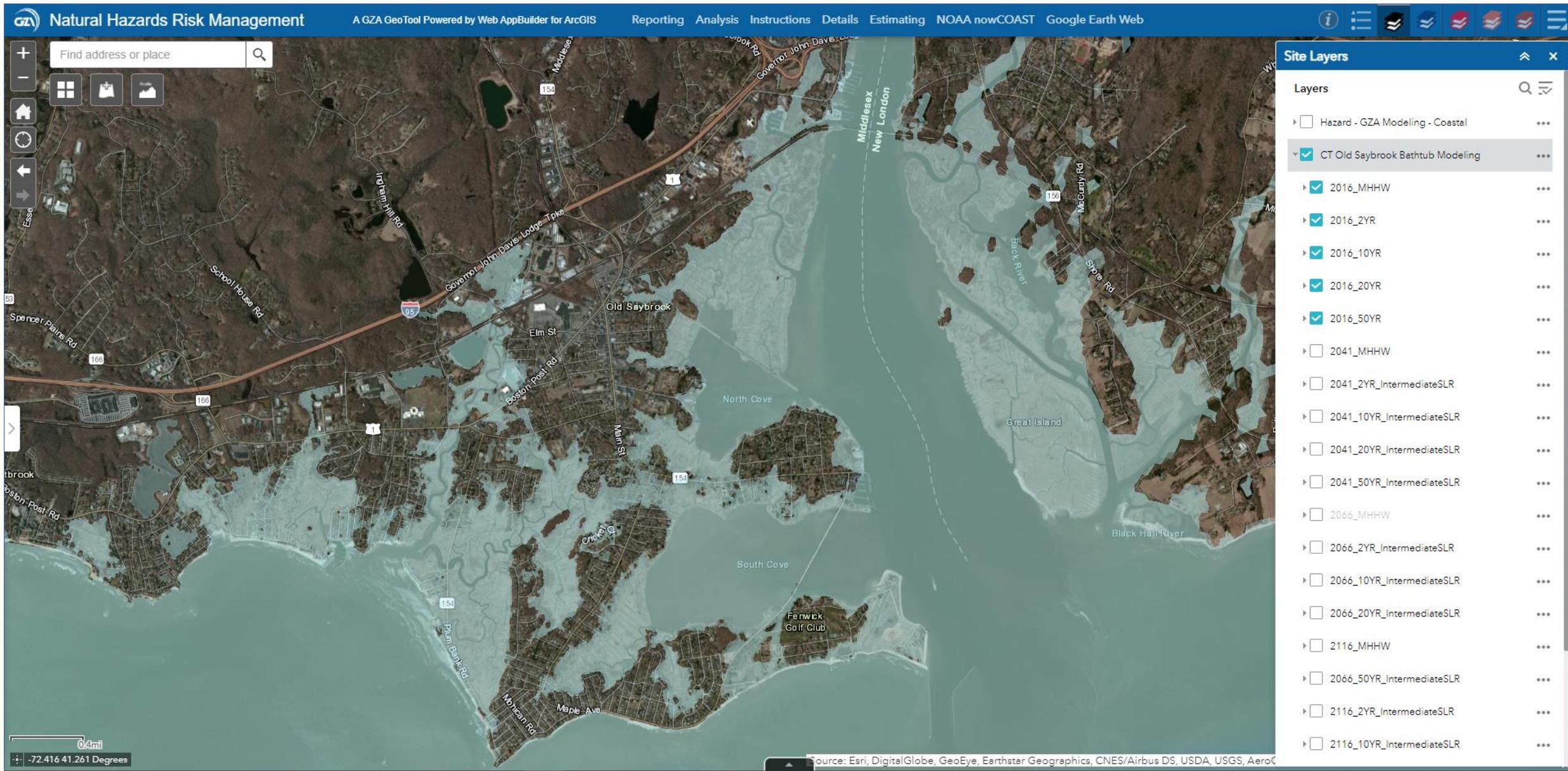
Current FEMA Special Flood Hazard Areas. The 100-year recurrence interval flood shown in green and the 500-year recurrence interval flood shown in brown.

Old Saybrook Coastal Resilience and Adaptation Study GZA | p4

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

-72.377 41.318 Degrees

FLOOD HAZARD CHARACTERIZATION – INUNDATION MODELING



FLOOD HAZARD CHARACTERIZATION – WAVE MODELING

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

Legend

2016 50-Year Flood (Max. Water Level ft)

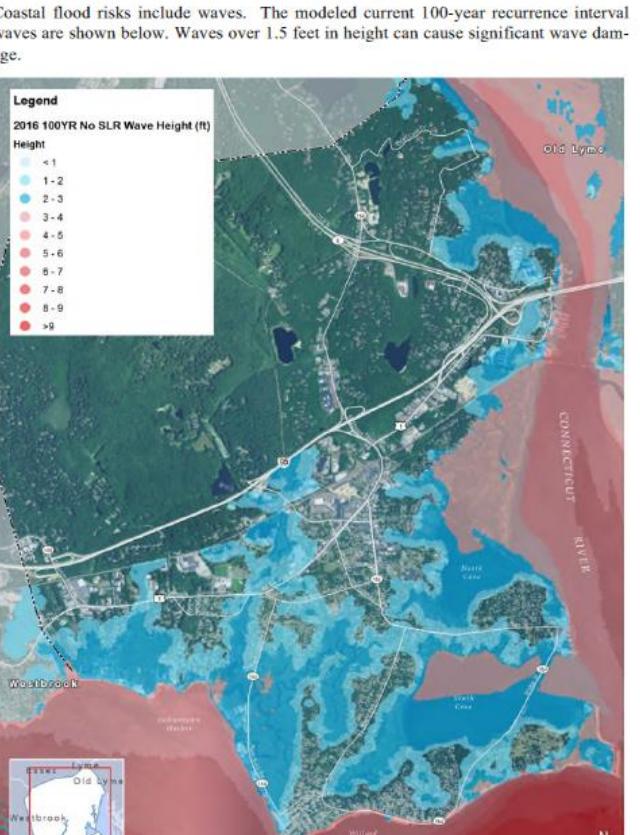


Coastal flood risks include waves. The modeled current 100-year recurrence interval waves are shown below. Waves over 1.5 feet in height can cause significant wave damage.

Legend

2016 100YR No SLR Wave Height (ft)

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



CONNECTICUT

Hazard - GZA Modeling - Coastal

Old Saybrook - Wave (100-year)

Height Range (ft)
0.0 - 1.5
1.6 - 2.6
2.7 - 3.8
3.9 - 5.0
5.1 - 6.3
6.4 - 7.8
7.9 - 9.4
9.5 - 10.9
11.0 - 12.2
12.3 - 13.9

Current 50-year recurrence interval flood.

Current 100-year recurrence interval wave heights.

