CDBG-DR 2015

CLIMATE CHANGE RISK VULNERABILITY, RISK ASSESSMENT AND ADAPTATION STUDY

WATERFORD, CONNECTICUT

Prepared For:
Town of Waterford
15 Rope Ferry Road
Waterford, CT 06385

Prepared By:
Kleinfelder Northeast, Inc.
215 First Street
Cambridge, MA 02142

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INTRODUCTION

The effects of climate change present themselves in a variety of ways, including an increase in extreme precipitation, sea level, and storm surge resulting in heightened risks of flooding. The Town of Waterford has already experienced impacts to its infrastructure, natural resources, and economy from these hazards. Hurricane Sandy (2012) resulted in widespread power outages, disrupting daily life and municipal services. During Sandy, waves overtopped the dunes at the Town Beach and other south facing beaches changing the characteristics of the Alewife Cove and Goshen Cove channels due to siltation, along with impacts to other natural resource impacts. Roadway and drainage infrastructure were also damaged by flooding from extreme rainfall during Tropical Storm Irene (2011) and in March 2010 from an unnamed storm.

The Town of Waterford recognizes that future changes in climate patterns will have significant ramifications for its infrastructure and natural resources affecting its residents, businesses, and government. The *Climate Change Risk, Vulnerability Assessment and Adaptation Study* project allows the Town to proactively identify the risks associated with these changes, and to develop prioritized strategies to address them.

The Town of Waterford applied for and was awarded a $175,000 Community Development Block Grant - Disaster Recovery (CDBG-DR) grant to fund this study. The grant was awarded through the Connecticut Department of Housing. Abby Piersall, AICP, the Town of Waterford's Planning Director, was the Town's Project Manager responsible for administering the grant on behalf of the Town.

This project had five primary goals:

1. Develop appropriate rainfall, tidal, sea level rise and storm surge scenarios for the Town of Waterford for present, near-term and long-term time frames.
2. Produce high-quality maps and graphics showing the likelihood, extent and magnitude of flooding impacts.
3. Identify critical infrastructure, facilities and natural resources in Waterford that are vulnerable to present and future flooding events.
4. Develop and prioritize potential short-term and long-term adaptation strategies, with order-of-magnitude cost estimates where appropriate, including regulatory and policy changes, to help the Town manage its infrastructure and natural resources in the face of increasing flood risks.
5. Engage the public and government officials to solicit feedback on proposed strategies so that the Town can make informed decisions that will help to avoid future costly impacts to public and private property.

It is important to note that this vulnerability assessment and adaptation planning study is in no way connected with flood risk studies and mapping efforts periodically conducted by the Federal Emergency Management Agency (FEMA) to produce Flood Insurance Rate Maps (FIRMs) for the Town of Waterford. The coastal flood maps prepared as part of this study were developed for long-term planning using very different methods, scenarios, and data than are used by FEMA to prepare FIRMs. Data from this report should not be used in any way as a substitute for FIRMs as the legally-binding basis for determining flood insurance premiums and the minimum required inputs for the design and permitting of projects within the floodplain.

A. PROJECT TEAM

The Town of Waterford selected the team of Kleinfelder Northeast, Inc. (Kleinfelder) through a Request for Proposal process. Kleinfelder, located in Cambridge, MA, was the prime consultant responsible for client liaison, modeling, vulnerability assessment, adaptation planning, and public process. Woods Hole Group, located in Falmouth, MA, was a subconsultant to Kleinfelder responsible for coastal flood modeling. Martinez Couch & Associates of Rocky Hill, CT, another subconsultant to Kleinfelder, was responsible for surveying, vulnerability assessment and aerial drone photography used to develop rendered videos simulating future flooding impacts.

The team's primary members included:

- Andre Martecchini, PE – Kleinfelder - Project Manager, Adaptation Planning, Public Process
- Nasser Brahim – Kleinfelder - Project Scientist, Vulnerability Assessment, Adaptation Planning
- Kirk Bosma, PE – Woods Hole Group – Coastal Flood Modeling
- Dr. Indrani Ghosh, PhD – Kleinfelder – Riverine Hydraulic Modeling
- George Pendleton, PE – Martinez Couch Associates – Surveying, Vulnerability Assessment

Kleinfelder worked closely with a Town Working Group consisting of the following individuals:

- Abby Piersall, AICP – Planning Director and Town Project Manager
- Maureen Fitzgerald – Environmental Planner
- Kristen Zawacki, Public Works Director (through June 2017)
- Brian Long – Public Works Director
- Neftali Soto – Utility Director/Chief Engineer
- Jeff Sims – Chair, Conservation Commission
- Bert Chenard – Waterford Planning and Zoning Commission
- Dan Matheson – Assistant Director of Public Works
- Jim Bartelli - Assistant Utilities Director
- Steve Bellos – Emergency Manager
- Bruce Miller – Fire Services Director
- Peter Schlink – Fire Marshal

B. CITIZEN PARTICIPATION

As noted above, one of the primary goals of the project was to raise public awareness of increasing flood risks posed by extreme precipitation, sea level, and storm surge, and the potential strategies available to adapt to those changes over time.

The Town established a Citizen Participation Plan to provide a framework for citizen participation in the planning and implementation of the project. It includes policies on providing public notice, outreach to vulnerable populations, access to meetings and information, opportunities for public comments, and mechanisms for complaints and grievances.

Five Working Group meetings were held over the course of the project to review interim findings and to solicit feedback from members of the Working Group. All meetings of the Working Group were posted and open to the public.

- September 28, 2016 – Presented project overview, introduction to climate change parameters, draft Citizen Participation Plan, and goals for stakeholder meetings.
- October 31, 2016 – Presented and discussed results of the climate change parameters analysis, and data needs for the vulnerability assessment.
- February 16, 2017 – Presented and discussed coastal and riverine flood mapping results, identification of vulnerable areas, and vulnerability assessment methods.
- April 18, 2017 – Presented and discussed vulnerability assessment results, site selection for flood animations, and public workshop planning.
- August 9, 2017 – Presented and discussed preliminary adaptation recommendations, and public meeting planning.

On October 18, 2016, a presentation was made to the Town of Waterford Board of Selectmen describing the project goals and objectives, the general process that would be undertaken, and the tentative schedule.

On October 31, 2016, a presentation was made to the Town of Waterford Planning and Zoning Commission to review potential changes to regulations and policies.

Two general public meetings were held at the Waterford Town Hall to present interim findings to the public and to solicit comments.

- May 24, 2017 – Presented project goals and objectives; description of parameters used for coastal and riverine flood projections; coastal and riverine maps and vulnerabilities; and conducted breakout groups to introduce adaptation strategies.
- August 29, 2017 – Presented potential adaptation strategies, order-of-magnitude costs, and recommendations for potential regulatory/policy changes.

Kleinfelder also attended, staffed a table, distributed a project leaflet, and talked with interested citizens at the Waterford Free Summer Concert Series at Waterford Beach Park on July 26, 2017.

C. ACKNOWLEDGEMENTS

We would like to thank members of the Town of Waterford Working Group who provided valuable guidance, information about historic flooding events, local knowledge of facilities, roads and natural resources and important feedback to data presented at the various Working Group and public meetings. Their valuable input helped improve the accuracy of our conclusions and helped make our recommendations more meaningful and implementable.

We would also like to thank the Connecticut Department of Housing for funding this important project through a CDBG-DR grant.

FLOOD MAPPING

A. PARAMETERS

The establishment of parameters was critical to developing appropriate climate change scenarios for heavy rainfall, sea level rise, and storm surge.

Time Horizons

The Working Group selected 2016, 2030, and 2070 to be the data collection time periods for the climate parameters. Multiple time horizons were investigated to demonstrate that, in general, climate change is expected to accelerate and cause increasing impacts over time. Present day climate conditions, determined by sources of historic, local climate data, were used to identify priority adaptation projects. Parameters for 2030 and 2070 were based on climate change projections to identify incremental and opportunistic adaptation strategies.

Time horizons are important for communities to determine what adaptation actions need to be taken and how soon. In general, flooding issues that occur today are a high priority. Changes in future temperatures and sea level rise are dependent on multiple factors, including rates of greenhouse gas emission and natural system responses to those changes. Uncertainties related to future climate predictions are managed by using reasonably reliable data sources and methods to develop the projections of future impacted areas.

Tide and Storm Surge

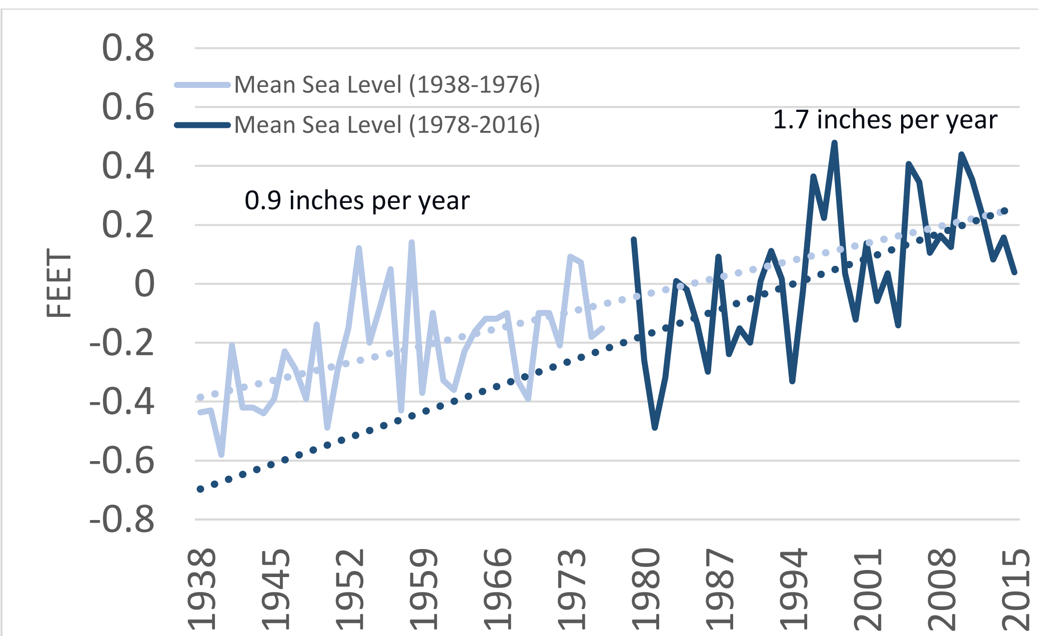


Figure 1 - Observed Acceleration of Sea Level Rise in Waterford

Figure 1 above shows monthly mean sea level in Waterford, as measured at the NOAA tide gage in New London since 1938. Data from the period 1938-1976 is shown in light blue, and 1978-2015 is in dark blue. In total, mean sea level has risen about 0.65 feet since 1938. While on average it has risen at a rate of 1.0 inch per decade, a closer look at the data reveals that sea level rise has accelerated over time. From 1938 to 1976 the rate of sea level rise was slightly below 1.0 inch per decade, but from 1978 to 2015 it rose at a rate of 1.7 inches per decade, or 84% faster. Most sea level rise projections for the future anticipate a similar and worsening acceleration trend over time as climate change becomes more pronounced.

To determine how much additional sea level rise Waterford should plan for in the future, the study uses sea level rise projections derived from the National Climate Assessment's global sea level rise scenarios. Several Connecticut laws mandate that these scenarios be used for coastal planning and infrastructure design. The National Climate Assessment provides three global sea level rise scenarios: Highest, Intermediate-High, and Intermediate-Low. The scenarios reflect different assumptions about how much and how fast key factors will contribute to sea level rise in the future. Figure 2 shows the relative increase in sea level in feet from 2016 for Waterford for the Highest, Intermediate-High, and Intermediate-Low scenarios.

Scenarios	Time horizons (year) and projections (feet)								
	2020	2030	2040	2050	2060	2070	2080	2090	2100
Highest SLR	0.1	0.6	1.1	1.7	2.4	3.2	4.2	5.2	6.3
Intermediate-High SLR	0.1	0.4	0.7	1.1	1.5	2.0	2.5	3.2	3.8
Intermediate-Low SLR	0.0	0.1	0.1	0.2	0.3	0.4	0.4	0.5	0.6

Figure 2 - Predicted Relative Sea Level Rise Scenarios in Waterford from 2016 (feet)

As glaciers and ice sheets on Greenland and Antarctica melt, water is added to the ocean's volume causing sea level to rise relative to land. In addition, as the ocean heats up, its volume expands further. The Highest scenario assumes maximum melting and significant thermal expansion. The Intermediate scenarios assume more limited melting and different degrees of thermal expansion. More information is provided in the NOAA Technical Report on Global Sea Level Rise Scenarios for the US National Climate Assessment (2012).

In 2017, the Connecticut Institute for Resilience and Climate Adaptation (CIRCA), at the University of Connecticut, released the *Sea Level Rise and Coastal Flood Risk in Connecticut* (2017) report. It estimates 1.7 feet of sea level rise in Connecticut by 2050. This projection is consistent with the Highest scenario in Figure 2.

Tide is a key parameter being studied in this project. The concern is that, as sea level rises, certain areas in town could eventually flood during daily or astronomical high tide cycles. Higher tide at the discharge-end of a drainage system could also chronically reduce that system's ability to drain properly. In Waterford, there are two high tides each day. The higher of the daily high tides is averaged over longer periods of time to estimate the Mean Higher High Water (MHHW) elevation. The three labeled points on the Highest sea level rise curve shown in Figure 3 are the MHHW elevations in 2016, 2030, and 2070. These present and projected MHHW elevations were used to develop sea level rise flooding maps. While it is not certain that the Highest scenario will accurately predict future sea levels, it is the safest scenario to plan for and it provides the most flexibility as a planning tool.

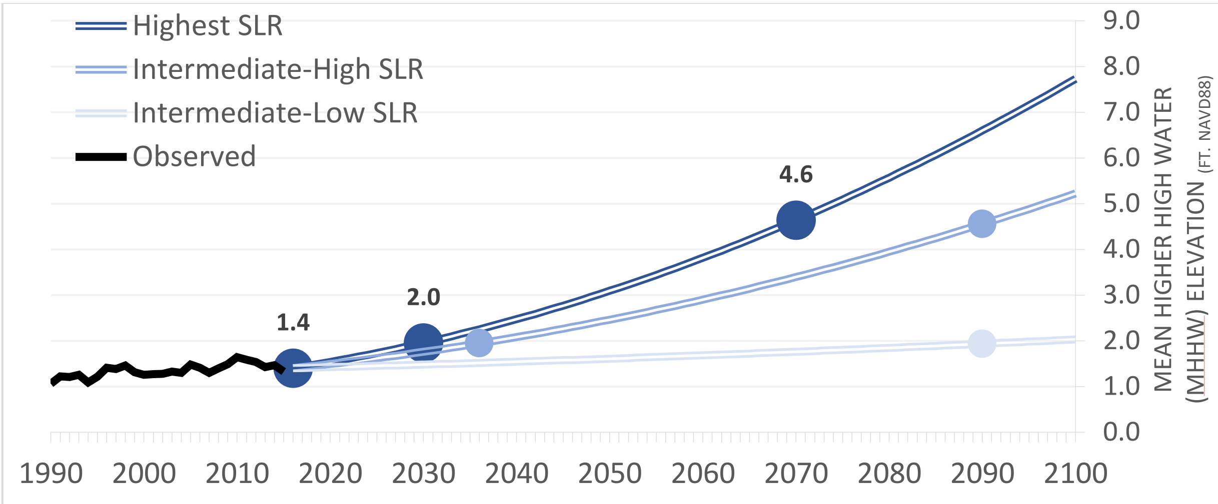


Figure 3 - Daily High Tide (MHHW) with Sea Level Rise Factored In

Heavy Precipitation

A robust set of measures were used to develop climate change projections for heavy rainfall in Waterford to manage the uncertainties inherent in projections. Two different climate projection data sources were evaluated, which rely on different downscaling methods. One source was the USDOT CMIP5 Climate Data Processing Tool, and the other was the University of Idaho MACA Statistically Downscaled Climate Data from CMIP5. The University of Idaho data more closely reproduced the rainfall design storms from NOAA Atlas 14 for the baseline period. In addition, the downscaled results are provided at a higher resolution than the USDOT data, meaning they are more localized. Based on these factors, University of Idaho data was used to develop Waterford's heavy rainfall projections.

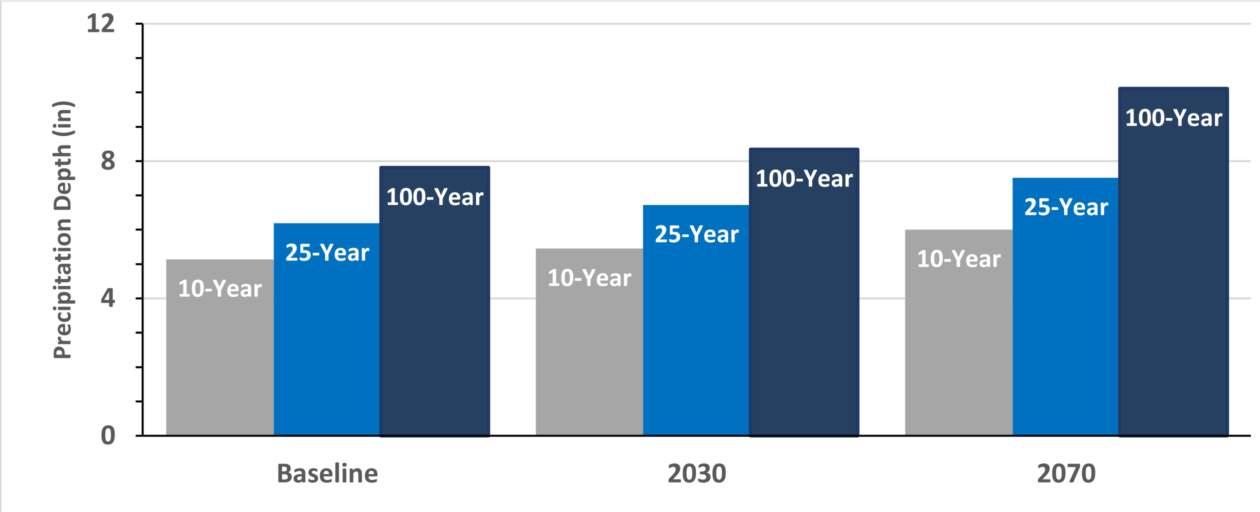


Figure 4 - Baseline and 24-Hour Design Storms Projected Rainfall

Figure 4 above shows the baseline 10-year, 25-year, and 100-year 24-hour design storms from NOAA Atlas 14 and the projected future design storms for Waterford. Note that the baseline 100-year storm is roughly equal to the 25-year storm in 2070. That is a four-fold increase in the frequency of these very heavy rainfall events. Similarly, the present 25-year storm is roughly equal to the 10-year storm in 2070.