Old Saybrook Coastal Resilience and Adaptation Study GZA | p6

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

72.39241.261 Degrees

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

Old Saybrook Coastal Resilience and Adaptation Study

ESSENTIAL FACILITIES

Old Saybrook Coastal Resilience and Adaptation Study

HIGH LOSS POTENTIAL FACILITIES

Old Saybrook Coastal Resilience and Adaptation Study

COMMUNITIES

Old Saybrook Coastal Resilience and Adaptation Study

SHELTERING AND EVACUATION

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

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

A detailed analysis of New England hurricane evacuation was also performed by the USACE and FEMA and pre-cane Evacuation Study, Technical Data Report, dated 2005. Evacuation statistics were developed for three evacuation zones for Old Saybrook:

- Zone 1 (Category 1 and 2 hurricanes flood inundate 100 people or less, people are vulnerable, will be impacted and may require evacuation; and
- Zone 2 (Category 3 and 4 hurricanes flood inundate 260 people or less, people are vulnerable, will be impacted and may require evacuation; and
- Zone 3 (areas located outside of coastal flood inundation 440 to 800 people or less, people are vulnerable, will be impacted and may require evacuation)

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

A percentage of evacuating people will require shelter. The remainder of evacuating people will shelter out-of-area. Current public shelter capacity is about 450 to 500 people. This analysis also indicates that there is also an alternative, in particular for smaller, higher frequency events.

Old Saybrook Coastal Resilience and Adaptation Study

NATURAL RESOURCES: MARSHES

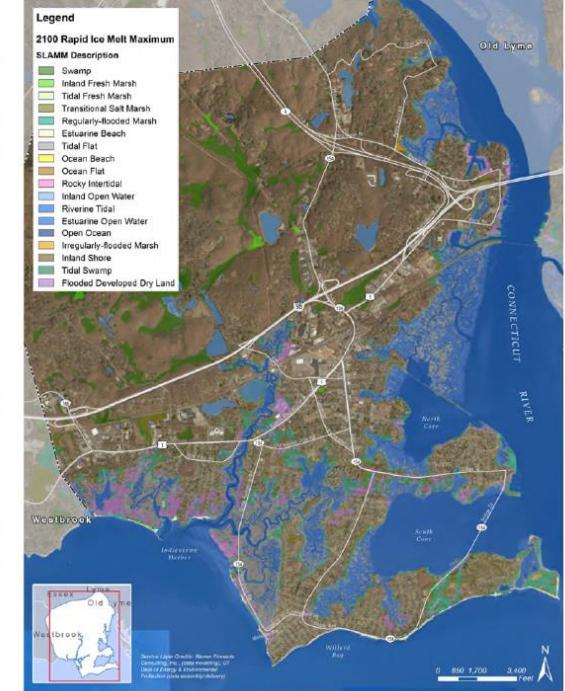
The "Application of the Sea-Level Affecting Marsh Model to Coastal Connecticut", prepared for the New England Interstate Water Pollution Control Commission by Warren Pinnacle Consulting, Inc., provides insight into the behavior of Old Saybrook's marshes when subject to sea level rise. The marshes provide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

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

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

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

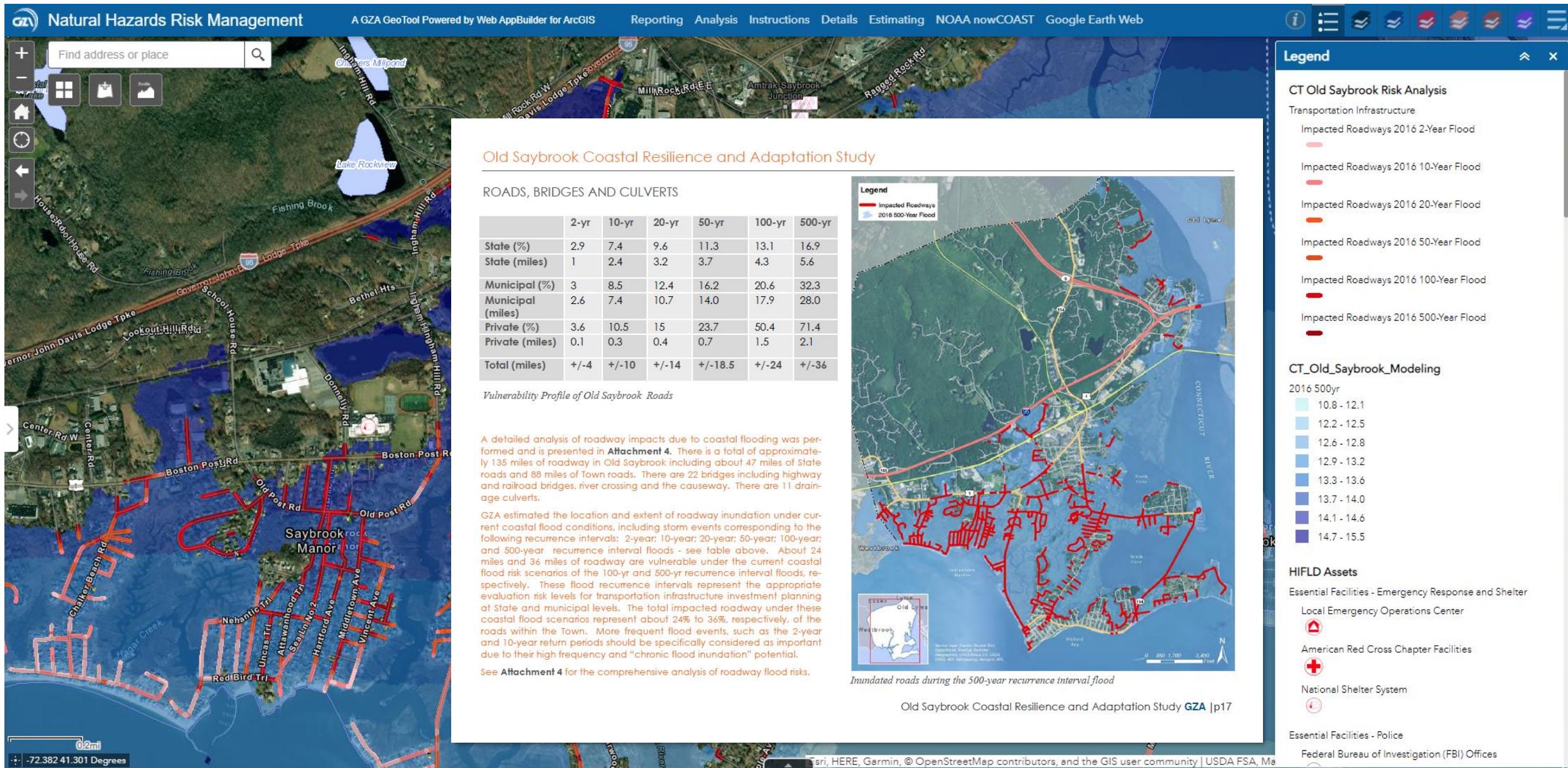
The analysis also indicates that the effect of sea level rise is not just a function of the total amount of sea level rise but also the rate of relative sea level change. The higher rate of sea level change under the SLAMM Rapid Ice Melt maximum sea level rise scenario, relative to scenarios with lower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



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

FLOOD HAZARD RISK – ROADWAY IMPACTS

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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-year and 500-year 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.

Legend

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

Inundated roads during the 500-year recurrence interval flood

Old Saybrook Coastal Resilience and Adaptation Study GZA |p17

02mi

-72.382 41.301 Degrees

Esri, 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.

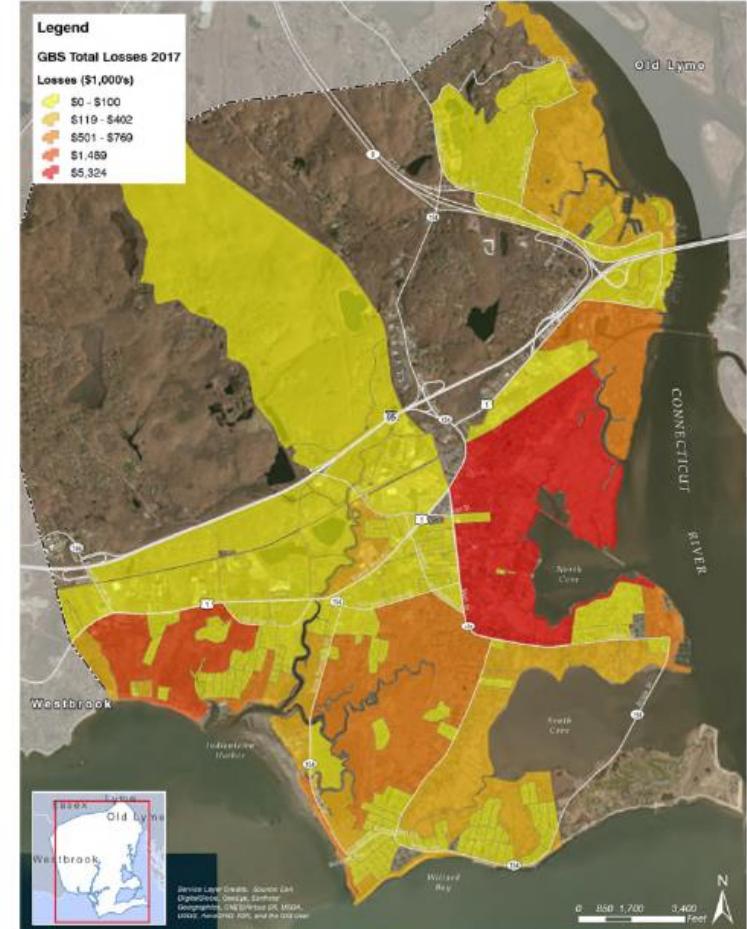
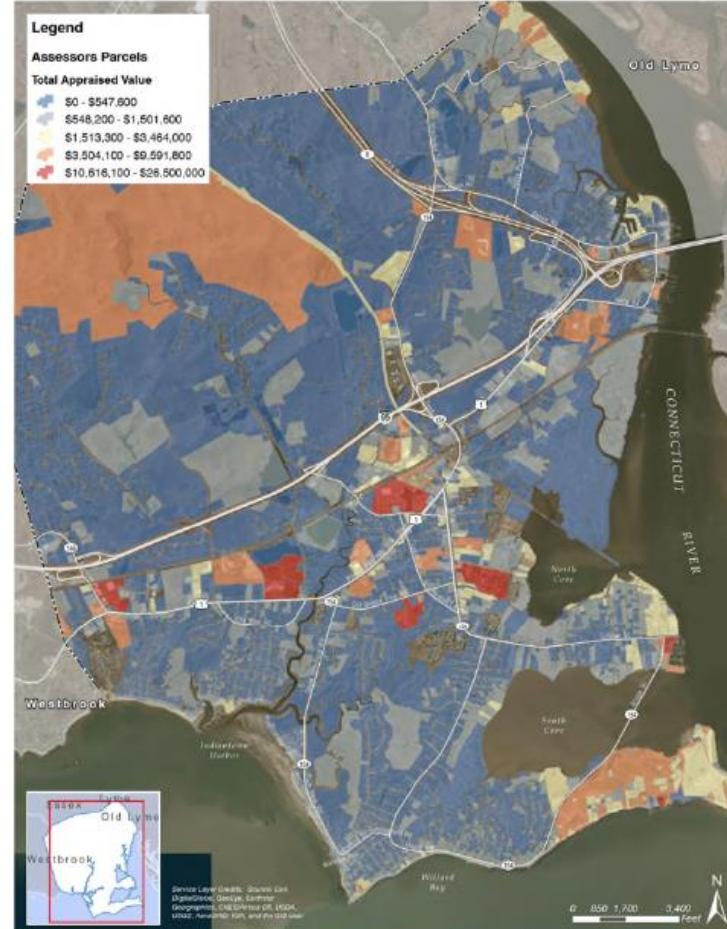
Repetitive loss properties represent an economic risk to both property owners and Town insurance rates.

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

Old Saybrook Coastal Resilience and Adaptation Study



ADAPTATION STRATEGIES, ACTIONS AND MEASURES

Old Saybrook Coastal Resilience and Adaptation Study

Attachment 5: Neighborhood Resilience and Adaptation Study

Adaptation Alternative A: Strategic Realignment

Section diagram 1-1'

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

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

Section diagram 2-2'

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

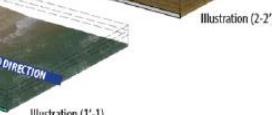


Illustration (2-2')