B. COASTAL FLOODING

The Town of Waterford is highly vulnerable to coastal flooding and to the longer-term impacts of sea level rise and increasingly extreme storm surge.

The vulnerability assessment for Waterford utilized existing information available from Woods Hole Group and dynamic models developed by the United States Army Corps of Engineers. These models incorporate the dynamic factors of tides, waves, winds, storm surge, and sea level rise and extend throughout all the water bodies and rivers surrounding Waterford.

The model results were used to generate flooding probabilities and associated water depths, and flooding pathways, for Waterford under current day conditions as well as future sea level rise scenarios in 2030 and 2070. Additionally, an analysis was conducted to evaluate the change in Mean Higher High Water (MHHW) expected in 2030 and 2070 (no hydrodynamic modeling was required for the MHHW increase assessment). Flood extents, depths, and probabilities are illustrated on a series of GIS-based inundation maps.

The results of simulations for 2016, 2030 and 2070 were used to generate maps of potential flooding probabilities and associated water depths throughout Waterford. Two different map types are produced.

- Percent Risk of Flooding Maps - These maps can be used to identify locations, structures, assets, etc. that lie within different flood risk levels. For example, a building that lies within the 20% flood exceedance probability zone would have a 20% chance of flooding in any year under that climate projection (e.g., 2030-timeframe). Stakeholders can then determine if that level of risk is acceptable, or if some action might be required to adapt.

- Depth of Flooding Maps – These maps show the estimated difference between the projected water surface elevation for a given percent risk of flooding and existing ground elevation derived from the 2014 Sandy LiDAR (Light Detection and Ranging) survey. For this study, we produced Depth of Flooding Maps for the 1% Probability of Exceedance which has approximately a 100-year recurrence interval.

Depth of flooding maps were also developed for the effects of sea level rise alone, which do not include any effects from storm surge. These maps were developed as "bath-tub models" by creating a planar water surface consisting of the predicted sea level rise (global SLR plus land subsidence) for the years 2030 and 2070 plus the current Mean Higher High Water (MHHW) elevation.

The following town-wide coastal flood maps can be found in Appendix A:

- Present, 2030, 2070: Percent probability of flooding maps (total of 3)
- Present, 2030, 2070: Depth of flooding for 1% (100-year) storm maps (total of 3)
- Present, 2030, 2070: MHHW depth of flooding maps (total of 3)

More detailed flood map books can be found on the Town's website at the following link:

http://www.waterfordct.org/planning-development/pages/climate-change-vulnerability-risk-assessment-and-adaptation-study

C. RIVERINE FLOODING

The Town of Waterford is already experiencing riverine flooding, which will likely become more severe with climate change. The following flood maps, included in Appendix A, assess the probability of riverine flooding:

- Riverine flooding: Present FEMA, 100-yr 2030 and 2070 (total of 3 maps)
- Riverine comparison: Present FEMA, 2030 and 2070 comparison (1 map)
- Comparison of coastal and riverine: present, 2030 and 2070 maps that shows difference in extent between the 1% probability of coastal flooding and the 100-yr riverine flooding (3 maps)

The riverine flood mapping analysis focused on the eight drainage basins in the Town of Waterford:

- Hunts Brook
- Jordan Brook
- Latimer Brook
- Niantic River
- Oil Mill Brook
- Southeast Shoreline (East)
- Southeast Shoreline (West)
- Thames River.

These same drainage basins were also the focus of the Town's 2013 FEMA Flood Insurance Study (FIS).

Peak flood flows for seven of the eight drainage basins were calculated using the CTDOT standard USGS Regression Equations (CTDOT Drainage Manual Chapter 6, 2000) for 10-, 25- and 100-yr recurrence intervals for present, 2030 and 2070. These regression equations were developed from 10-45 years of records from stream gaging stations in Connecticut used to predict a stream's capacity during storm events. These regression equations were selected to be consistent with the 2013 FIS, because detailed riverine flood modeling is outside the scope of the current study.

Peak flood flows were calculated using the following parameters: 24-hr rainfall depth, drainage area, stream length, streambed slope, and percent drainage area underlain by coarse-grained stratified drift. Rainfall depths were based on climate change projections for various 24-hr design storms developed as part of this current study. The drainage area and stream length for each of the drainage basins were estimated using GIS. If a watershed lay partially outside of the Waterford Town boundary, a ratio of the area within the Town line to the total watershed area was used. Streambed slopes within each watershed were calculated from corresponding profiles provided in Vol. 3 and 4 of the FEMA 2013 Flood Insurance Study. If profiles were not available in the FIS, elevations were determined from 2-ft contours (downloaded from CT-DEEP website) using GIS waterbody boundaries and average slope calculated along the stream length.

Results of the above analysis estimate that peak flood flows in the rivers increase by approximately 12% (2030) and 34% (2070) for the 10-year storms, 10% (2030) and 26% (2070) for the 25-year storms, and 7% (by 2030) and 26% (by 2070) for the 100-year storms.

The 100-year peak flood flows were then used to determine the corresponding depths of flow for present, 2030 and 2070 based on an empirical relationship that was determined and used by FEMA in a nationwide study. The percent change in depth of flow for the 2030 and 2070 100-year flood, in relation to present, was estimated, and the same ratio was applied to determine the change in existing and future 100-year flood elevations, or in other words, determine the 100-year riverine flood elevation by 2030 and 2070. The change in the 100-year depth of flow between present and future scenarios was also used to determine the corresponding change in the 100-year floodplain area (referred to as the Special Flood Hazard Area - SFHA). This is defined on Flood Insurance Rate Maps as the area inundated by the 100-year, or 1% annual chance flood.

Results of these analyses estimate that the 100-year flood elevation and 100-year floodplain area increase 3-4% by 2030 and approximately 10% by 2070, compared to present FIS elevations.

This change in extent of the SFHA by 2030 and 2070 was mapped in GIS by proportionally increasing the area of the existing SFHA and by determining the intersect of the future SFHA with the projected 100-year flood elevation for 2030 and 2070. For existing FEMA 100-year flood zones that do not have a flood elevation defined, the extents of the future SFHA areas were mapped by only proportionally increasing the present SFHA areas by the change in present and future depths of flow.

A limitation of this approach is that it is mainly applicable in areas that are relatively flat and do not have abrupt slope changes in the vicinity of the floodplain. This is true for most of the drainage basins, except the upstream reaches of Jordan's Brook. However, considering the scale of this present study, we believe that this level of approximation is appropriate. If critical vulnerabilities are discovered in these areas, the Town may wish to carry out a more refined analysis of those areas in future studies.

D. RESULTS

Limitations

The sea level rise and storm surge predictions made in this report are based on some of the most recent developments in the science of regional climate change. However, it should be noted that the scenarios investigated in this limited study represent only some of the possible scenarios and combinations of sea level rise and storm surge. It should also be noted that there are many uncertainties involving the science of climate change.

The flood maps in Appendix A show flood levels over land only. For this level of study, it was not possible to create accurate 3D modeling of every building to show how flood waters would actually flow around or through buildings. For example, if a building is raised on pilings, water could be covering the land below the building footprint, but not actually touching the occupied first level of the building. The intent of the inundation maps is to illustrate the impacts, extent, and general water depths of potential sea level rise and storm surge scenarios, but not to indicate any specific damage scenarios for a particular building or structure.

Information shown on the coastal flood maps illustrates predicted flooding resulting from coastal flooding caused by storms (such as hurricanes and nor'easters) combined with sea level rise estimates developed by NOAA for the stated time periods. These flood maps expressly do not include flooding attributed to wave run-up, overtopping of seawalls, and backups within municipal drainage infrastructure. **These flood maps shall not be used to represent the extent of flooding for which flood insurance is required**.

Projections depicted on these flood maps are the best judgment of Kleinfelder and the Project Team, but, in no way shall the flood levels depicted be interpreted as any guaranteed predictions of future events, and they shall only be used for general planning purposes.

Vulnerable Areas in Waterford

The results shown in Table 1 below identify coastal and riverine flooding exposure in different areas of Waterford.

Table 1 - Areas in Waterford Vulnerable to Coastal and Riverine Flooding

	Coastal						Riverine	
	Daily High Tide + Sea Level Rise		≥ 1% (100 yr) Probability Flood + Sea Level Rise		≥ 0.1% (1,000 yr) Probability Flood + Sea Level Rise		≥ 1% (100 yr) Probability River Flooding	
Area	2030	2070	2030	2070	2030	2070	2030	2070
Mago Point	Not Impacted	Impacted	Impacted	Impacted	Impacted	Impacted	Impacted	Impacted
Ridgewood	Not Impacted	Impacted	Impacted	Impacted	Impacted	Impacted	Impacted	Impacted
Pleasure Beach	Not Impacted	Impacted	Impacted	Impacted	Impacted	Impacted	Not Impacted	Not Impacted
Goshen Cove	Not Impacted	Impacted	Impacted	Impacted	Impacted	Impacted	Not Impacted	Not Impacted
Town Beach	Not Impacted	Impacted	Impacted	Impacted	Impacted	Impacted	Not Impacted	Not Impacted
Jordan Cove	Not Impacted	Impacted	Impacted	Impacted	Impacted	Impacted	Impacted	Impacted
Avenues	Not Impacted	Not Impacted	Impacted	Impacted	Impacted	Impacted	Impacted	Impacted
Quaker Hill	Not Impacted	Not Impacted	Impacted	Impacted	Impacted	Impacted	Impacted	Impacted
Central	Not Impacted	Not Impacted	Not Impacted	Not Impacted	Impacted	Impacted	Impacted	Impacted

Not Impacted | Impacted

Using flood maps and data collected to assess the infrastructure impacted allows one to consider both how likely a damaging flood event is, and also, when to take action regarding future infrastructure upgrades. Identifying vulnerable infrastructure allows the Town to prioritize spending of their capital funds. The Town-owned infrastructure assets that are subject to flooding in either or both the 2030 and 2070 scenarios are identified in Table 2 (buildings and facilities) and Appendix B (roadways).

Three animated videos were created using unmanned aerial vehicle (drone) imagery and topography collected specifically for this project along with the project flood model results to illustrate the extent of possible future coastal flooding in the Quaker Hill, Ridgewood and Avenues areas of Waterford. Figures 5, 6 and 7 below show "still" shots from the videos depicting the areas today with no flooding, and simulated flooding in 2030 and 2070 for a 1% probability (100 year) storm and sea level rise. Links to the videos can be found at the Town's website:

http://www.waterfordct.org/planning-development/pages/climate-change-vulnerability-risk-assessment-and-adaptation-study

Figure 5 - Quaker Hill Area Looking North Along Old Norwich Road - 1% (100 Year) Coastal Floods

Figure 6 - Ridgewood Area Looking North Along Shore Drive – 1% (100 Year) Coastal Floods

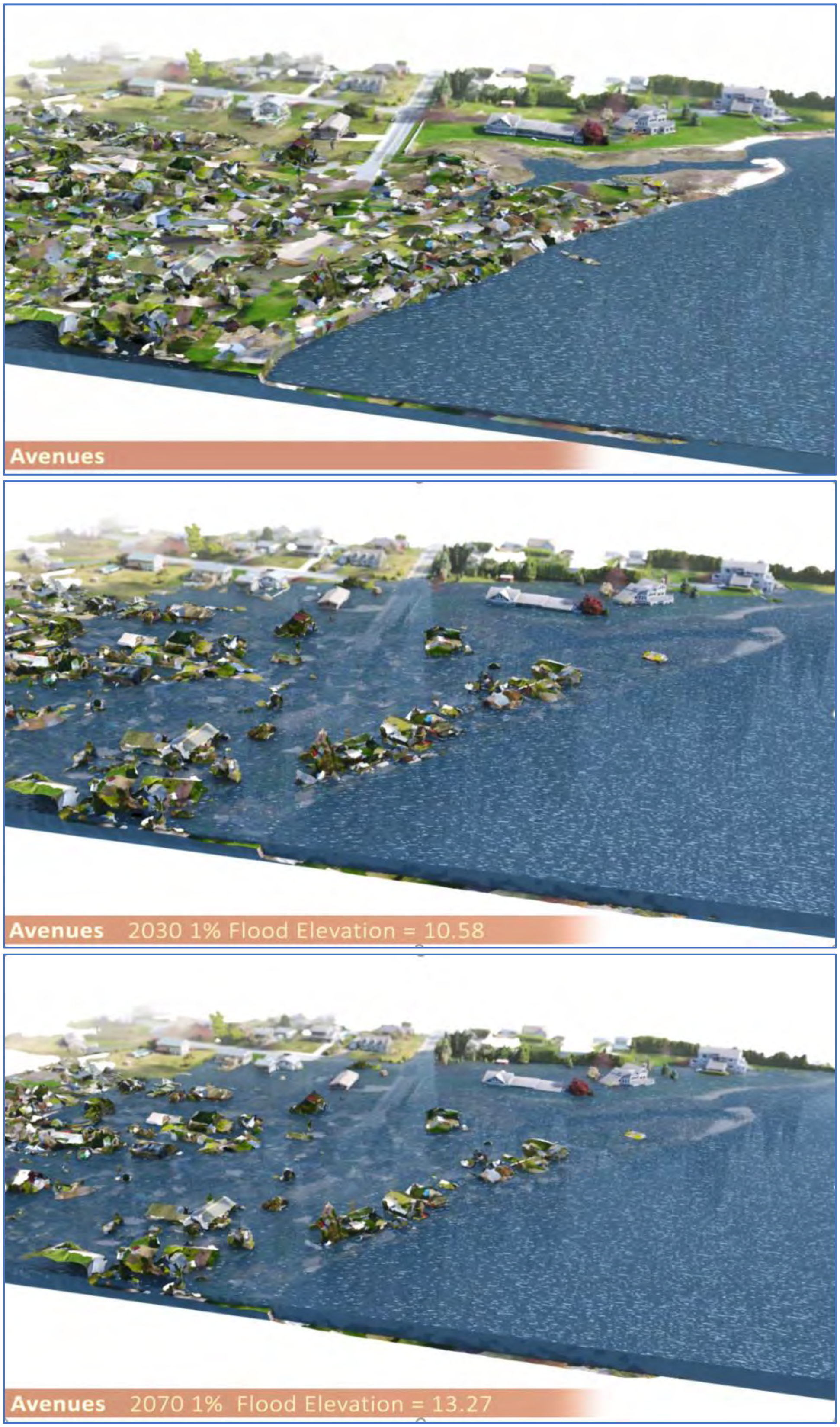


Figure 7 - Avenues Area Looking South Between 1st and 2nd Avenues – 1% (100 Year) Floods

VULNERABILITIES AND ADAPTATION STRATEGIES

A. METHODS

The Town of Waterford owns various properties, infrastructure, and facilities. These assets serve important public functions, including public safety, transportation, wastewater, stormwater management, education, recreation, historic preservation, and environmental conservation.

A vulnerability assessment was performed on Town-owned assets. The purpose was to determine which assets may experience flooding in the future, what the resulting impacts could be, and which assets could be adapted to minimize the effects of flooding.

Once priority vulnerabilities were identified, adaptation strategies were developed. Adaptation strategies include physical, regulatory, and operational changes that can reduce the impact of flooding on important public functions.

Town Assets:

- *Roadways and bridges*
- *Wastewater pump stations*
- *Fire stations*
- *Police stations*
- *Schools*
- *Town offices*
- *Maintenance facilities*
- *Historic properties*
- *Recreational facilities*
- *Beaches*
- *Marshes/Wetlands*

Data Collection

Kleinfelder reviewed as-built drawings and various local and state reports and records provided by the Town of Waterford for infrastructure assets. The Town also provided Geographic Information Systems (GIS) layers for some assets. Kleinfelder staff then made several field visits with Town personnel to visually observe and photograph critical assets. If these assets were not on the GIS layers provided by the Town, they were added in. Asset information included their location, condition, use, importance, and past flooding issues.

The following resources, some provided by Town staff, were reviewed as part of the data collection effort:

- GIS data from the Town of Waterford, CT, UConn Connecticut Environmental Conditions Online, Connecticut DEEP, US Census Bureau, FEMA, and Esri.
- *Hazard Mitigation Plan Update Annex for the Town of Waterford*. Town of Waterford. 2012.
- *Wastewater Pump Station Flooding Vulnerability Evaluation for the Waterford Utility Commission*. Wright-Pierce. 2016.
- Wastewater Facilities Plan Update. Waterford Utilities Commission. 2011.
- Elevation certificates for various wastewater pump stations and Quaker Hill Fire Station.
- *Adapting to Coastal Storms and Flooding: Report on a 2014 Survey of Waterford Residents*. Clark University and The Nature Conservancy. 2015.
- *Town of Waterford Hazards and Community Resilience Workshop Summary of Findings*. The Nature Conservancy. 2015.
- Evacuation Routes Map, Emergency Planning Zone for Millstone Station.
- Engineering drawings for various bridges.

- Map and narrative of flood vulnerability from prior storm events in 1982, 2010, and 2012 in Waterford, CT. Town of Waterford.
- Map of drainage issues during the 1970s-1980s in Waterford, CT. Town of Waterford.
- *Flood Insurance Study, New London County, Connecticut*. Federal Emergency Management Agency. 2013.
- Town of Waterford Zoning Map
- Beebe Brook watershed map
- *Assessing the Impacts of Hurricane Sandy on Coastal Habitats*. National Fish and Wildlife Foundation. 2012.
- *A Salt Marsh Advancement Zone Assessment of Waterford, CT*. The Nature Conservancy. 2013.
- *Stabilization of Goshen Cove Outlet Feasibility Study at Harkness Memorial State Park, Waterford, CT*. Woods Hole Group. 2015.

Vulnerability Assessment

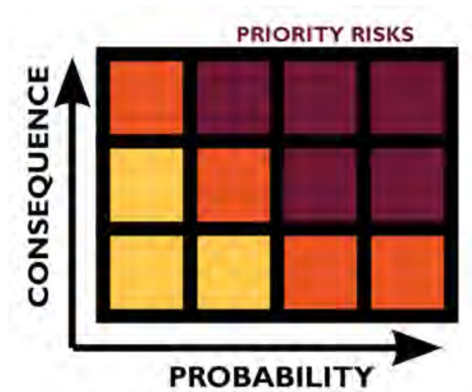
The coastal and riverine flooding maps developed for the project were overlaid on the asset maps in GIS. Each asset was assessed to determine the type, probability, and depth of flooding that the asset could be exposed to in present, 2030, and 2070 scenarios. The impacts from these flooding conditions were evaluated using information gathered in the data collection process.

In some cases, additional field work was carried out to verify vulnerabilities. Buildings and their utilities, for example, are sometimes elevated above predicted flood levels. Though maps may show them as being located in a flood zone, they may not be subject to significant flood damage.

After an initial screening to determine assets vulnerable to flooding, surveyors from Martinez Couch & Associates surveyed critical elevations of wastewater pump stations and other potentially vulnerable buildings. To make the most of this field work, the surveyors created new elevation certificates for several pump stations that are raised above ground levels.

Risk-Based Prioritization

The identified vulnerable assets were further prioritized based on their levels of risk. Risk takes into account both the probability (likelihood) of an asset being impacted, and the resulting consequence of that impact.



Decision-makers are encouraged to consider both of these factors when setting priorities for limited funding. That way, when faced with limited resources, they can focus on addressing issues that are relatively more likely and more consequential than others.

B. VULNERABILITY ASSESSMENT RESULTS

Vulnerable Buildings/ Facilities

Over 130 buildings on Town-owned parcels were assessed for vulnerability to coastal flooding (high tide and storm surge) and riverine flooding (1% annual probability) under present climate conditions and projected conditions in 2030 and 2070.

In the scenarios and time horizons studied, there were several positive findings:

- Town-owned buildings are not likely to be exposed to direct flooding at high tide with no storm surge in 2030 and 2070, taking into account future sea level rise projections.
- The Town Hall, Public Library, Community Center, Public Safety Complex, schools, fire stations (except Quaker Hill Fire Station), and emergency shelters are unlikely to be exposed to direct flooding in extreme coastal and riverine events in the 2030 and 2070 time frames.

However, several vulnerabilities were identified:

- Roadways used to access some Town-owned facilities are vulnerable to flooding. That could make them inaccessible during or immediately after a major flood event.
- Some wastewater pump stations and recreational facilities are vulnerable to coastal and/or riverine flooding.
- The Public Works Facility and Quaker Hill Fire Station may be vulnerable to riverine and coastal flooding, respectively, by 2070.

Table 2 below lists the facilities that are vulnerable to coastal and/or riverine flooding. The facilities are ranked by type, time horizon, and probability of exceeding the critical elevation of the facility for coastal flooding or the depth above critical elevation for riverine flooding. For coastal flooding, the table shows the probability of exceeding the critical elevation of the facility for combined sea level rise (SLR) and storm surge for a storm with a recurrence interval of 1% (100-years). For riverine flooding, the depth of flooding with a 1% annual probability of occurrence is used as a proxy for probability. The probability and depth of flooding values are based on flood maps, flood elevation data, and the critical elevation of the facility.

Table 2 - Facilities Vulnerable to Coastal and/or Riverine Flooding

Facility	Critical Elevation	Coastal			Riverine		
		Present	2030	2070	Present	2030	2070
Mago Point Pump Station	6.91	5%	20%	50%	6.09	6.48	7.39
Niantic River Pump Station	10.40	0.5%	1%	5%	1.60	1.96	2.80
Oil Mill Pump Station	10.63	0.5%	0.5%	5%	1.37	1.73	2.57
Town Beach Restrooms	5.60	10%	20%	100%	No	No	No
Town Beach Gazebos	6.00	10%	20%	100%	No	No	No
Jordan Park House Bldg. 13	15.00	No	No	0.1%	0.00	0.45	1.50
Jordan Park House Bldg.15	14.00	No	No	0.2%	1.00	1.45	2.50
Bolles Court Pump Station	10.07	0.5%	1%	5%	No	0.23	0.93
Quaker Hill Pump Station	10.30	0.5%	1%	5%	No	0.00	0.70
Shore Drive Pump Station	9.66	0.5%	0.5%	5%	No	No	No
Seaside Drive Pump Station	10.28	0.2%	0.5%	5%	No	No	No
Gardiners Wood Pump Station	10.70	0.2%	0.2%	2%	No	No	No
Stony Brook Pump Station	13.10	0.1%	0.2%	1%	No	No	0.10
Colonial Drive Pump Station	11.86	0.01%	0.2%	1%	No	No	No
East Neck Pump Station	12.78	No	0.1%	0.5%	No	No	No
Dock Road Pump Station	12.70	No	0.1%	0.5%	No	No	No
Harrison's Landing Pump Sta.	15.70	No	No	0.2%	No	No	No
Jordan Park House Bldg. 14	16.00	No	No	No	No	No	0.50
Public Works Facility	122.39	No	No	No	No	No	6.31
Quaker Hill Fire Station	14.40	No	No	0.5%	No	No	No

Colors indicate the time horizon of vulnerability: [red] = Present [orange] = 2030 [yellow] = 2070

The critical elevations (NAVD88 datum) shown in Table 2 for each asset that may be subject to flooding were determined based on the lowest elevation at which exposure to flooding would impair the asset's intended function. The lowest possible entry point where water can enter a building and damage critical equipment is the critical elevation. The critical elevation is unique for each facility or asset being evaluated. Figure 8 illustrates the concept of critical elevation. In this example, the critical elevation is the elevation of the basement window through which water would flood equipment in the basement critical to the operation of the building.

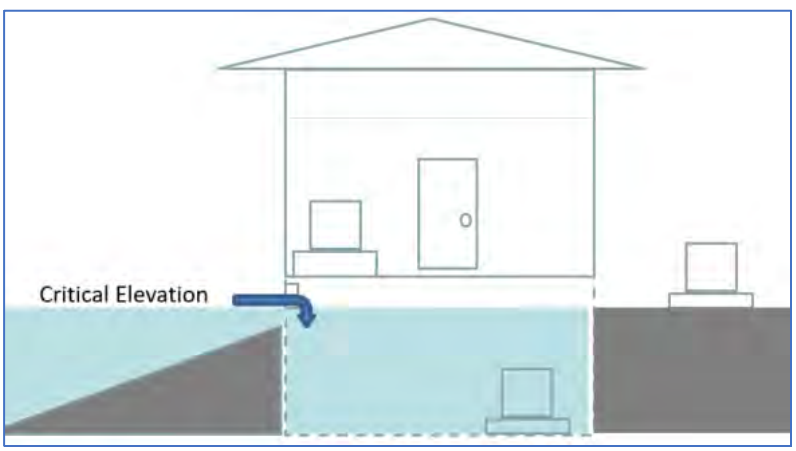


Figure 8 - Illustration of Critical Building Elevation

For buildings, pump stations and similar facilities, critical elevations were estimated using the following data sources:

- Information provided by Town staff.
- As-built drawings or other similar documents provided by Town staff
- On-site survey or observations
- LiDAR survey data

Table 3 prioritizes the potentially flood-impacted facilities qualitatively based on risk as a function of probability of flooding and consequence of flooding. Facilities were assigned a probability of flooding category based on the following:

High	Flooding occurs in present both for Coastal and Riverine Flood
Medium	Flooding occurs in present or 2030 for either Coastal or Riverine Flood
Low	Flooding occurs in 2070 for either Coastal or Riverine Flood

Consequences of flooding were determined based on the type of facility. Wastewater pump stations, fire stations and DPW facilities were determined to have a high consequence of flooding, because failure of these facilities would have severe impacts on post-flooding recovery. Historic structures were determined to have a medium consequence of flooding. Although they do not affect post-flood recovery, flooding of historic buildings could have high cost impacts to restore the buildings and could result in losses of historic significance. Town beach facilities were considered to have a low consequence of flooding as they do not affect post-flood recovery and can easily be replaced with minimal impact to the public.

Table 3 – Buildings and Facilities Prioritized by Risk

		PROBABILITY		
		Low	Medium	High
CONSEQUENCE	High	East Neck Pump Station Dock Road Pump Station Harrison's Landing Pump Sta. Public Works Facility Quaker Hill Fire Station	Bolles Court Pump Station Quaker Hill Pump Station Shore Drive Pump Station Seaside Drive Pump Station Gardiners Wood Pump Station Stony Brook Pump Station Colonial Drive Pump Station	Mago Point Pump Station Niantic River Pump Station Oil Mill Pump Station
	Medium	Jordan Park House Bldg. 14	Jordan Park House Bldg. 13 Jordan Park House Bldg. 15	
	Low		Town Beach Gazebos Town Beach Restrooms	

Based on this ranking, the three most vulnerable and highest-risk facilities are:

- Mago Point Pump Station
- Niantic River Pump Station
- Oil Mill Pump Station

Wastewater pump stations make up the bulk of buildings potentially impacted by flooding. Many pump stations are located at low areas of town. The Town of Waterford pumps its sewage to the New London wastewater treatment plant for treatment. There is an interconnected network of pump stations in Waterford as shown in Figure 9. Some pump stations are more critical than others because they not only collect wastewater from the surrounding area, but they also receive and pass through wastewater from other pump stations.

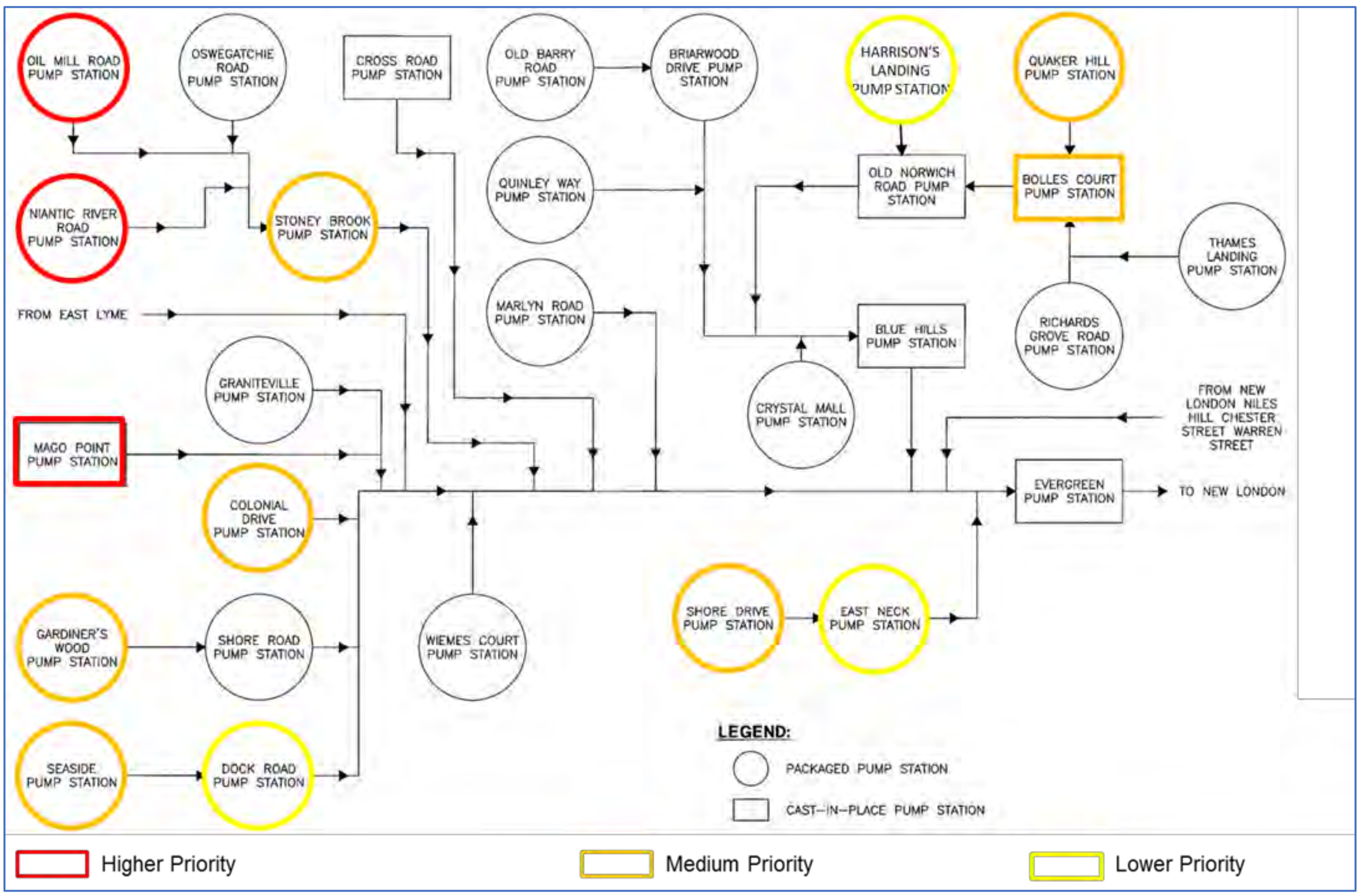


Figure 9 - Wastewater Pump Station Interconnectivity in the Town of Waterford

Figure 10 shows the approximate wastewater service areas with vulnerable pump stations. If pump stations are rendered inoperable due to flooding of the pumps or electrical equipment, sewer service in these areas would be disrupted until the water receded and the pump stations could be repaired. Disruption of the sanitary sewer pumping system could result in overflowing manholes and sewer back-ups.

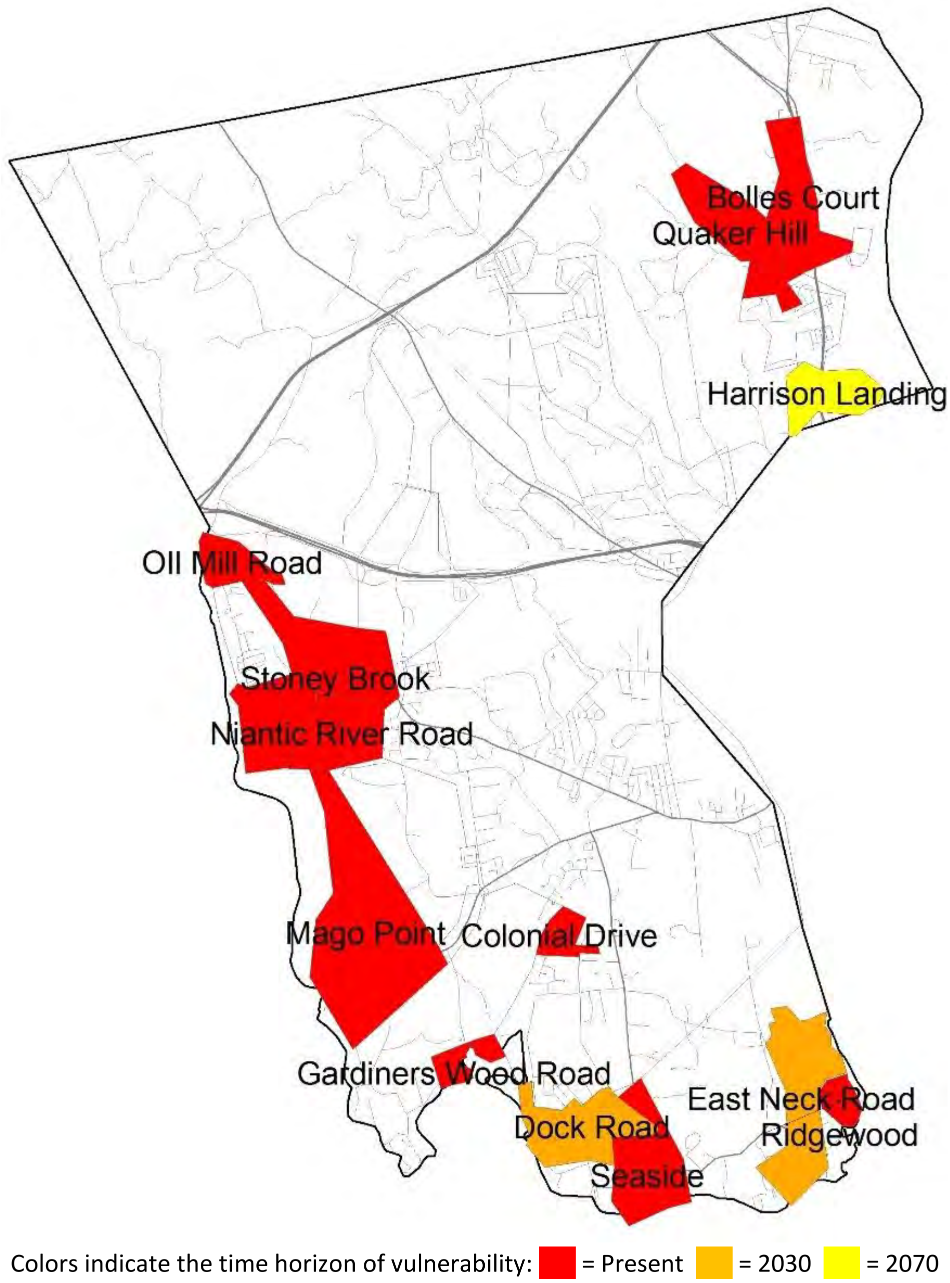


Figure 10 - Wastewater Service Areas Served by Vulnerable Pump Stations

As shown on FEMA Flood Insurance Rate Map (FIRM) No. 09011C0503J effective August 5, 2013 (see Figure 11), the Evergreen Pump Station is not currently located in either the 100-year or 500-year flood zones. The Evergreen Pump Station is not shown to be subject to coastal flooding in 2030 or 2070. From the FIRM map, the pump station is at the edge of the Fenger Brook flood plain, which is delineated as a Zone A flood hazard, which does not have a Base Flood Elevation determined. As such, it is not possible to establish future projected riverine flood elevations under this project using the methodology for establishing riverine flood elevations for this project. Because this is an important pump station, we recommend that the Town request that FEMA remap this area to determine a Base Flood Elevation.