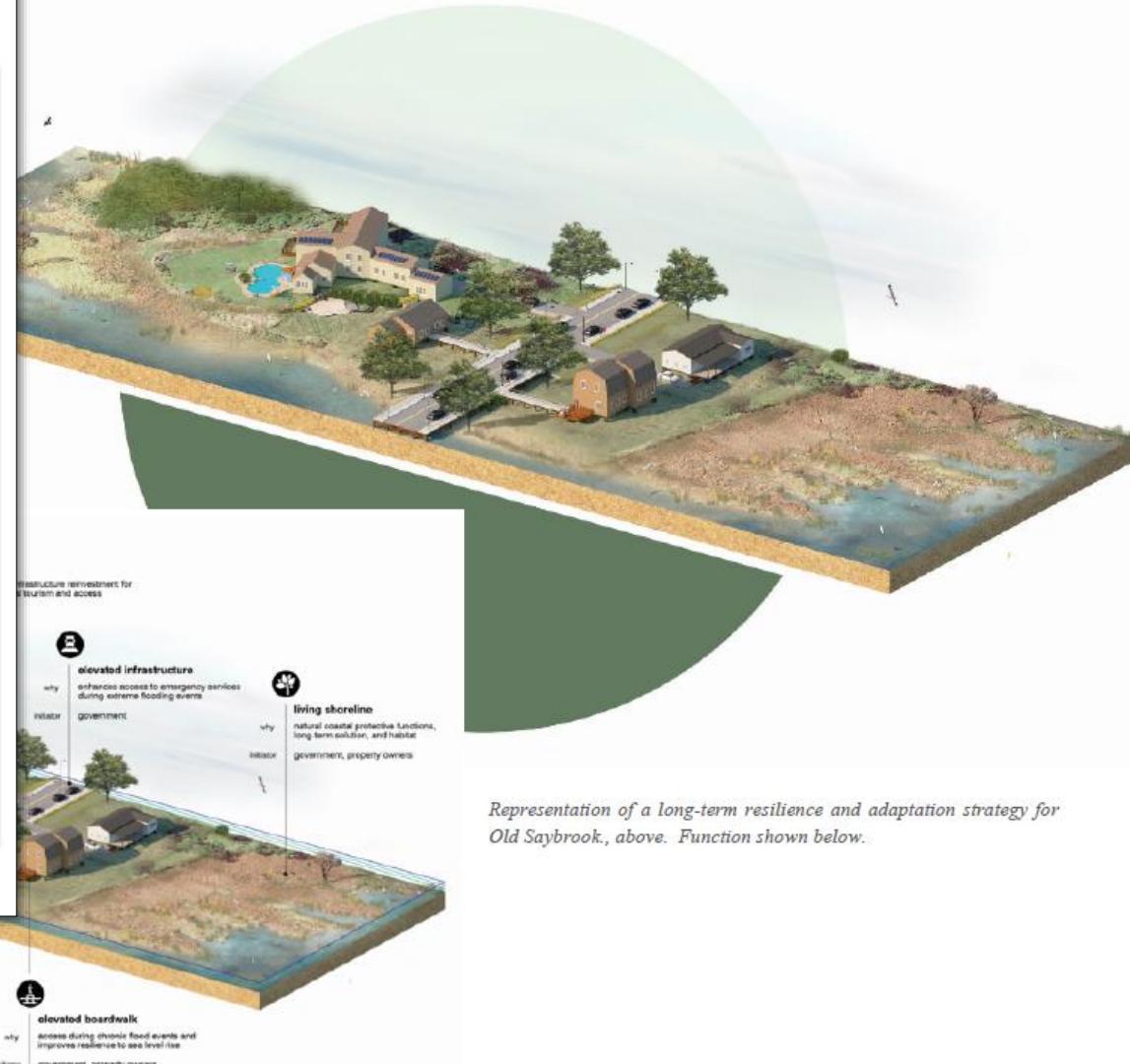
Old Saybrook Community Coastal Resilience Study
Community Workshop



Beach Community Workshop

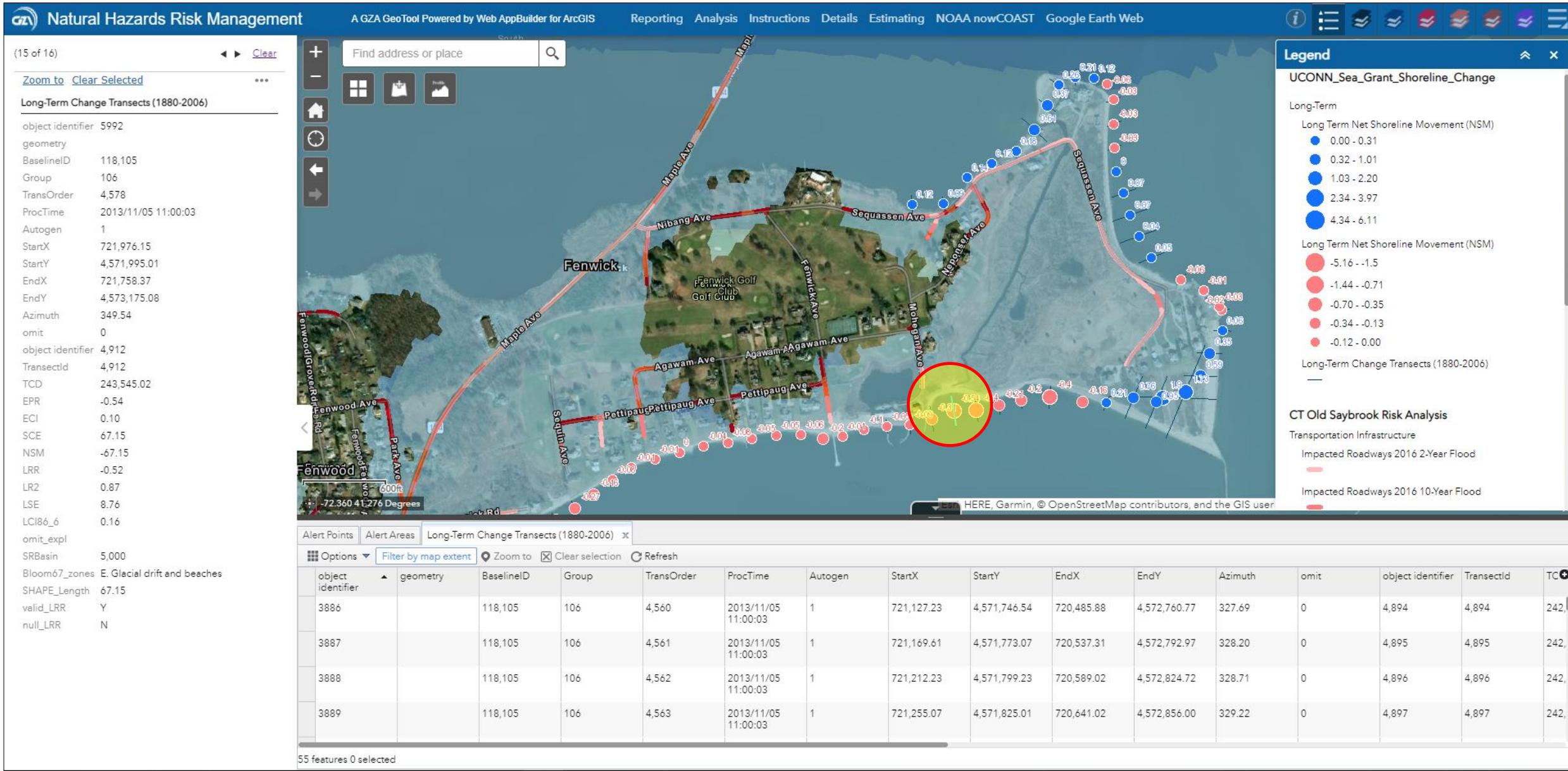
Figure 5-2: Adaptation Strategy A - Strategic Realignment

Old Saybrook Coastal Resilience and Adaptation Study GZA | 5-10

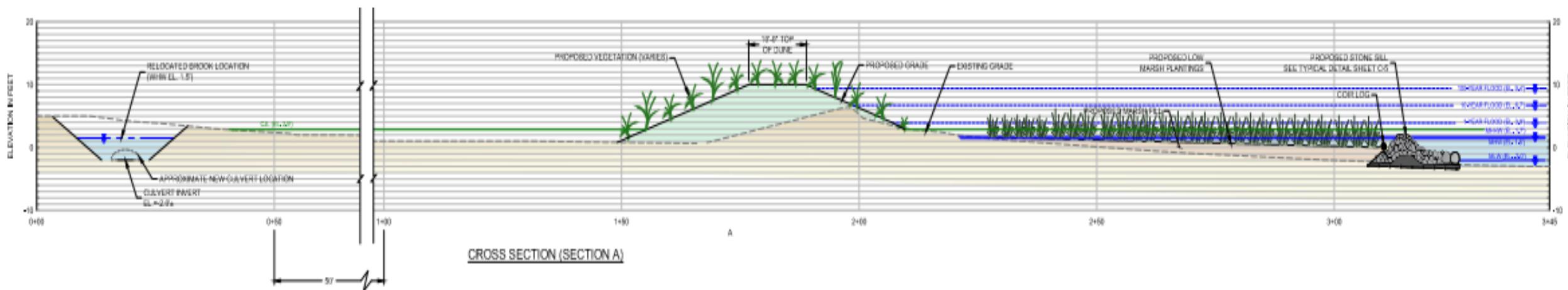
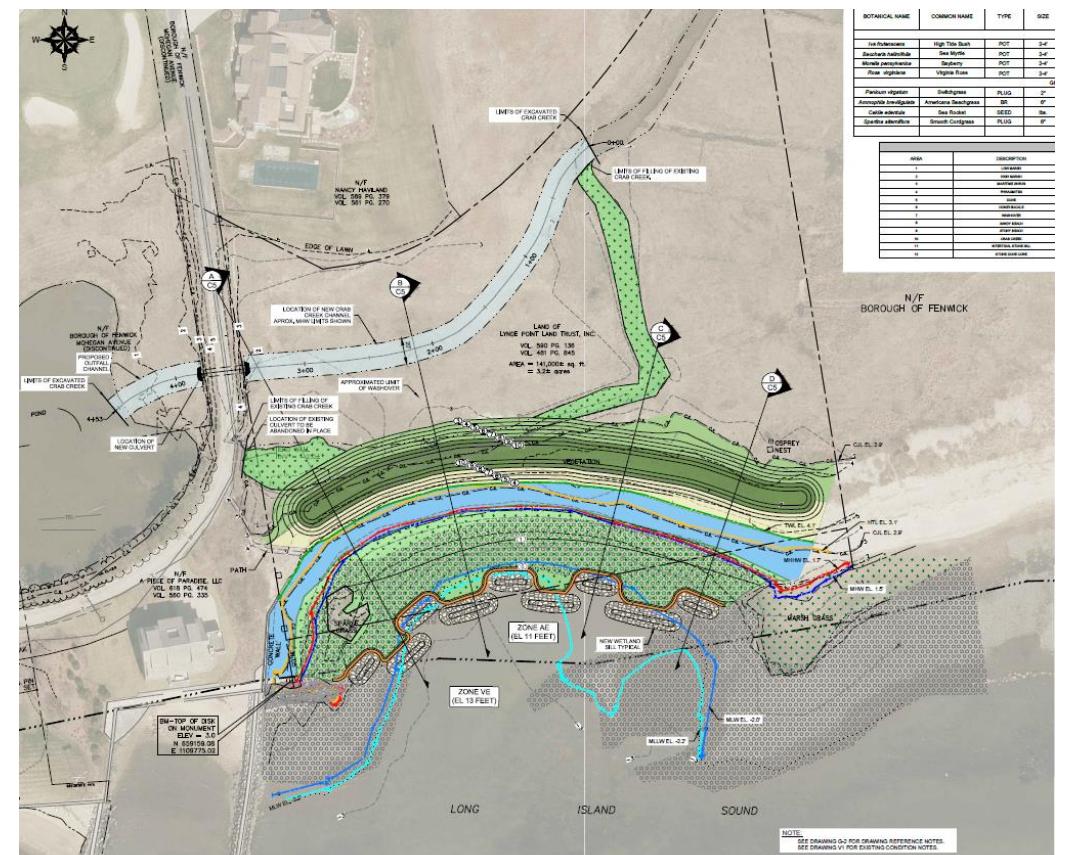


Representation of a long-term resilience and adaptation strategy for Old Saybrook, above. Function shown below.

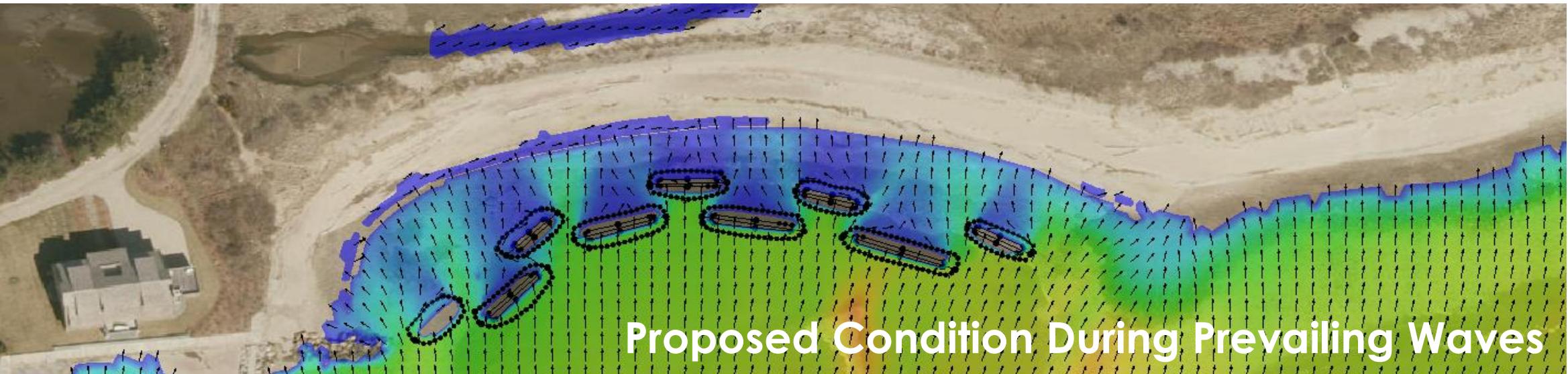
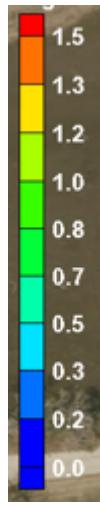
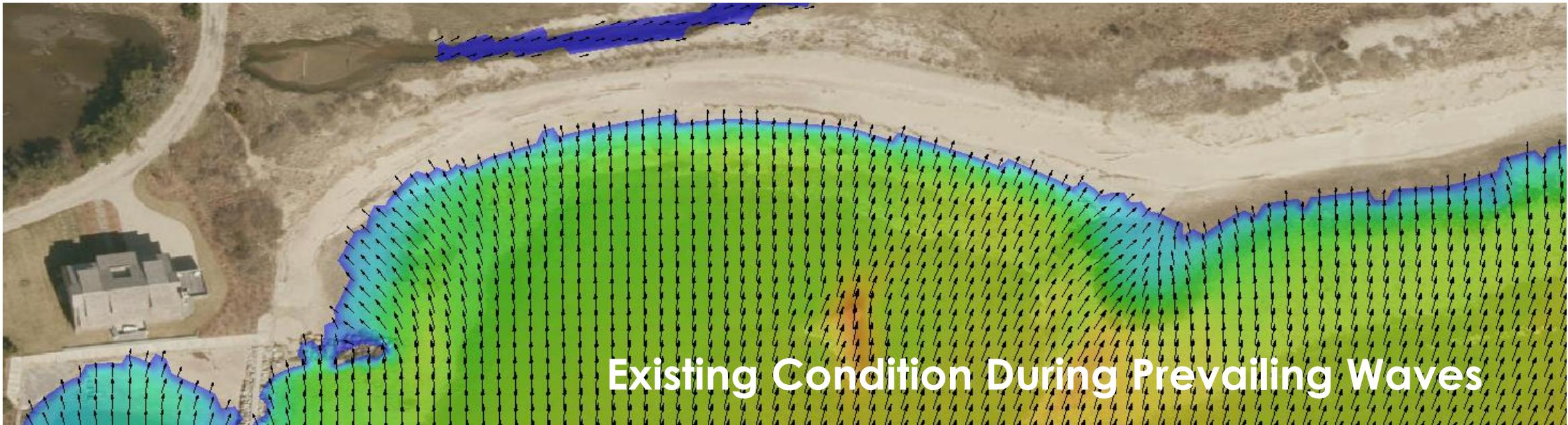
SHORELINE CHANGE