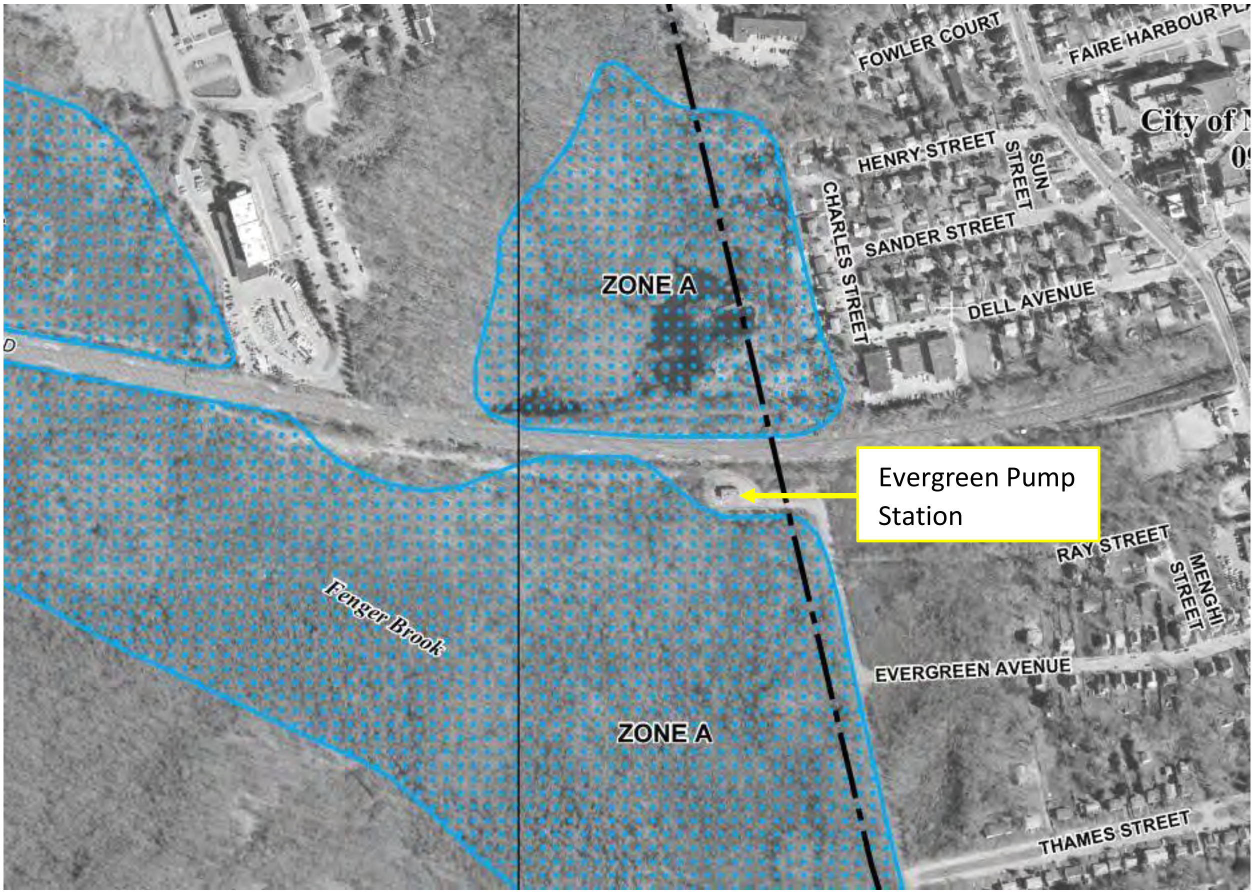


Figure 11 - Delineated Flood Hazard Zone at Evergreen Pump Station (source: FEMA FIRM 09011C0503J)

Vulnerable Roads

Numerous roads in Waterford are wholly or partially vulnerable to coastal and/or riverine flooding in the present, 2030 and 2070 timeframes. Figure 12 shows major roads in Waterford vulnerable to coastal flooding, which includes sea level rise and storm surge. Figure 13, shows major roads vulnerable to riverine flooding. A complete list of roads vulnerable to flooding is included in Appendix B. Detailed flood map books can be found on the Town's website at the following link:

http://www.waterfordct.org/planning-development/pages/climate-change-vulnerability-risk-assessment-and-adaptation-study

Figure 12 - Major Roads in Waterford Vulnerable to Coastal Flooding (SLR and Storm Surge)

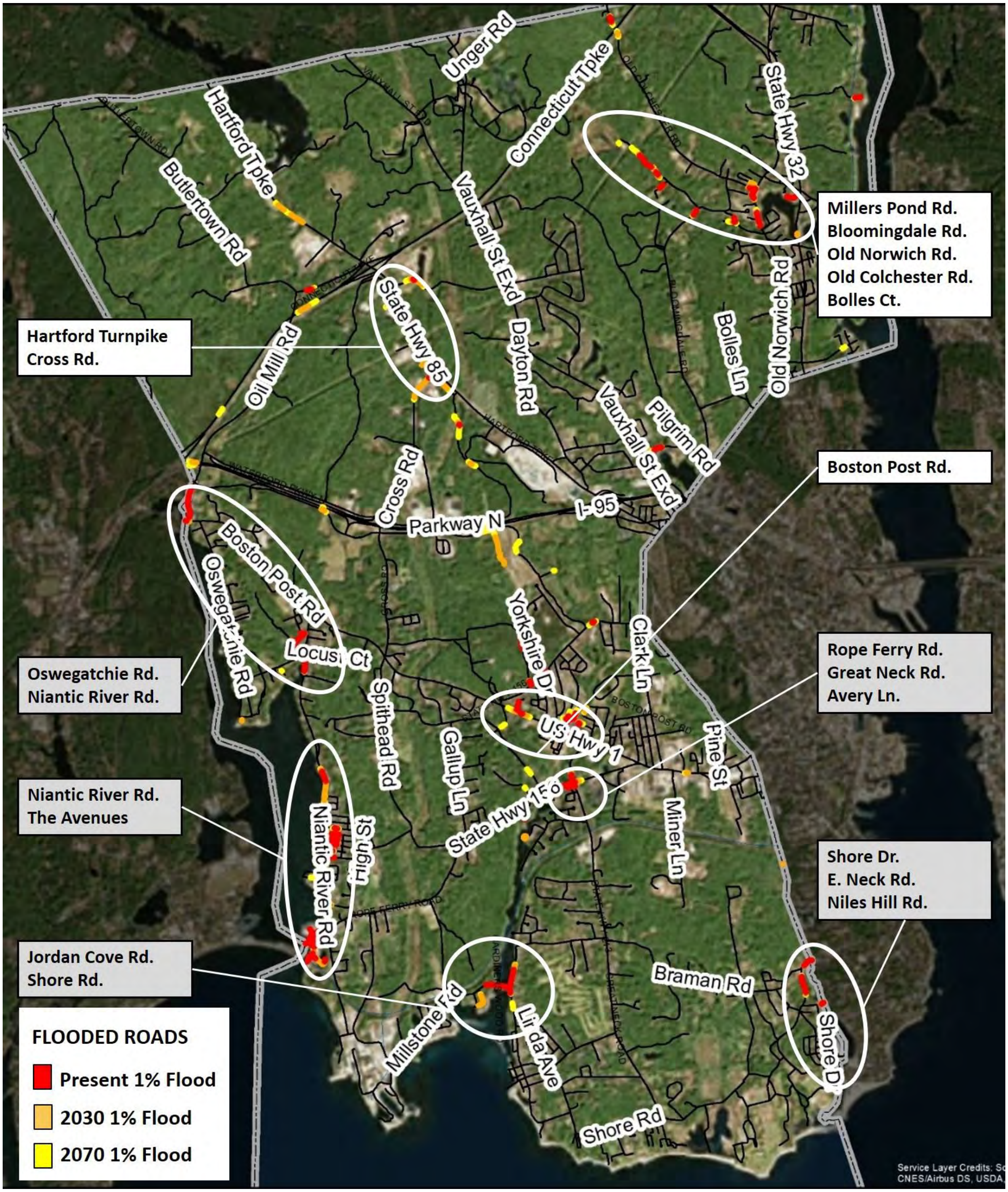


Figure 13 - Major Roads in Waterford Vulnerable to Riverine Flooding

Although the focus of this study was on Town-owned infrastructure, many of the roads that are vulnerable to flooding are state or federal roads, which are critical evacuation and circulation routes in the Town. Therefore, although the critical state or federally-owned roads are not municipally-owned, they have been included in the vulnerability assessment. The Town can use the results of this study to help negotiate future road adaptation improvements with state or federal agencies.

Critical elevations for roads were estimated using LiDAR survey data. The low point of a roadway section subject to flooding was used as the critical elevation. Engineering plans showing critical elevations were also available for some bridges.

Roadway flooding has a number of potential consequences. The most common impact is a temporary disruption to economic activity and access to public services. At a minimum, flooded roadways can be closed for short periods after a flood to allow for debris removal and cleanup. At worst, flooded roads can be closed for extensive periods of time for extensive repairs to wash-out embankments, damaged pavements, damaged or exposed utilities, signage and safety equipment. The most significant impacts affect life safety. For example, the most common cause of flood-related drowning deaths is from people driving through moving or standing water on roadways. Another danger is that emergency services will be unable to respond to medical emergencies and fires in areas isolated by flooding.

<u>Vulnerable Natural Resources</u>

Figure 14 shows several significant coastal natural resource areas, including saltwater marsh and beach that might be negatively impacted by the effects of rising sea levels. Fresh water wetlands are not included in this study under the assumption that rising sea levels will not affect inland freshwater resources and that precipitation rates will not change so dramatically that freshwater wetlands will be negatively affected.

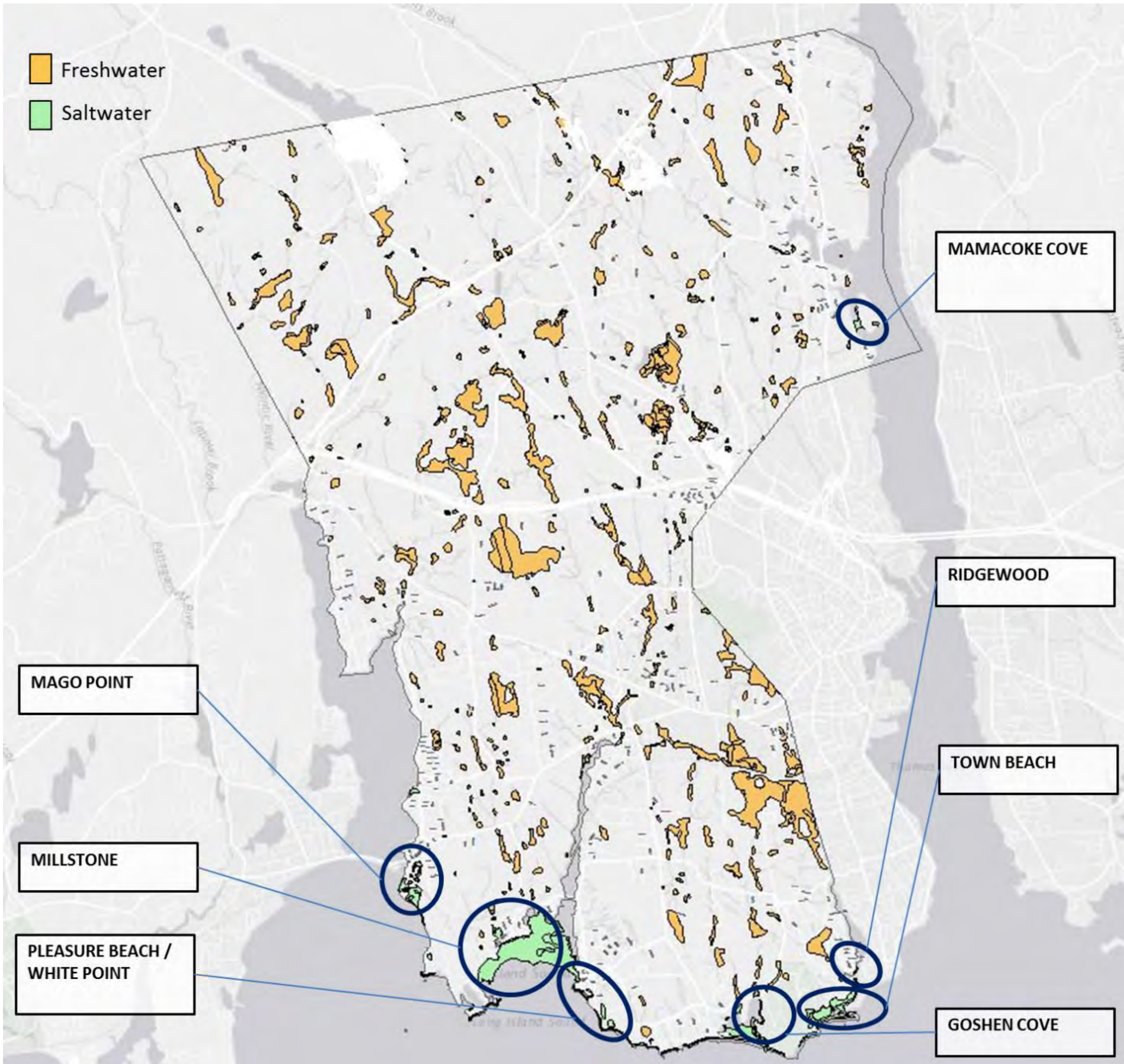


Figure 14 - Natural Resource Areas Vulnerable to Coastal Flooding

C. STAKEHOLDER ENGAGEMENT

Early in the process of developing adaptation strategies, the Town held a public workshop to involve community stakeholders in the decision-making process. The workshop, held on May 24, 2017, began with a presentation on the Town's climate change projections, flooding scenarios, and vulnerability assessment results. The presentation also included illustrations of different adaptation strategies. Next, workshop participants broke out into groups to develop strategies for adapting vulnerable assets in different sections of Town.

Groups were given maps showing 1% annual chance flood extents and depths, vulnerable assets, and other community features. They were also given colored blocks representing different adaptation strategies. Each block had a cost, and the groups were given a limited budget to address the vulnerabilities in their areas. Once all groups had decided how they would allocate their budgets, each group presented their plan to the entire workshop.

Design Options	Points
Elevated road	2
Bridge / culvert	2
Adapted building	1
Elevated open space	1
Flood wall	1
Adapted wetland	1
Beach / dune	2

Through this exercise, participants learned about community flood risks, adaptation strategies, and the trade-offs that must be made when resources are limited. They also meaningfully contributed to the identification and development of potential strategies to address the Town's vulnerabilities. The strategies they identified, shown in Figures 15 through 17, were further considered and developed as the project continued.

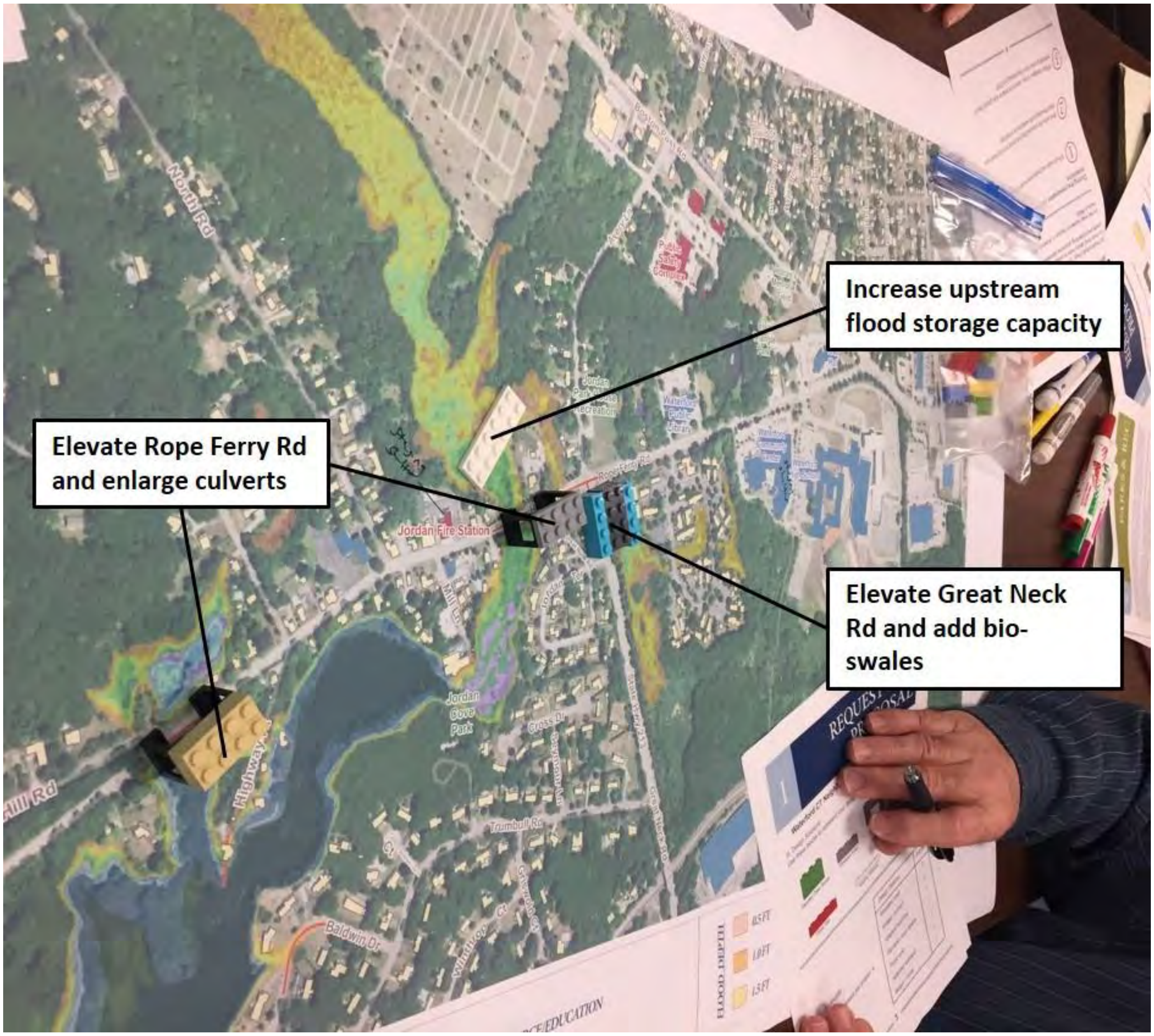


Figure 15 - Workshop Participant Adaptation Recommendations for Central Waterford