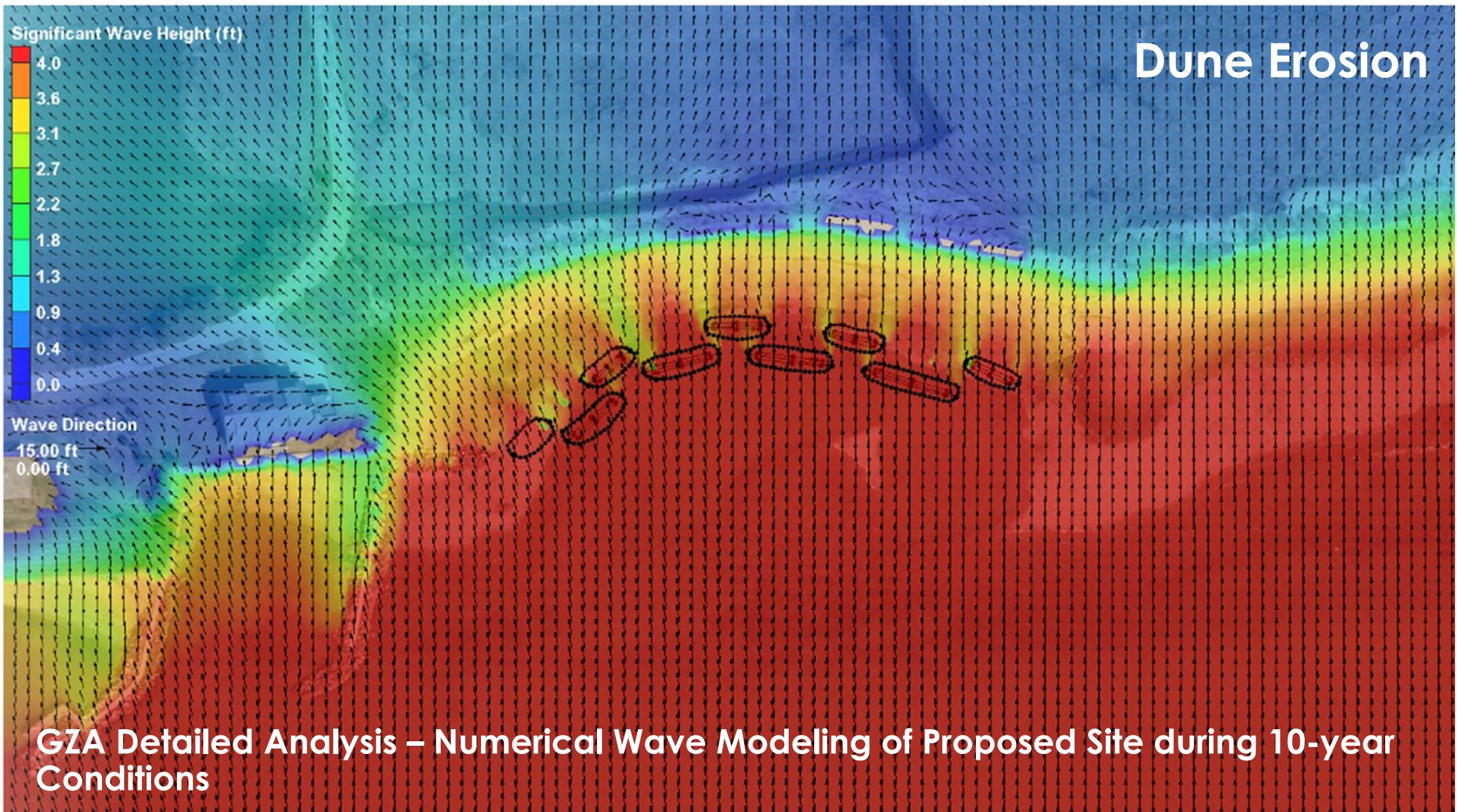
LIVING SHORELINE CONCEPT DESIGN



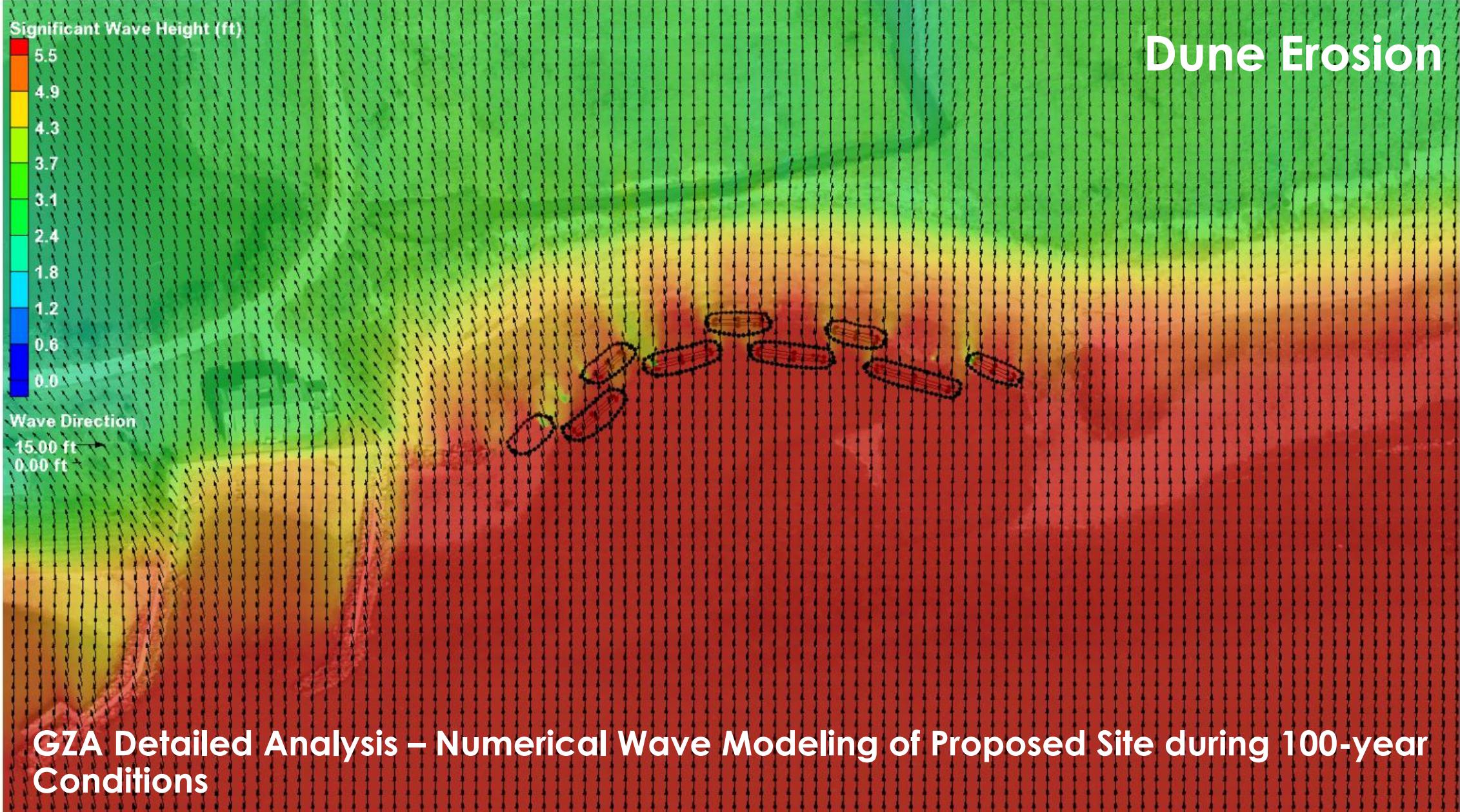
Living Shoreline Design Stress Analysis: Adverse Effects



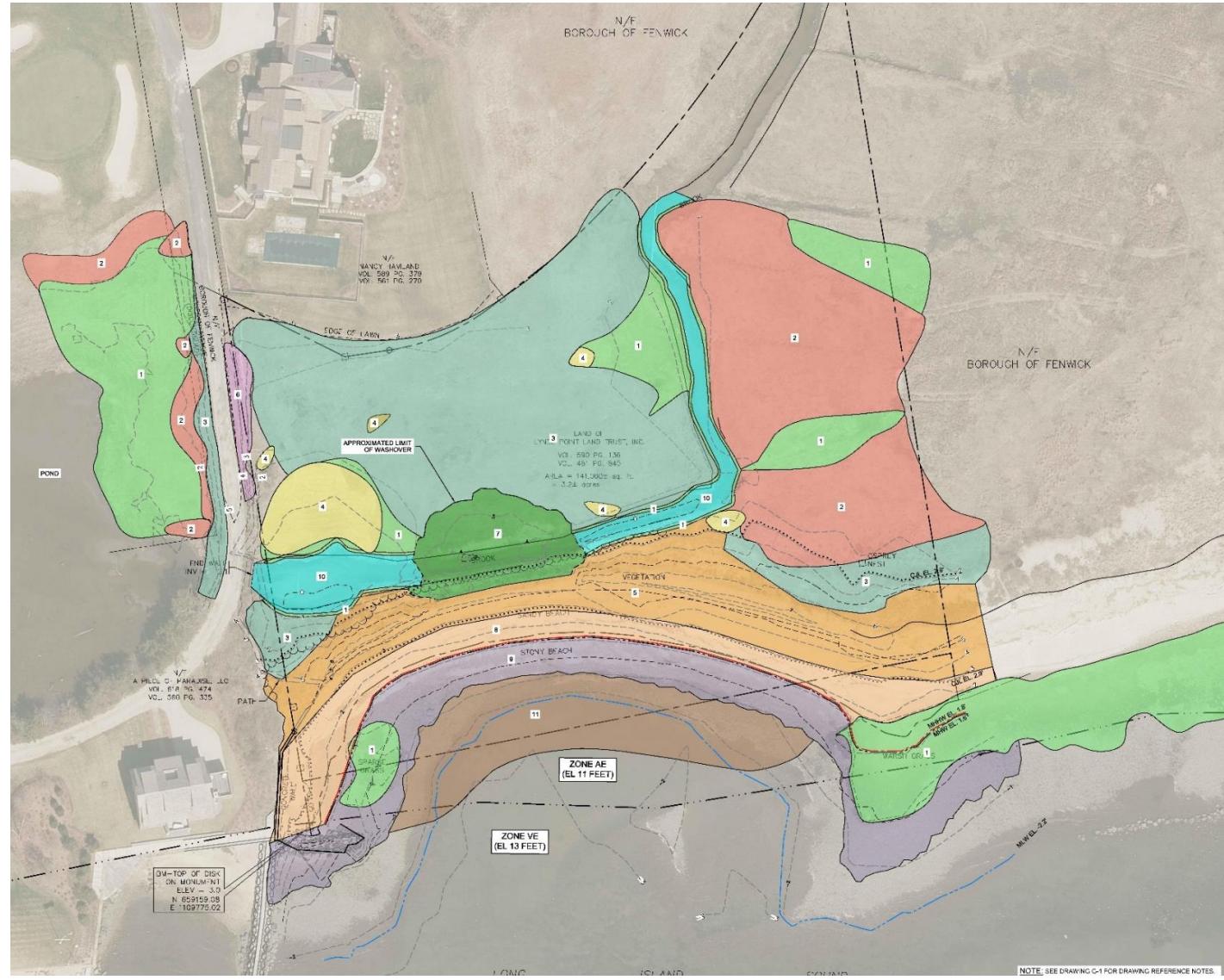
Living Shoreline Design Stress Analysis: Adverse Effects