Figure 16 - Workshop Participant Adaptation Recommendations for Jordan Cove

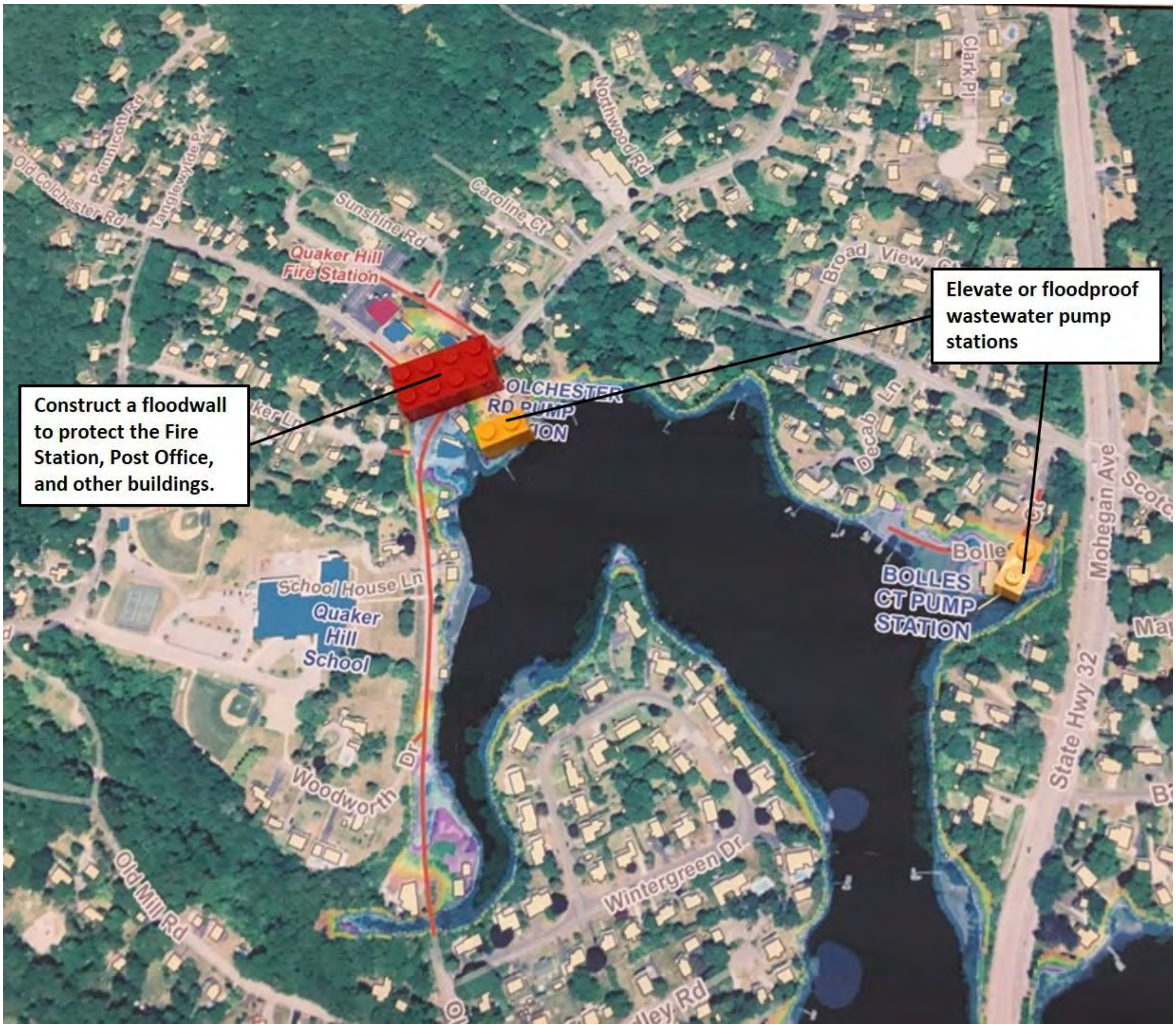


Figure 17 - Workshop Participant Adaptation Recommendations for Quaker Hill

Kleinfelder and the Town also staffed a public information table at a summer concert at the Town Beach on July 26, 2017, and handed out a leaflet describing the project.

The Town held a final public meeting on August 29, 2017 at which the draft adaptation recommendations were presented to the public for feedback.

On September 26, 2017, a draft of this report was issued for public review and comment. It was posted on the Town's website and hard copies were made available for public review at the Planning Department in Town Hall, Community Center and the Public Library. The public comment period was closed on October 12, 2017. Comments received from the public, as well as the Town Working Group, were incorporated into this final report.

D. ADAPTATION STRATEGIES - GENERAL

This section describes general adaptation strategies and specific recommendations for Town-owned facilities, roadways, and natural resources. Additional policy recommendations are provided in a separate section.

There are four basic approaches to adapt to the long-term effects of rising sea levels, storm surge and extreme precipitation:

- Do Nothing
- Protection
- Accommodation
- Retreat

Doing nothing is an approach whereby the Town invests neither funds nor time to proactively deal with the long-term effects of sea level rise, storm surge and extreme precipitation. In essence, this means that the Town will need to react to the after-effects of future storms. Although this approach minimizes capital cost outlays in the present, it can potentially result in much higher cost impacts and disruptions to public services in the future. A good real-time example of this approach is what happened recently during Hurricane Maria in Puerto Rico. A lack of investment in making the electrical and water distribution infrastructure more resilient to storms has now resulted in major disruptions to basic services that will negatively affect the economy of the island for many years to come. As the intent of this project is to propose potential solutions to adapt to future extreme storm events, no further consideration will be made of the do-nothing strategy.

The three remaining approaches to adaptation are conceptually illustrated in Figure 18, comparing existing conditions in a typical cross-section with three alternative future conditions where the respective adaptation approaches are implemented. Each approach is explained below, along with examples.

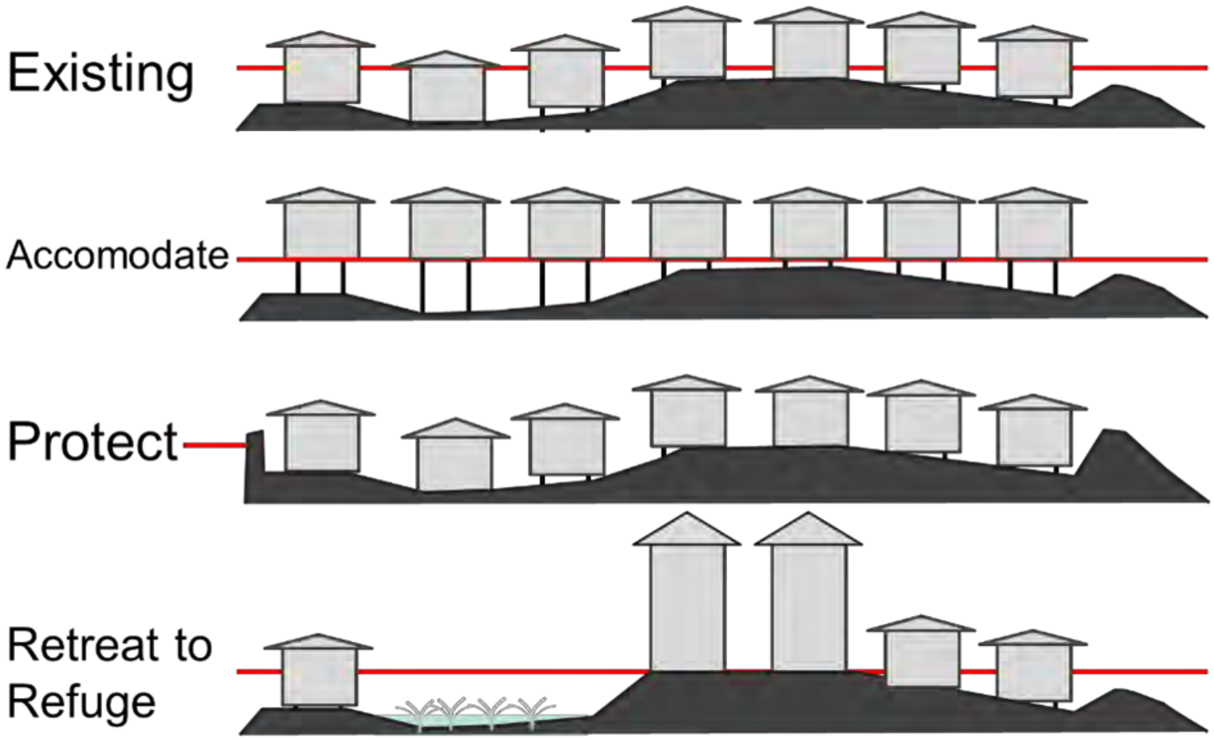


Figure 18 - Conceptual Illustration of Protect, Accommodate and Retreat Strategies Approaches

Protection

Protection strategies try to prevent unsafe conditions and physical damage from occurring by creating a barrier between flood water and vulnerable areas, infrastructure, and buildings. To be truly effective over the longer term, existing protective structures may need to be raised incrementally, in response to sea level rise, and strengthened to withstand the forces of increasingly powerful storms. New structures may also be needed to protect areas that have not historically flooded.

Sea walls, beach dunes, dikes, bulkheads, levees, revetments, flood gates, temporary flood protection barriers, dry floodproofing, and hurricane barriers are all examples of protection strategies that aim to prevent flood water from reaching sensitive areas.

Examples of existing protective structures in Waterford include a seawall and stone revetment along Niantic River Road as shown in Figure 19 and a concrete flood wall and raised electrical panels at the Bolles Court Pump Station as shown in Figure 20.

Figure 19 - Seawall and Stone Revetment along Niantic River Road

Figure 20 - Concrete Flood Wall and Raised Electrical Panels at Bolles Court Pump Station

Accommodation

Accommodation strategies accept that vulnerable areas, infrastructure, and buildings will flood, but aim to minimize and control physical damage and unsafe conditions. Accommodation strategies may include physical, operational, or regulatory measures as shown in Figure 21.

Type of Measure	Examples		
Physical	Construct an artificial floodway to convey flood water away from roadways and homes to a natural area or flood-tolerant green space that can store the water with limited damage.	Raise new and existing structures, for example on stilts or piles, above flood elevations with additional freeboard to provide a safety factor.	Implement wet floodproofing measures such as raising occupied spaces and utilities above flood elevations, building with flood damage resistant materials, or using flood-resilient structural design.
Operational	Improve flood evacuation and emergency planning by updating scenarios and plans, training first responders, or providing education and resources to residents and businesses in high flood risk areas.		
Regulatory	Strengthen building codes and zoning to require or encourage projects in high flood risk areas to implement increased setbacks, physical accommodation measures, onsite flood storage, or protection or enhancement of existing natural systems (e.g., dunes, wetlands).		

Figure 21 - Examples of Accommodation Strategies

Retreat

Retreat strategies recognize the fact that in some areas it may be too costly, technically not feasible, or politically unrealistic to prevent damage from rising sea levels and storm surge, and that the best strategy is to remove vulnerable infrastructure, buildings, or populations from high-risk flood zones. These areas can then be transformed back to more natural states to provide protective, recreational, or other functions that are compatible with occasional or regular flooding. Retreat strategies require significant planning to relocate infrastructure and buildings or re-settle populations in areas outside of high-risk flood zones.

Examples of retreat strategies include property buyouts, relocation of roads and infrastructure, implementation of new zoning or other regulations that limit new construction, reconstruction, or expansion of structures in high-risk flood areas, and policies and programs that steer development towards areas that are safe from flood risks.

Cost Estimating

When appropriate, order-of-magnitude cost estimates were developed for several potential adaptation strategies. These cost estimates are based on engineering judgement and are not based on detailed engineering studies or analyses. As such, these cost estimates are only intended to be used for general planning purposes, and not detailed construction cost budgeting. Before more accurate project budget cost estimates can be made, additional surveying, subsurface exploration, engineering, and permitting must be performed.

Where possible, approximate quantities associated with a potential strategy were estimated, and then appropriate unit costs were assigned to these quantities. The estimates also included mark-ups for general conditions (15%), contractor overhead (5%), contractor profit (5%), design contingency (25%), insurance and bonds (1.5%) and Town of Waterford project costs (20%) for such things as project supervision, consultant fees, and bidding/advertising.

E. ADAPTATION STRATEGIES - BUILDINGS/FACILITIES

Base Flood Elevations

Flood maps produced for this project depict potential water surface elevations at various time frames for a 1% (100 year) probability event. These are known as the Base Flood Elevations (BFE). This means that there is a 1% chance in the given year that there will be a storm that generates flood elevations exceeding the elevations shown in the table. The currently approved FEMA Flood Insurance Rate Maps define the current legally-binding BFEs for the Town of Waterford. Table 4 below depicts potential future BFEs, taking into account the effects of future sea level rise and storm surge and higher precipitation levels. In most cases, the BFEs shown in Table 4 are higher than the current FEMA BFEs.

Table 4 - Potential Future Base Flood Elevations (BFEs) for 1% (100-Year) Probability Flood

Facility	Critical Elevation	Coastal			Riverine		
		Present	2030	2070	Present	2030	2070
Bolles Court Pump Station	10.07	9.87	10.42	13.11	10.00	10.30	11.00
Quaker Hill Pump Station	10.30	9.87	10.42	13.11	10.00	10.30	11.00
Jordan Park House Building 13	15.00	9.11	9.66	12.35	15.00	15.45	16.50
Jordan Park House Building 14	16.00	9.11	9.66	12.35	15.00	15.45	16.50
Jordan Park House Building 15	14.00	9.11	9.66	12.35	15.00	15.45	16.50
Shore Drive Pump Station	9.66	8.89	9.53	12.22	No	No	No
East Neck Pump Station	12.78	8.89	9.53	12.22	No	No	No
Colonial Drive Pump Station	11.86	8.89	9.53	12.22	No	No	No
Gardiners Wood Pump Station	10.70	8.89	9.53	12.22	No	No	No
Dock Road Pump Station	12.70	8.89	9.53	12.22	No	No	No
Seaside Drive Pump Station	10.28	8.89	9.53	12.22	No	No	No
Mago Point Pump Station	6.91	10.03	10.58	13.27	13.00	13.39	14.3
Oil Mill Pump Station	10.63	10.03	10.58	13.27	12.00	12.36	13.2
Stony Brook Pump Station	13.10	10.03	10.58	13.27	12.00	12.36	13.2
Niantic River Pump Station	10.40	10.03	10.58	13.27	12.00	12.36	13.20
Public Works Facility	122.39	No	No	No	117.00	120.51	128.7
Harrison's Landing Pump Sta.	15.70	9.87	10.42	13.11	11.00	11.33	12.10
Quaker Hill Fire Station	14.40	9.87	10.42	13.11	No	No	No

Colors indicate the time horizon of vulnerability: [red] = Present [orange] = 2030 [yellow] = 2070

Design Flood Elevations

When designing adaption measures to protect against the effects of long-term flooding, a Design Flood Elevation (DFE) needs to be established to determine the height of flood protection required to protect the asset.

DFEs for pump stations will be determined based on the design guide specific to the design of wastewater treatment works in New England: *Technical Report-16,* "*Guides for the Design of Wastewater Treatment Works*" from the New England Interstate Water Pollution Control Commission (NEIWPCC). In this document, under the section *Protection of New and Existing Equipment*, it states: *Apply the standard of a 1% annual chance of flood elevation (100-year flood elevation) plus 2 feet for non-critical equipment and plus 3 feet for critical equipment*. As most equipment inside a pump station, such as electric switches and panels, pump motors and emergency generators, is considered critical equipment, the DFE for pump stations will be defined as the BFE plus 3 feet.

DFEs for other vulnerable buildings will be determined using the American Society of Civil Engineers publication ASCE 24-14 “Flood Resistant Design and Construction”. Table 6-1 in ASCE 24-14 defines DFE’s depending on the Flood Design Class of the Facility. For Fire Stations, the Flood Design Class is Class 4, with an additional freeboard of 2 ft. For other buildings, the Flood Design Class is Class 2, with an additional freeboard of 1 ft.

DFEs for the impacted buildings and facilities in Waterford are shown in Table 5 below. For example, to be more resilient by 2070, the Quaker Hill Pump Station should be protected to an elevation of 16.11, which is the higher of the coastal and riverine flood DFEs.

Table 5 - Proposed Design Flood Elevations (DFEs) for 1% (100-Year) Probability Flood

Facility	Critical Elevation	Coastal			Riverine		
		Present	2030	2070	Present	2030	2070
Bolles Court Pump Station	10.07	12.87	13.42	16.11	13.00	13.30	14.00
Quaker Hill Pump Station	10.30	12.87	13.42	16.11	13.00	13.30	14.00
Jordan Park House Building 13	15.00	10.11	10.66	13.35	16.00	16.45	17.50
Jordan Park House Building 14	16.00	10.11	10.66	13.35	16.00	16.45	17.50
Jordan Park House Building 15	14.00	10.11	10.66	13.35	16.00	16.45	17.50
Shore Drive Pump Station	9.66	11.89	12.53	15.22	N/A	N/A	N/A
East Neck Pump Station	12.78	11.89	12.53	15.22	N/A	N/A	N/A
Colonial Drive Pump Station	11.86	11.89	12.53	15.22	N/A	N/A	N/A
Gardiners Wood Pump Station	10.70	11.89	12.53	15.22	N/A	N/A	N/A
Dock Road Pump Station	12.70	11.89	12.53	15.22	N/A	N/A	N/A
Seaside Drive Pump Station	10.28	11.89	12.53	15.22	N/A	N/A	N/A
Mago Point Pump Station	6.91	13.03	13.58	16.27	16	16.39	17.30
Oil Mill Pump Station	10.63	13.03	13.58	16.27	15	15.36	16.20
Stony Brook Pump Station	13.10	13.03	13.58	16.27	15	15.36	16.20
Niantic River Pump Station	10.40	13.03	13.58	16.27	15	15.36	16.20
Public Works Facility	122.39	N/A	N/A	N/A	118.00	121.5	129.7
Harrison’s Landing Pump Sta.	15.70	12.87	13.42	16.11	14.00	14.33	15.10
Quaker Hill Fire Station	14.40	11.87	12.42	15.11	N/A	N/A	N/A

Colors indicate the time horizon of vulnerability: = Present = 2030 = 2070

Pump Stations: DFE = BFE + 3 ft.
Fire Stations: DFE = BFE + 2 ft.
Other Buildings: DFE = BFE + 1 ft.

Impacted Wastewater Pump Stations

The proposed Design Flood Elevations exceed the critical elevations at a total of 13 wastewater pump stations at various time frames, which would cause flooding of the pump stations. If flooding were to occur, the likely result would be damage to electrical equipment, pump motors and emergency generators that could potentially keep the pump stations out of service for an extended period of time while repairs are made. This would require the Town to provide emergency pumping. Even if the pump stations could be cleaned and re-started quickly, there would likely be long-term corrosion effects that would greatly reduce the service life of the facilities. Therefore, the adaptation strategies to protect these pump stations will focus on floodproofing these vulnerable pump stations to the Design Flood Elevation to prevent damage from flooding.

The Town of Waterford has two basic types of wastewater pump stations:

- Cast-in-Place (examples include Mago Point, Bolles Court, Evergreen)
- Package-Type (examples include Oil Mill, Niantic River, Stoney Brook, Colonial Drive, Gardiners Wood, Seaside, Quaker Hill, Shore Drive)

Cast-in-Place pump stations are larger and custom-built to meet specific requirements for that site. Package-type pump stations are typically smaller in size and more uniform in design and layout. Much of the equipment in a package-type pump station was procured from the same vendor and is similar in each pump station.

<u>Mago Point Wastewater Pump Station</u>

Mago Point wastewater pump station will be used to illustrate flood proofing strategies for a typical cast-in-place pump station.

Critical Elevation (NAVD88): 6.91 (bottom of exterior mounted electrical panels).

Figure 22 below shows some photos of the Mago Point Pump Station with some approximate elevations shown on the photos.

Figure 22 - Photos of Mago Point Wastewater Pump Station

Figure 23 below shows a typical cross-section through the pump station from as-built drawings provided by Town staff. The proposed Base Flood and Design Flood Elevations are shown superimposed on the cross-section.

The ground floor is at El. 5.41 and the first floor is at El. 12.08. There are several critical electrical panels mounted on the exterior of the building, with the lowest elevation at about El. 6.91. This is the critical elevation at which the facility will lose power and cease to operate. There is also an exterior electrical transformer mounted on a slab at El. 9.42. Flood water above El. 12.08 will spill into the lower parts of the pump station, which will damage critical electrical and pump equipment in the lower rooms. The emergency generator is located on the first level at approximately El. 13.08.

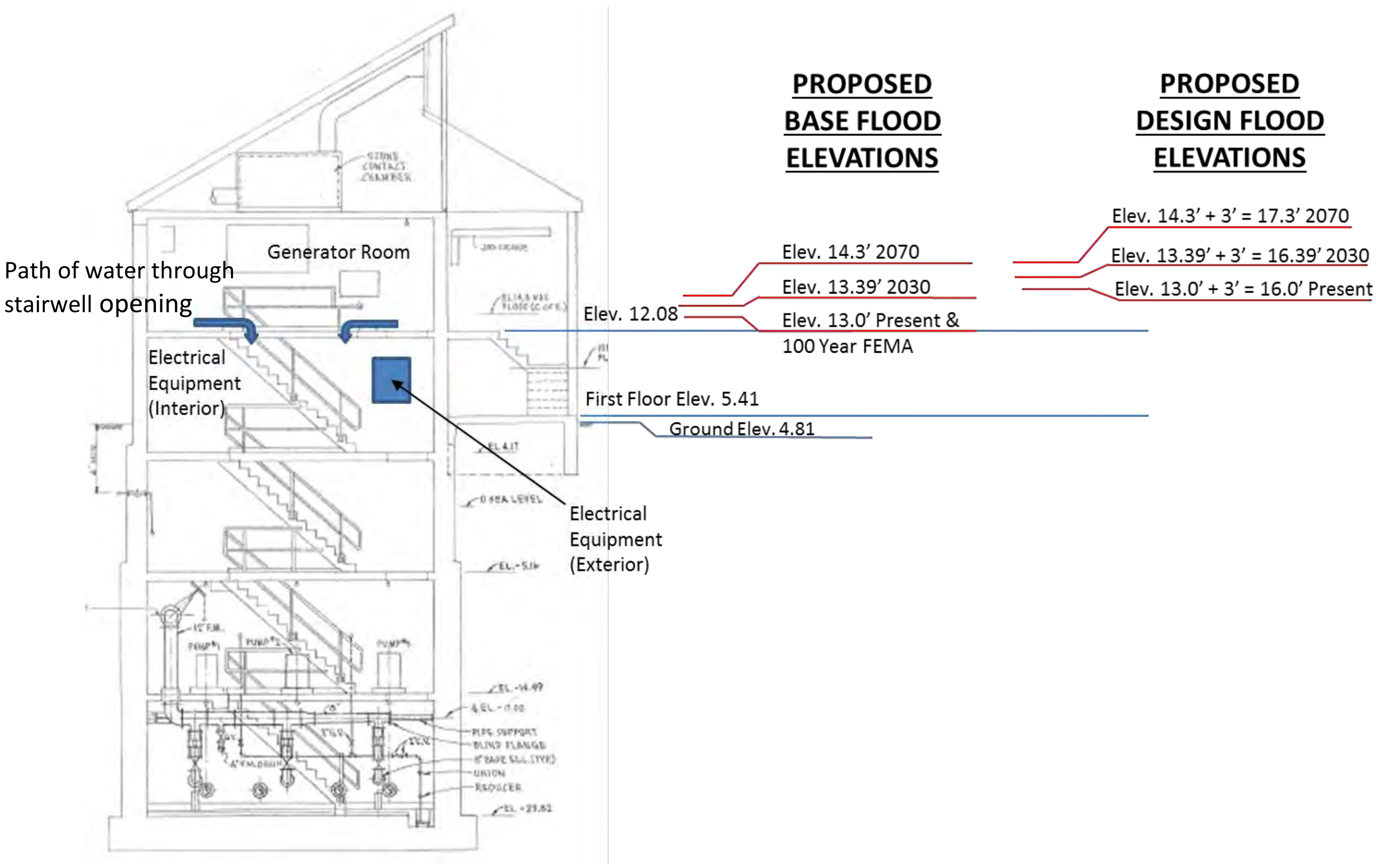


Figure 23 - Cross-Section of Mago Point Wastewater Pump Station

For the Mago Point wastewater pump station there are three different strategies for floodproofing the facility:

Adaptation Strategy No. 1 – Floodproof to Elevation 13.08 – Estimated Cost = $347,000

This strategy provides shorter-term protection to the pump station to Elevation 13.08. This elevation is the approximate elevation at which water would start flooding into the second story of the building through the generator louvers, which would in turn cause extensive damage to pumps and electrical equipment inside the building. This strategy elevates exterior vulnerable equipment above Elevation 13.08, which is slightly below the projected DFE of 13.39 for 2030. Protecting to this elevation maintains service to the entire area serviced by the pump station (see Figure 10), and is relatively less costly as compared to strategies 2 and 3. Specific recommendations include the following:

- Raise the exterior-mounted electrical equipment above El. 13.08.
- Raise the exterior electrical transformer above El. 13.08.
- Construct an exterior steel platform to access the raised exterior-mounted panels and transformer. Provide a stairway to the elevated platform.
- Install two watertight doors at the ground level.
- Install a removable watertight cover over the stairwell opening at the first level, which leads down to the lower rooms in the facility. The purpose of this cover is to install it in advance of a major flood to prevent water above El.12.08 from being able to flood the lower sections of the pump station.
- Install a roof access hatch and access ladder to be able to enter the building when the lower entrance doors are closed during a flood event.
- Check the design of the existing chemical tank tie-down system locate outside the building to ensure that is strong enough to resist buoyancy forces at a flood El. 13.08 with an empty tank. Replace the tie-down system if necessary.

Adaptation Strategy No. 2 – Floodproof to Elevation 17.30 – Estimated Cost = $645,000

This strategy provides long-term protection for the pump station to the 2070 DFE 17.30. Protection consists of a permanent perimeter flood wall around the pump station with a sump pump system that can drain rain water or water that seeps under the wall. This option will have more visual impact to the surrounding neighborhood, but will offer more flood protection than Strategy 1. Protecting to this elevation maintains service to the entire area serviced by the pump station (see Figure 10). Specific recommendations include the following:

- Construct a cantilevered flood wall around the perimeter of the building with one opening for access to the building. The wall should encompass the building as well as the exterior transformer and chemical storage tank located outside the pump station.
- Construct a removable flood barrier in the wall opening that can be closed in advance of a major flood. There are several options for this type of flood barrier closure including a sliding flood door or watertight double-doors installed within an opening in the wall. Figure 24 shows examples of these types of barriers. A double door system that is always closed would be the best solution as it does not need to be closed in advance of a storm, unlike the sliding door which needs to be closed.

- Install a sump pump system to drain the space between the wall and the building from rain water and flood water that may seep under the wall. The sump pump should discharge over the wall and should be connected to the facilities emergency generator.

Figure 24 - Example of Sliding Flood Door (left) and Floodproof Double-Door (right)

<u>Adaptation Strategy No. 3 – Reconstruct and Floodproof Pump Station House – Estimated Cost = $1,050,000</u>

This strategy also provides long-term protection for the pump station to the 2070 DFE 17.30. Protection consists of replacing the pump station enclosure with a flood-resistant structure. This option will offer more flood protection than Strategy 1, but is much more expensive. Protecting to this elevation maintains service to the entire area serviced by the pump station (see Figure 10). Specific recommendations include the following:

- Reconstruct the above grade portions of the pump station enclosure as a flood-resistant structure capable of withstanding a flood to El. 17.30. In this option, the exterior-mounted electrical panels, transformer and chemical tank should be moved into the building interior. Install watertight doors and construct building walls to resist a 17.30 flood elevation.

<u>Gardiners Wood Wastewater Pump Station</u>

Gardiners Wood wastewater pump station is a package-type unit that will be used to illustrate flood proofing strategies for a typical package-type pump station.

Critical Elevation (NAVD88): 10.70 (wet-well hatch located outside the pump station).

Figure 26 below shows some photos of the Gardiners Wood Pump Station with some approximate elevations shown on the photos.

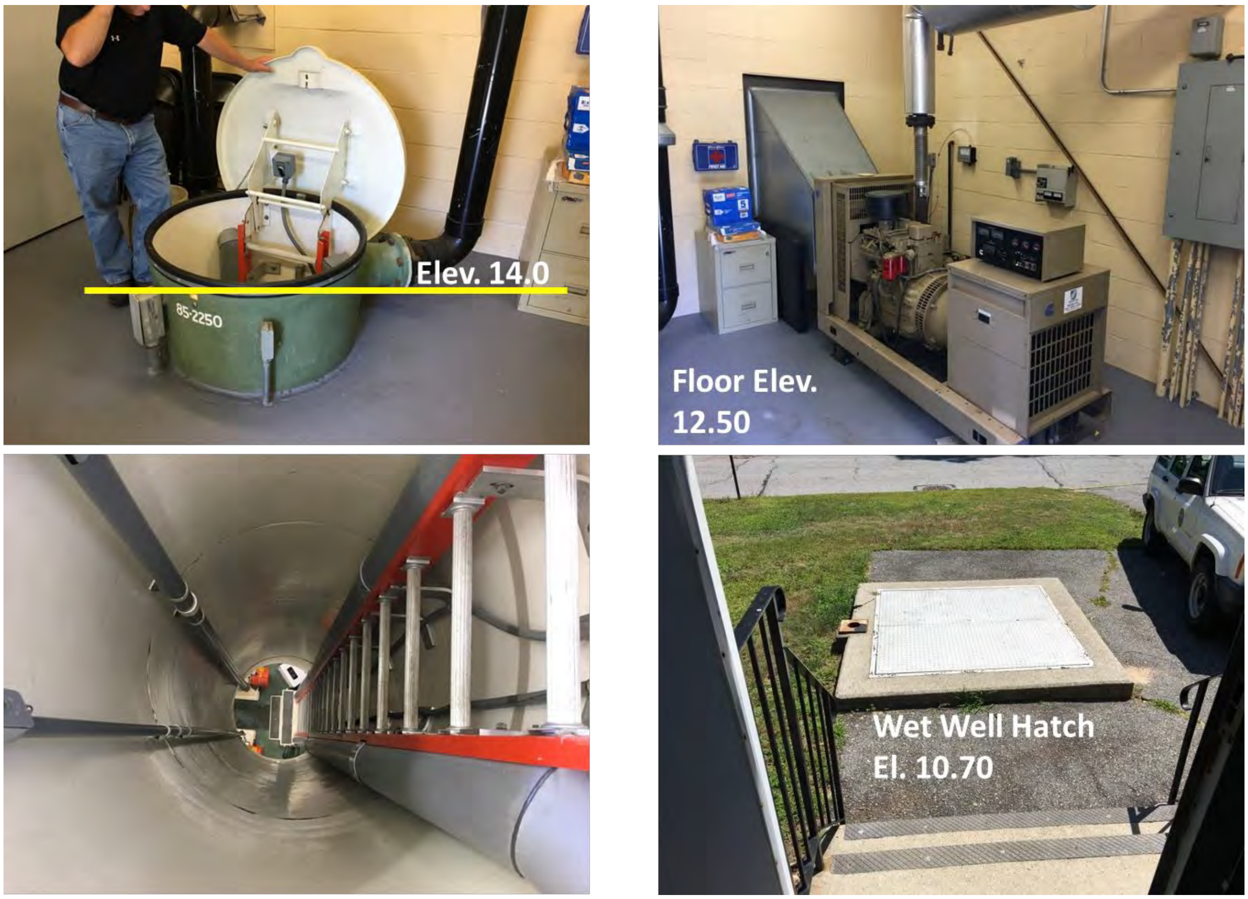


Figure 25 - Photos of Gardiners Wood Wastewater Pump Station

Figure 26 below shows a typical cross-section through the pump station from as-built drawings provided by Town staff.

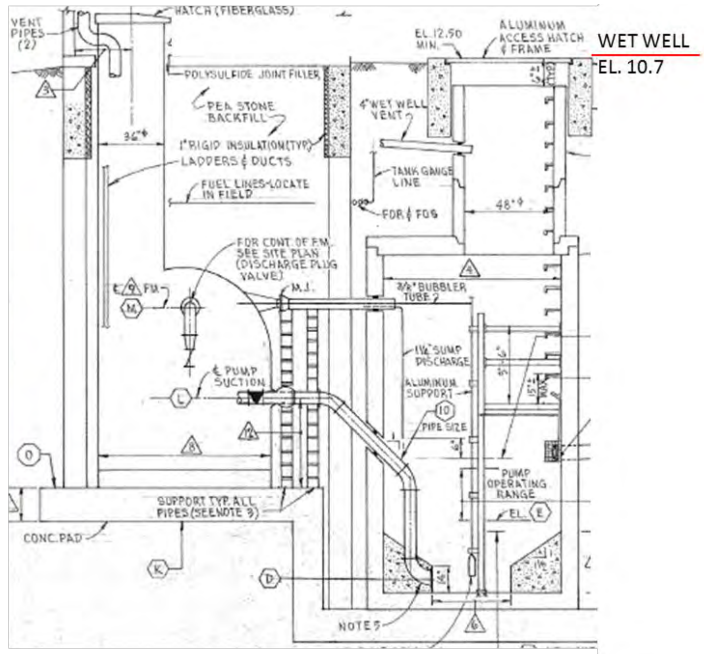


Figure 26 - Photo and Cross-Section of Gardiners Wood Wastewater Pump Station

The critical elevation for this pump station is El. 10.70, which is the wet-well cover located outside the building. If water is above El. 10.70, it will flood the wet well which will cause the pump station to cease operating. The floor level inside the building is at El. 12.50. There is a round access hatch at El. 14.50, which provides access to the pump room below. The emergency generator is located only a few inches above the floor level. There are several electrical and control panels located on the interior walls about 3'-4" above the floor level.

<u>Adaptation Strategy – Floodproof to Elevation 15.22 – Estimated Cost = $147,000</u>

This strategy provides long-term protection to the pump station to Elevation 15.22. This elevation is the projected DFE in 2070. Protecting to this elevation maintains service to the entire area serviced by the pump station (see Figure 10). Specific recommendations include the following:

- Extend interior access hatch to El. 15.22. This will allow access to the lower Pump room during a flood.
- Raise the emergency generator, louvers to the outside and interior electrical panels to El. 15.22. Construct an access platform to provide code-required access to the electrical equipment and generator.
- Install a watertight door into the building.
- Replace wet-well hatch with a watertight hatch designed to a flood depth of El. 15.22.
- Install a roof access hatch and access ladder to be able to enter the building when the entrance door is closed during a flood event.

Adaptation Strategies for Buildings and Facilities

Adaption strategies and associated estimated construction costs for the 13 wastewater pumping stations and other Town-owned buildings potentially affected by flooding are shown in Table 6.

Table 6 - Adaptation Recommendations for Buildings and Facilities

BUILDING OR FACILITY	DFE/ YEAR	ADAPTATION RECOMMENDATIONS	ESTIMATED CONSTRUCTION COST
MAGO POINT PUMP STATION	**El. 13.08 ≈2030**	**Adaptation Strategy No. 1 – Floodproof to Elevation 13.08** This strategy provides shorter-term protection to the pump station to Elevation 13.08. This elevation is the approximate elevation at which water would start flooding into the second story of the building through the generator louvers, which would in turn cause extensive damage to pumps and electrical equipment inside the building. This strategy elevates exterior vulnerable equipment above Elevation 13.08, which is slightly below the projected DFE of 13.39 for 2030. Protecting to this elevation maintains service to the entire area serviced by the pump station, and is relatively less costly as compared to strategies 2 and 3. Specific recommendations include the following: • Raise the exterior-mounted electrical equipment above El. 13.08. • Raise the exterior electrical transformer above El. 13.08. • Construct an exterior steel platform to access the raised exterior-mounted panels and transformer. Provide a stairway to the elevated platform. • Install two watertight doors at the ground level. • Install a removable watertight cover over the stairwell opening at the first level, which leads down to the lower rooms in the facility. The purpose of this cover is to install it in advance of a major flood to prevent water above El.12.08 from being able to flood the lower sections of the pump station. • Install a roof access hatch and access ladder to be able to enter the building when the lower entrance doors are closed during a flood event. • Check the design of the existing chemical tank tie-down system locate outside the building to ensure that is strong enough to resist buoyancy forces at a flood El. 13.08 with an empty tank. Replace the tie-down system if necessary.	**$347,000**
	El. 17.30 2070	**Adaptation Strategy No. 2 – Floodproof to Elevation 17.30** This strategy provides long-term protection for the pump station to the 2070 DFE 17.30. Protection consists of a permanent perimeter flood wall around the pump station with a sump pump system that can drain rain water or water that seeps under the wall. This option will have more visual impact to the surrounding neighborhood, but will offer more flood protection than Strategy 1. Protecting to this elevation maintains service to the entire area serviced by the pump station. Specific recommendations include the following: • Construct a cantilevered flood wall around the perimeter of the building with one opening for access to the building. The wall should encompass the building as well as the exterior transformer and chemical storage tank located outside the pump station. • Construct a removable flood barrier in the wall opening that can be closed in advance of a major flood. There are several options for this type of flood barrier closure including a sliding flood door or watertight double-doors installed within an opening in the wall. Figure 22 shows examples of these types of barriers. A double door system that is always closed would be the best solution as it does not need to be closed in advance of a storm, unlike the sliding door which needs to be closed. • Install a sump pump system to drain the space between the wall and the building from rain water and flood water that may seep under the wall. The sump pump should discharge over the wall and should be connected to the facilities emergency generator.	**$645,000**
	El. 17.30 2070	**Adaptation Strategy No. 3 – Reconstruct and Floodproof Pump Station House** This strategy also provides long-term protection for the pump station to the 2070 DFE 17.30. Protection consists of replacing the pump station enclosure with a flood-resistant structure. This option will offer more flood protection than Strategy 1, but is much more expensive. Protecting to this elevation maintains service to the entire area serviced by the pump station. Specific recommendations include the following: • Reconstruct the above grade portions of the pump station enclosure as a flood-resistant structure capable of withstanding a flood to El. 17.30. In this option, the exterior-mounted electrical panels, transformer and chemical tank should be moved into the building interior. Install watertight doors and construct building walls to resist a 17.30 flood elevation.	**$1,050,000**