Living Shoreline Design Stress Analysis: Adverse Effects



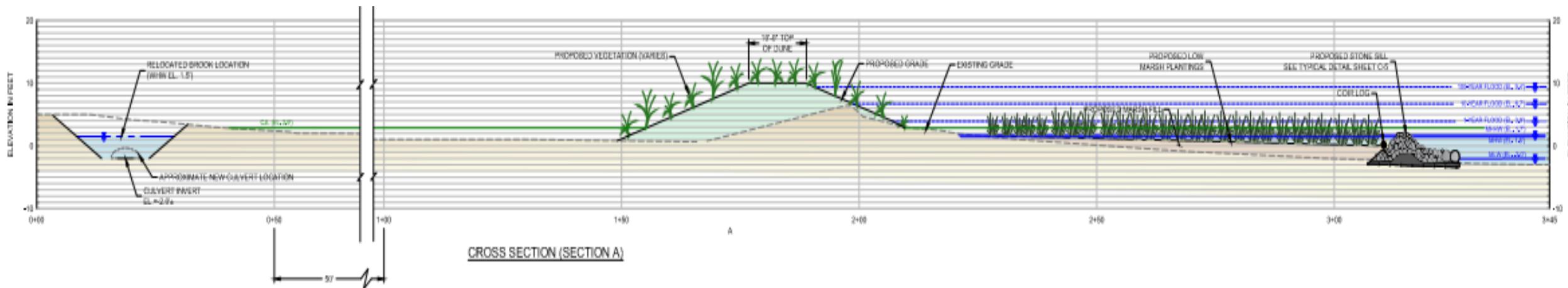
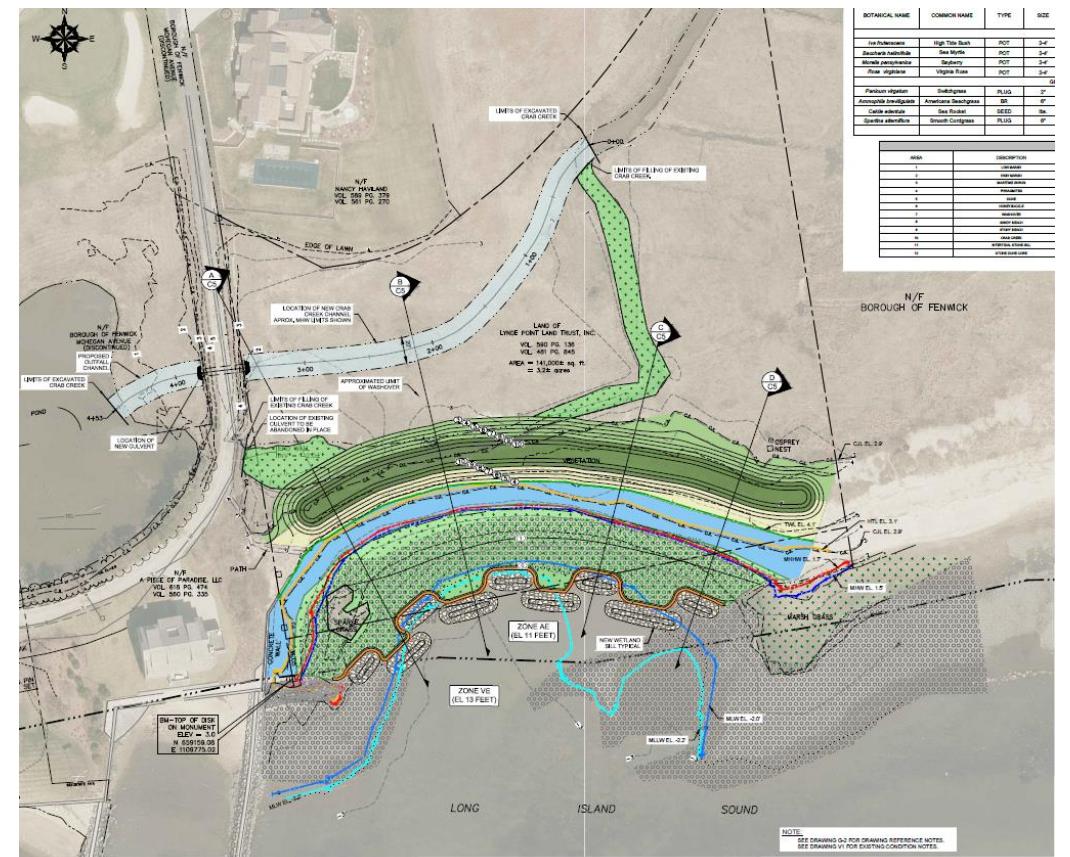
SITE CHARACTERIZATION: ECOLOGICAL



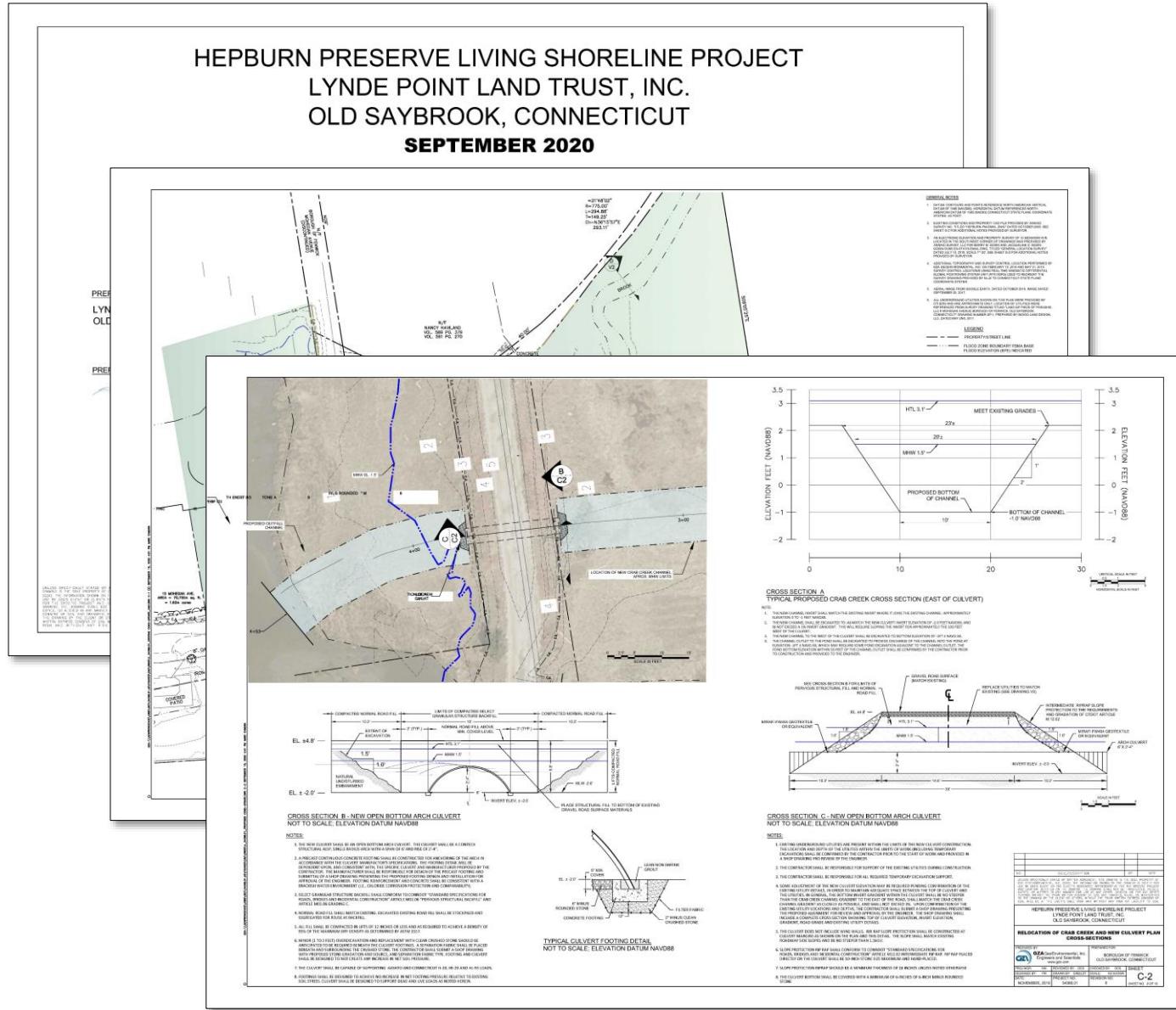
LIVING SHORELINE CONCEPT DESIGN



Conceptual Living Shoreline Design



LIVING SHORELINE FINAL DESIGN AND CONSTRUCTION



THANK YOU



Daniel Boudreau, GISP

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