Table 6 – Adaptation Recommendations for Building and Facilities (Continued)

BUILDING OR FACILITY	DFE/ YEAR	ADAPTATION RECOMMENDATIONS	ESTIMATED CONSTRUCTION COST
GARDINERS WOOD PUMP STATION	**El. 15.22 2070**	**Adaptation Strategy – Floodproof to Elevation 15.22** This strategy provides long-term protection to the pump station to Elevation 15.22. This elevation is the projected DFE in 2070. Protecting to this elevation maintains service to the entire area serviced by the pump station. Specific recommendations include the following: • Extend interior access hatch to El. 15.22. This will allow access to the lower Pump room during a flood. • Raise the emergency generator, louvers to the outside and interior electrical panels to El. 15.22. Construct an access platform to provide code-required access to the electrical equipment and generator. • Install a watertight door into the building. • Replace wet-well hatch with a watertight hatch designed to a flood depth of El. 15.22. • Install a roof access hatch and access ladder to be able to enter the building when the entrance door is closed during a flood event.	**$147,000**
HARRISON'S LANDING PUMP STATION	**El. 16.11 2070**	**No Recommendations** • The critical elevation for the pump station is El. 15.70, which is only 5 inches below the DFE of 16.11. This also does not occur until 2070, so extensive adaptation is not warranted now.	**$0**
QUAKER HILL PUMP STATION	**El. 16.11 2070**	**Adaptation Strategy - Floodproof to Elevation 16.11** This strategy provides long-term protection to the pump station to Elevation 16.11. This elevation is the projected DFE in 2070. Protecting to this elevation maintains service to the entire area serviced by the pump station. Specific recommendations include the following: • Extend interior access hatch to elevation 16.11. This will allow access to the lower chambers during a flood. • Raise the emergency generator, louvers to the outside and interior electrical panels to elevation 16.11. Construct an access platform to provide code-required access to the electrical equipment and generator. • Install a watertight door into the building. • Replace wet-well hatch with a watertight hatch designed to a flood depth of elevation 16.11. • Install a roof access hatch and access ladder to be able to enter the building when the entrance door is closed during a flood event.	**$149,000**
SHORE DRIVE PUMP STATION	**El. 15.22 2070**	**Adaptation Strategy - Floodproof to Elevation 15.22** This strategy provides long-term protection to the pump station to Elevation 15.22. This elevation is the projected DFE in 2070. Protecting to this elevation maintains service to the entire area serviced by the pump station. Specific recommendations include the following: • Extend interior access hatch to elevation 15.22. This will allow access to the lower chambers during a flood. • Raise the emergency generator, louvers to the outside and interior electrical panels to elevation 15.22. Construct an access platform to provide code-required access to the electrical equipment and generator. • Install a watertight door into the building. • Replace wet-well hatch with a watertight hatch designed to a flood depth of elevation 15.22. • Install a roof access hatch and access ladder to be able to enter the building when the entrance door is closed during a flood event. • Raise exterior electrical meter to El. 15.22.	**$149,000**

Table 6 – Adaptation Recommendations for Building and Facilities (Continued)

BUILDING OR FACILITY	DFE/ YEAR	ADAPTATION RECOMMENDATIONS	ESTIMATED CONSTRUCTION COST
COLONIAL DRIVE PUMP STATION	**El. 15.22 2070**	**<u>Adaptation Strategy - Floodproof to Elevation 15.22</u>** This strategy provides long-term protection to the pump station to Elevation 15.22. This elevation is the projected DFE in 2070. Protecting to this elevation maintains service to the entire area serviced by the pump station. Specific recommendations include the following: • Raise the emergency generator, louvers to the outside, interior electrical panels, transformer and electrical box to elevation 15.22. Construct an access platform to provide code-required access to the electrical equipment and generator. • Install a watertight door into the building. • Replace wet-well hatch with a watertight hatch designed to a flood depth of elevation 15.22. • Install a roof access hatch and access ladder to be able to enter the building when the entrance door is closed during a flood event.	**$128,000**
DOCK ROAD PUMP STATION	**El. 15.22 2070**	**<u>Adaptation Strategy - Floodproof to Elevation 15.22</u>** This strategy provides long-term protection to the pump station to Elevation 15.22. This elevation is the projected DFE in 2070. Protecting to this elevation maintains service to the entire area serviced by the pump station. Specific recommendations include the following: • Raise the emergency generator, louvers to the outside and interior electrical panels to El 15.22. Construct an access platform to provide code-required access to the electrical equipment and generator. • Install a watertight door into the building. • Replace wet-well hatch with a watertight hatch designed to a flood depth of elevation 15.22. • Install a roof access hatch and access ladder to be able to enter the building when the entrance door is closed during a flood event.	**$128,000**
SEASIDE DRIVE PUMP STATION	**El. 15.22 2070**	**<u>Adaptation Strategy - Floodproof to Elevation 15.22</u>** This strategy provides long-term protection to the pump station to Elevation 15.22. This elevation is the projected DFE in 2070. Protecting to this elevation maintains service to the entire area serviced by the pump station. Specific recommendations include the following: • Extend interior access hatch to elevation 15.22. This will allow access to the lower chambers during a flood. • Raise the emergency generator, louvers to the outside and interior electrical panels to El 15.22. Construct an access platform to provide code-required access to the electrical equipment and generator. • Install a watertight door into the building. • Replace wet-well hatch with a watertight hatch designed to a flood depth of elevation 15.22. • Install a roof access hatch and access ladder to be able to enter the building when the entrance door is closed during a flood event.	**$172,000**
NIANTIC RIVER PUMP STATION	**El. 16.27 2070**	**<u>Adaptation Strategy - Floodproof to Elevation 16.27</u>** This strategy provides long-term protection to the pump station to Elevation 16.27. This elevation is the projected DFE in 2070. Protecting to this elevation maintains service to the entire area serviced by the pump station. Specific recommendations include the following: • Extend interior access hatch to elevation 16.27. This will allow access to the lower chambers during a flood. • Raise the emergency generator, louvers to the outside and interior electrical panels to El 16.27. Construct an access platform to provide code-required access to the electrical equipment and generator. • Install a watertight door into the building. • Replace wet-well hatch with a watertight hatch designed to a flood depth of elevation 16.27. • Raise electric meter to El. 16.27. • Install a roof access hatch and access ladder to be able to enter the building when the entrance door is closed during a flood event.	**$148,000**

Table 6 – Adaptation Recommendations for Building and Facilities (Continued)

<table>
<tr><th>BUILDING OR FACILITY</th><th>DFE/ YEAR</th><th>ADAPTATION RECOMMENDATIONS</th><th>ESTIMATED CONSTRUCTION COST</th></tr>
<tr><td>STONY BROOK PUMP STATION</td><td>El. 15.22
2070</td><td><u>Adaptation Strategy - Floodproof to Elevation 15.22</u>

This strategy provides long-term protection to the pump station to Elevation 15.22. This elevation is the projected DFE in 2070. Protecting to this elevation maintains service to the entire area serviced by the pump station. Specific recommendations include the following:

• Replace wet-well hatch with a watertight hatch designed to a flood depth of El. 15.22.
• Raise exterior transformer to El. 15.22.</td><td>$47,000</td></tr>
<tr><td>OIL MILL PUMP STATION</td><td>El. 16.27
2070</td><td><u>Adaptation Strategy - Floodproof to Elevation 16.27</u>

This strategy provides long-term protection to the pump station to Elevation 16.27. This elevation is the projected DFE in 2070. Protecting to this elevation maintains service to the entire area serviced by the pump station. Specific recommendations include the following:

• Extend interior access hatch to elevation 16.27. This will allow access to the lower chambers during a flood.
• Raise the emergency generator, louvers to the outside and interior electrical panels to El 16.27. Construct an access platform to provide code-required access to the electrical equipment and generator.
• Install a watertight door into the building.
• Replace wet-well hatch with a watertight hatch designed to a flood depth of elevation 15.22.
• Raise electric meter to El. 16.27.
• Install a roof access hatch and access ladder to be able to enter the building when the entrance door is closed during a flood event.</td><td>$148,000</td></tr>
<tr><td rowspan="2">BOLLES COURT PUMP STATION</td><td>El. 14.00
2070
Riverine</td><td><u>Adaptation Strategy No. 1 - Floodproof to Elevation 14.00</u>

This strategy provides long-term protection to the pump station to Elevation 14.00. This elevation is the projected DFE in 2070 for Riverine flooding. Protecting to this elevation maintains service to the entire area serviced by the pump station. Specific recommendations include the following:

• Raise exterior transformer to El. 16.11. (The cost of raising the transformer is not substantially different to raise to El. 16.11 instead of El. 14.00)
• Install 2 watertight doors at ground level.
• Install a removable watertight cover over the stairwell opening at the first level, which leads down to the lower rooms in the facility. The purpose of this cover is to install it in advance of a major flood to prevent water from being able to flood the lower sections of the pump station.
• Install a roof access hatch and access ladder to be able to enter the building when the entrance door is closed during a flood event.</td><td>$200,000</td></tr>
<tr><td>El. 16.11
2070
Coastal</td><td><u>Adaptation Strategy No. 2 – Permanent Walls to El. 16.11</u>

This strategy provides long-term protection to the pump station to Elevation 16.11. This elevation is the projected DFE in 2070 for Coastal flooding. Protecting to this elevation maintains service to the entire area serviced by the pump station. Specific recommendations include the following:

• Construct a cantilevered flood wall around the perimeter of the building with one opening for access. The wall should encompass the building as well as the exterior transformer, chemical storage tank and electrical equipment outside the pump station.
• Construct a removable flood barrier in the wall opening that can be closed in advance of a major flood. There are a number of options for this type of flood barrier closure including a sliding flood door or floodproof double doors installed within an opening in the wall. A double door system that is always closed would be the best solution as it does not need to be closed in advance of a storm, unlike the sliding door which needs to be closed.
• Install a sump pump system to drain the space between the wall and the building from rain water and flood water that may seep under the wall. The sump pump should discharge over the wall.</td><td>$1,200,000</td></tr>
</table>

Table 6 – Adaptation Recommendations for Building and Facilities (Continued)

BUILDING OR FACILITY	DFE/ YEAR	ADAPTATION RECOMMENDATIONS	ESTIMATED CONSTRUCTION COST
PUBLIC WORKS FACILITY	**El. 129.7 2070**	**Adaptation Strategy No. 1 – Temporary Flood Barrier to El. 129.70** This strategy provides long-term protection to the Public Works Facility to Elevation 129.70 using a lower-cost temporary flood barrier system. This elevation is the projected DFE in 2070. Protecting to this elevation prevents flooding of the facility, although the surrounding roads may be flooded. Specific recommendations include the following: • Purchase, store and have ready for deployment during a flood event 400 ft. of 6 ft. high temporary flood barrier along east and south sides. • Install a sump pump system to drain the space between the wall and the building from rain water and flood water that may seep under the wall. The sump pump should discharge over the wall.	**$200,000**
	El. 129.7 2070	**Adaptation Strategy No. 2 – Permanent Flood Wall to El. 129.70** This strategy provides long-term protection to the Public Works Facility to Elevation 129.70 using a more expensive, but permanent flood wall system. This elevation is the projected DFE in 2070. Protecting to this elevation prevents flooding of the facility, although the surrounding roads may be flooded. Specific recommendations include the following: • Construct 400 ft. of 6 ft. high permanent flood wall along east and south sides of building with a passive vehicle barrier at the roadway entrance. • Install a sump pump system to drain the space between the wall and the building from rain water and flood water that may seep under the wall. The sump pump should discharge over the wall.	**$1,200,000**
	El. 129.7 2070	**Adaptation Strategy No. 3 – Replace Building with Flood-Resistant Building** This strategy provides long-term protection to the Public Works Facility to Elevation 129.70 with the most expensive solution, replacing the building. This elevation is the projected DFE in 2070. Protecting to this elevation prevents flooding of the facility, although the surrounding roads may be flooded. Specific recommendations include the following: • Replace the building with a new flood-proof building with the lowest floor above El.129.70.	**$11,314,000**
QUAKER HILL FIRE STATION	**El. 15.11 2070**	**Adaptation Strategy No. 1 – Floodproof to El. 15.11** This strategy provides long-term protection to the Quaker Hill Fire Station to Elevation 15.11. This elevation is the projected DFE in 2070. Protecting to this elevation will prevent flooding of the lower level of the station, which houses the kitchen, and some HVAC, communications and electrical systems. Implementing these recommendations will allow the station to function during a flood event, although many roads near the station may be flooded. Specific recommendations include the following: • Furnish and store a temporary 4 ft. high panelized flood barrier system that can be deployed before a major flood along the lower (northeast) side of the station and attached to the building at both ends. The total length of barrier is approximately 50 ft. • Regrade the small concrete block retaining wall at the northeast corner of the station and construct a concrete pad to receive the flood barrier to allow it to be attached to the building. • Seal miscellaneous electrical conduits and penetrations below El. 15.11 that would allow water to enter the building.	**$72,000**

F. ADAPTATION STRATEGIES - ROADWAYS

Many roads in Waterford are wholly or partially vulnerable to coastal and/or riverine flooding in the present, 2030 and 2070 timeframes. Roadway flooding has a number of potential consequences. The most common impact is a temporary disruption to economic activity and access to public services. At a minimum, flooded roadways can be closed for short periods after a flood to allow for debris removal and cleanup. At worse, flooded roads can be closed for extensive periods of time for extensive repairs to washed-out embankments, damaged pavements, damaged or exposed utilities, and damaged signage and safety equipment. The most significant impacts affect life safety. For example, the most common cause of flood-related drowning deaths is from people driving through moving or standing water on roadways. Another danger is that emergency services will be unable to respond to medical emergencies and fires in areas isolated by flooding.

Roadway flooding risks can be mitigated by a variety of physical strategies, including:

- Raising roadways or bridges above projected flood levels.
- Relocating roadways to routes over higher ground.
- Creating new emergency access routes to serve areas potentially cut off from flooding.
- Enlarging culverts to reduce flooding from flow restrictions (riverine only).
- Creating or enlarging stormwater pump stations (riverine only).
- Enlarging natural flood storage areas and diverting flows to these areas (riverine only).
- Adding bio-swales and other green infrastructure on roadsides to slow and store rainfall runoff and to improve runoff quality (riverine only).
- Adding structural protection to prevent erosion and roadway undermining.

These physical strategies are often challenging to implement. Raising or relocating roads by any substantial amount typically requires property takings and might result in impacts to adjacent wetlands. Increasing flood storage or flow through culverts can increase flooding upstream or downstream from the improvements. As such, these types of projects require technical study, stakeholder and community engagement, extensive permitting and significant capital resources.

The Town and the State of Connecticut have implemented many projects over the years to address roadway flooding risks, including replacing and enlarging culverts, elevating bridges, reinforcing roadway embankments, removing debris from culverts and drains, and improving roadway drainage systems.

Preventing all roads in Waterford from flooding is not realistically feasible due to the number of vulnerable roads, the extremely high capital cost to raise or otherwise protect roads, and the numerous physical constraints to changing roadway alignments. The following operational strategies can be applied in many situations to help mitigate life safety impacts:

- Implement road closures in advance of flooding.
- Install permanent warning signs at road segments prone to flooding.
- Educate drivers of the dangers of driving through flooded roads.
- Issue early evacuation orders to areas typically isolated by flooding.
- Pre-stage emergency response assets in flood-isolated areas.
- Obtain emergency equipment, such as boats and high-water vehicles, to be able to provide emergency access to flood-isolated areas.

Figure 28 shows a network of evacuation and emergency access routes in Waterford that should be strengthened to improve the Town's resilience to flooding. It also identifies some possible adaptation strategies to improve the accessibility of certain areas that could otherwise become isolated during flooding events.

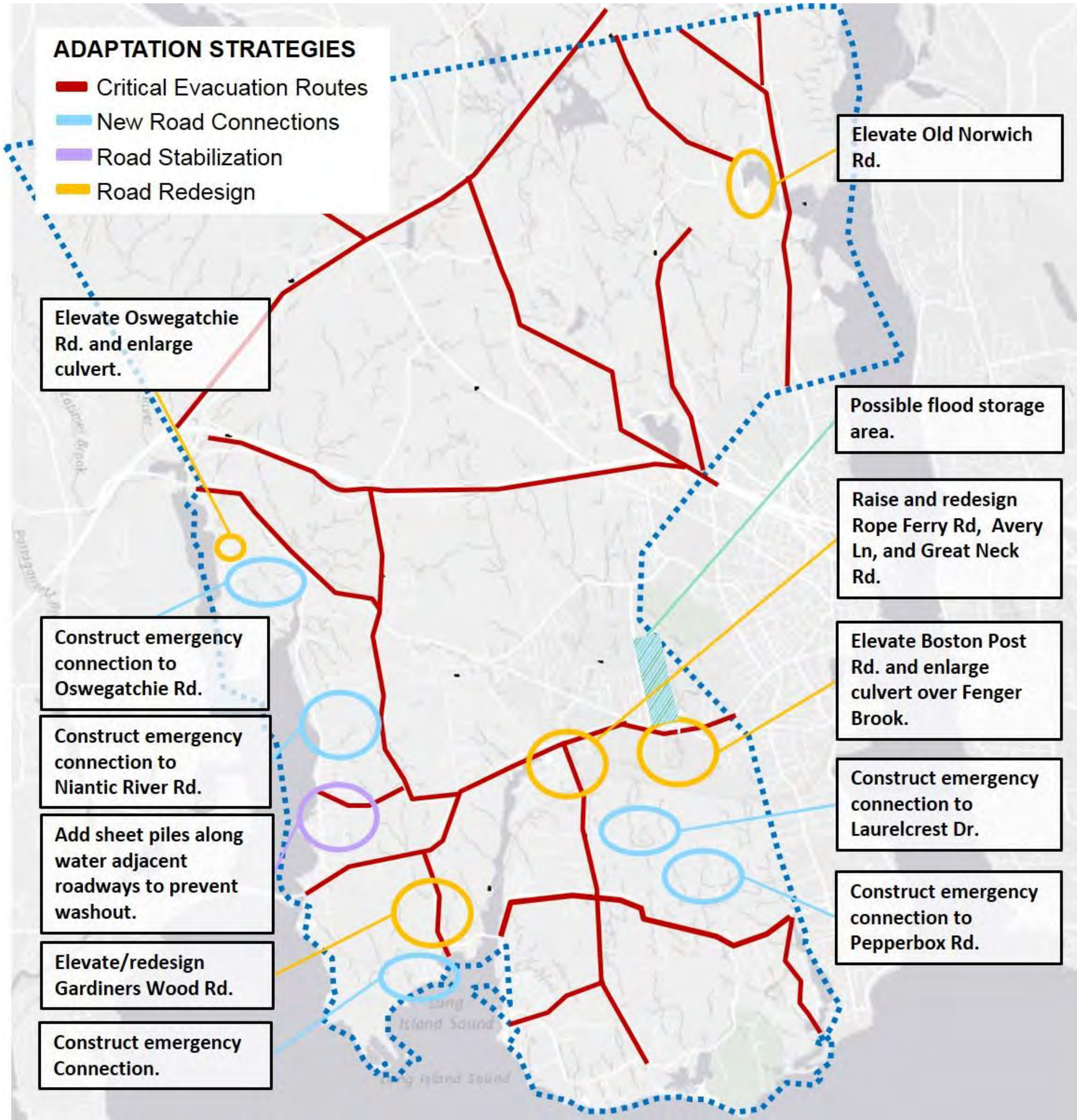


Figure 27 - Potential Adaptation Strategies to Strengthen Evacuation and Emergency Access Routes

Below are discussions on several adaptation strategies for several specific roads.

Adaptation Strategies – Gardiners Wood Road

The southern end of Gardiners Wood Road, at its intersection with Millstone Road East, is subject to coastal flooding in the present, 2030 and 2070 time frames.

The low-point elevation at Gardiners Wood Road near the railroad tracks is approximately El. 6.8. The projected coastal flood levels are El. 8.89 in the present, El. 9.53 in 2030 and El. 12.22 in 2070. Raising the road by 2.73 feet to be above the 2030 flood or 5.42 feet to be above the 2070 flood is not realistic because it would require raising the tracks to meet current required bridge under-clearances. Raising this section of high-speed track would require raising thousands of feet of embankment and track to meet track vertical curve requirements. Therefore, raising the road is not considered to be a feasible option.

The road also floods regularly from overwash caused by heavy precipitation running along Gardiners Wood Road from Rope Ferry Road. There is a relatively large drainage catchment area that drains along the road and eventually discharges under Jordan Cove Road into Long Island Sound. There are three culverts that the drainage must pass through, and it appears that these culverts might be undersized, which causes the water to back-up and flood onto the roadway. Performing a drainage study or culvert analyses to verify their capacity was not part of the scope of this project.

Adaptation Strategy No. 1 - Drainage Improvements on Gardiners Wood Road – Estimated Range of Construction Costs: $1,797,000 - $2,994,000

Adaptation Strategy No. 1, as illustrated in Figure 28 below, will help address flooding related to heavy precipitation with drainage improvements along the southern end of Gardiners Wood Road. It does not address coastal flooding issues, which would still flood the lower roadway area during a major storm surge event. Implementing this adaptation strategy will help to eliminate nuisance flooding that causes cumulative damage to the road and impacts emergency services to the neighborhood. Recommendations for this strategy include the following:

- Perform a detailed drainage and hydraulic study of the roadway corridor to project drainage flows along Gardiners Wood Road in the present, 2030 and 2070 time frames. Verify the capacities of the three existing culverts.
- Raise Gardiners Wood Road to fill in a low point in the vicinity to the entrance of the baseball fields at the south end of the road. The length of road to be raised is approximately 450 feet. The low point at about El 7.3 would be raised to about El. 10.5.
- Build a "constructed stormwater wetland" on the west side of Gardiners Wood Road just upstream of the 42-inch culvert that crosses Gardiners Wood Road. Provide a sediment forebay to remove sediment at the north end of the stormwater wetland to help reduce stormwater velocity and to remove sediment. The constructed wetland would act as a storage basin to attenuate the flow of stormwater and improve the water quality of the discharge into Long Island Sound. By raising the road in this area by up to 3 feet would substantially more storage volume for roadway runoff.
- Replace the existing 42-inch culvert under Gardiners Wood Road and the culvert under the railroad tracks with larger, higher capacity culverts. This will help to reduce overwash on the road when the existing culverts do not have sufficient capacity and geometry to pass through the required stormwater volume and velocity.

- Replace the Jordan Cove culvert with a larger culvert, if the drainage analysis indicates that the culvert is undersized in 2070. The cost estimate assumes replacement.
- Construct a large sediment forebay between the northernmost culvert under Gardiners Wood Road and the railroad track. This will help remove sediment from the flow prior to discharging into Long Island Sound.
- Clean all existing drainage pathways of accumulated sediment and debris that reduces the capacity of the drainage system.

It should be noted that during a major coastal flood event, water will overtop Jordan Brook Road and flood Gardiners Wood Road under the railroad bridge. In this case, the road will be impassable under the bridge. If the road is raised as proposed, coastal flooding would not affect the road north of the railroad, until it reached approximately El. 10.1. Flood barriers and tide gates could be installed to prevent coastal flooding beyond the railroad tracks, but the road south of the tracks would still be impassable, so these measures are not warranted for this strategy. The duration of coastal flooding is dependent on the storm duration and tide cycles, but in general would not be expected to be longer than 12 hours, assuming a storm lasts through two tide cycles. This area can be expected to drain relatively quickly due to its proximity to the coast.

<u>Adaptation Strategy No. 2 – Flood Walls on Gardiner Wood Road, Millstone Road East and Jordan Cover Road – Estimated Range of Construction Costs: $877,000 - $1,462,000</u>

This adaptation strategy, as illustrated in Figure 29, would address coastal flooding issues. Although this strategy could be implemented as a stand-alone strategy, we recommend that it be implemented together with Strategy No. 1, which addresses flooding issues due to heavy precipitation that could occur independent of coastal flooding. The costs shown are in addition to the costs identified in Strategy No. 1. Under this concept, Gardiners Wood Road and Millstone Road East could remain open during a coastal flood up to an elevation 12.22, which would provide emergency access to the neighborhood. Access to Jordan Cove Road, however, would be closed during the flood. This would address coastal flooding concerns through 2070. This concept includes the following:

- Construct concrete floodwalls with a top-of-wall elevation of El. 12.22. Building to El. 12.22 would result in a wall with a maximum height of about 4.92 feet in front of the house at 305 Millstone Road East. The wall would need to have openings at two house driveways, across Jordan Cove Road, and across Windward Way. These openings would need to be closed with a temporary barrier just prior to a major flood. The total length of floodwall (varying height) would be approximately 360 feet.
- Install a tide gate at the downstream end of the culvert under the railroad tracks to prevent coastal flood water from flooding Gardiners Wood Road through the culvert system. It should be noted that the tide gate will keep coastal flood waters out, but it will also prevent roadway drainage from precipitation from discharging to Long Island Sound. Assuming a major rain event is occurring simultaneously with a major coastal flood, there would be some drainage overflow onto the roadway. The exact quantities and expected depths of flooding would have to be determined as part of the drainage and hydraulic analysis for the project.
- Install a pre-packaged duplex pump system at the low point of the intersection of Millstone Road and Gardiners Wood Road to pump out any accumulation of drainage on the roadway. In lieu of a permanent fixed pump, a portable gas-fired pump could also be used.

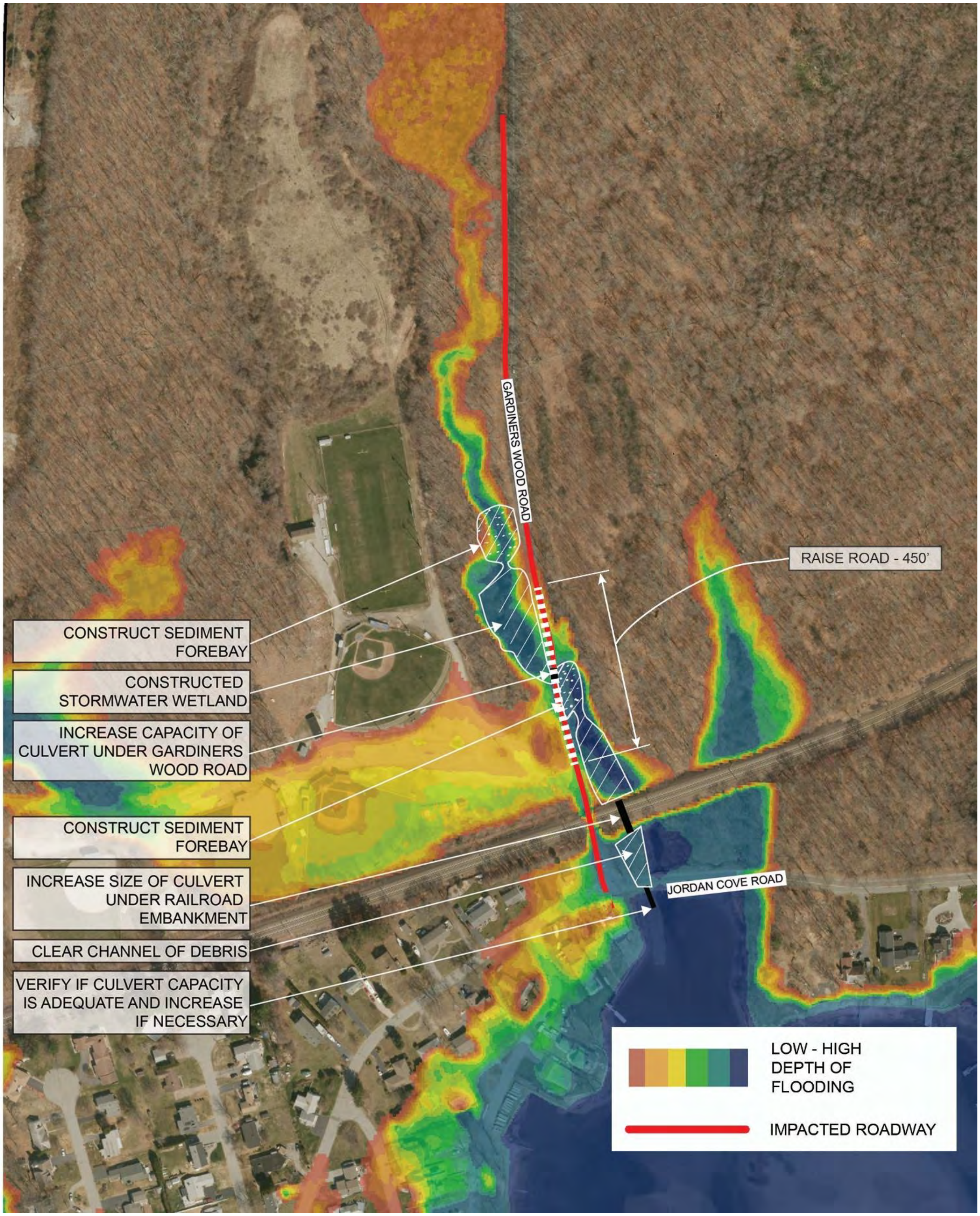


Figure 28 - Gardiners Wood Road Adaptation Strategy No. 1 - 2070, 100-Year Coastal Flood Scenario

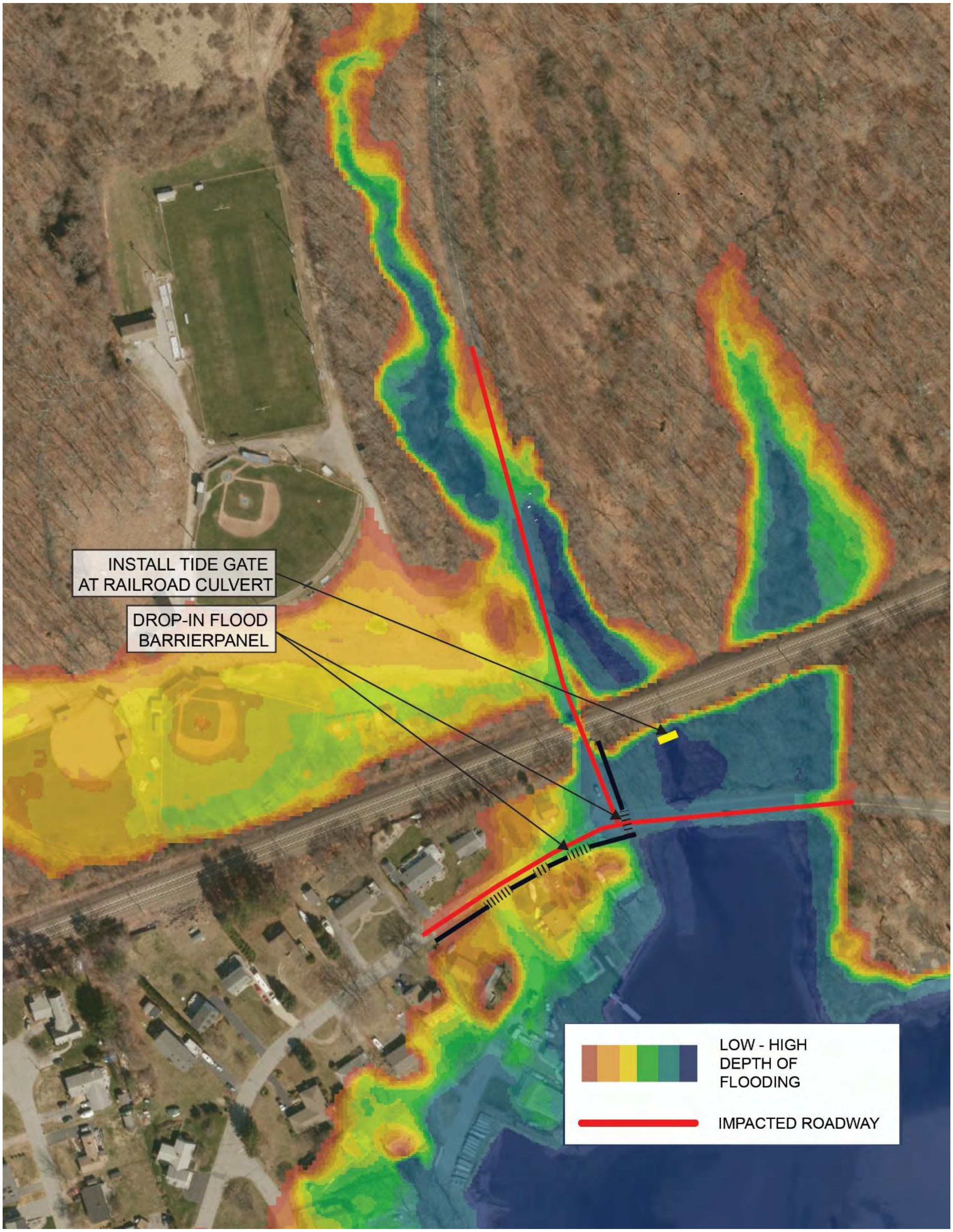


Figure 29 - Gardiners Wood Road Adaptation Strategy No. 2 - 2070, 100-Year Coastal Flood Scenario

Adaptation Strategies – Oswegatchie Road

As illustrated in Figure 30, there are two sections of Oswegatchie Road that are vulnerable to flooding. One is on the Niantic River near Point Comfort Road. The low point in the road is approximately El. 7.50 feet and the length that can flood is about 130 feet long. The other section of road is along the north end of Keeney Cove, near the intersection with Niantic River Road. This section of road is about 300 feet long and varies in elevation between El. 4.8 to about El. 5.8. For the 2030 timeframe, the predicted water elevations for a 1% (100 year) storm are El. 10.58 and El. 12.36 for coastal and riverine storms, respectively. For the 2070 timeframe, the predicted water elevations for a 1% (100 year) storm event are El. 13.27 and El. 13.2 for coastal and riverine storms, respectively.

If both ends of Oswegatchie Road are flooded, there is a relatively large neighborhood that would not have vehicular access into or out of the neighborhood during a flood. In addition, a major flood could cause major damage to the roadway infrastructure and associated utilities, which could be costly to repair and keep the road out of service for several weeks. This would be a public safety issue as well as a major inconvenience to citizens living in this area of town.

Adaptation Strategy No. 1 – Raise Oswegatchie Road near Point Comfort Road - Estimated Range of Construction Costs: $516,000 - $860,000

The best way to adapt to future flooding and to maintain emergency access to the adjacent neighborhood is to raise Oswegatchie Road just south of Point Comfort Road. We estimate that this road can be raised over a distance of about 500 feet to a minimum elevation near El. 13. Several driveways would need to be adjusted, but it appears that there is room to do so. This would provide long-term flood protection for a 100-year storm in 2070. This is the recommended approach to maintain at least one means of egress into the neighborhood.

Adaptation Strategy No. 2 – Reinforce Roadway Embankments- Estimated Range of Construction Costs: $118,000 - $196,000

If Oswegatchie Road is raised per Adaptation Strategy No. 1, it is not necessary to raise the section of road along Keeney Cove, as the adjacent neighborhood would have at least one means of emergency access. However, the road along Keeny Cove could be susceptible to erosion and possible collapse during an extreme coastal or riverine flood in the present, 2030 or 2070 timeframes. Therefore, to minimize the potential for roadway damage, this strategy reinforces the roadway embankments for about 300 feet of roadway directly adjacent to Keeny Cove with additional stone revetment or sheet pile cut-off walls to prevent erosion of the road embankment during a major storm. Although the road would be out of service during a major flood, the goal is to return it to service as quickly as possible after the water recedes. If sections of the road collapse, reopening the road would be greatly delayed. The total length of revetment reinforcement is estimated to be 300 feet.

Adaptation Strategy No. 3 – Construct New Emergency Road- Estimated Range of Construction Costs: $175,000 - $290,000

This strategy allows both ends of Oswegatchie Road to flood, but constructs a new emergency access road from Raymond Lane to Pamela Way to allow emergency services to access the otherwise isolated neighborhood. The general area of the potential emergency road is shown in Figure 30. There are also other possible starting and ending points for a small new emergency access road. This emergency road does not necessarily need to be a paved access road for daily use, but rather it can be a “Geo-Grid” cellular, interlocking HDPE paving grid for reinforcing grass, creating a surface that can be driven on. This road would normally be closed to vehicular traffic, but would be opened in advance of a major flood event. This strategy helps to provide emergency access to the neighborhood, but could result in potential damage to Oswegatchie Road, which could be costly to repair and keep the road out of service for several weeks, causing a major inconvenience to citizens living in this section of town.

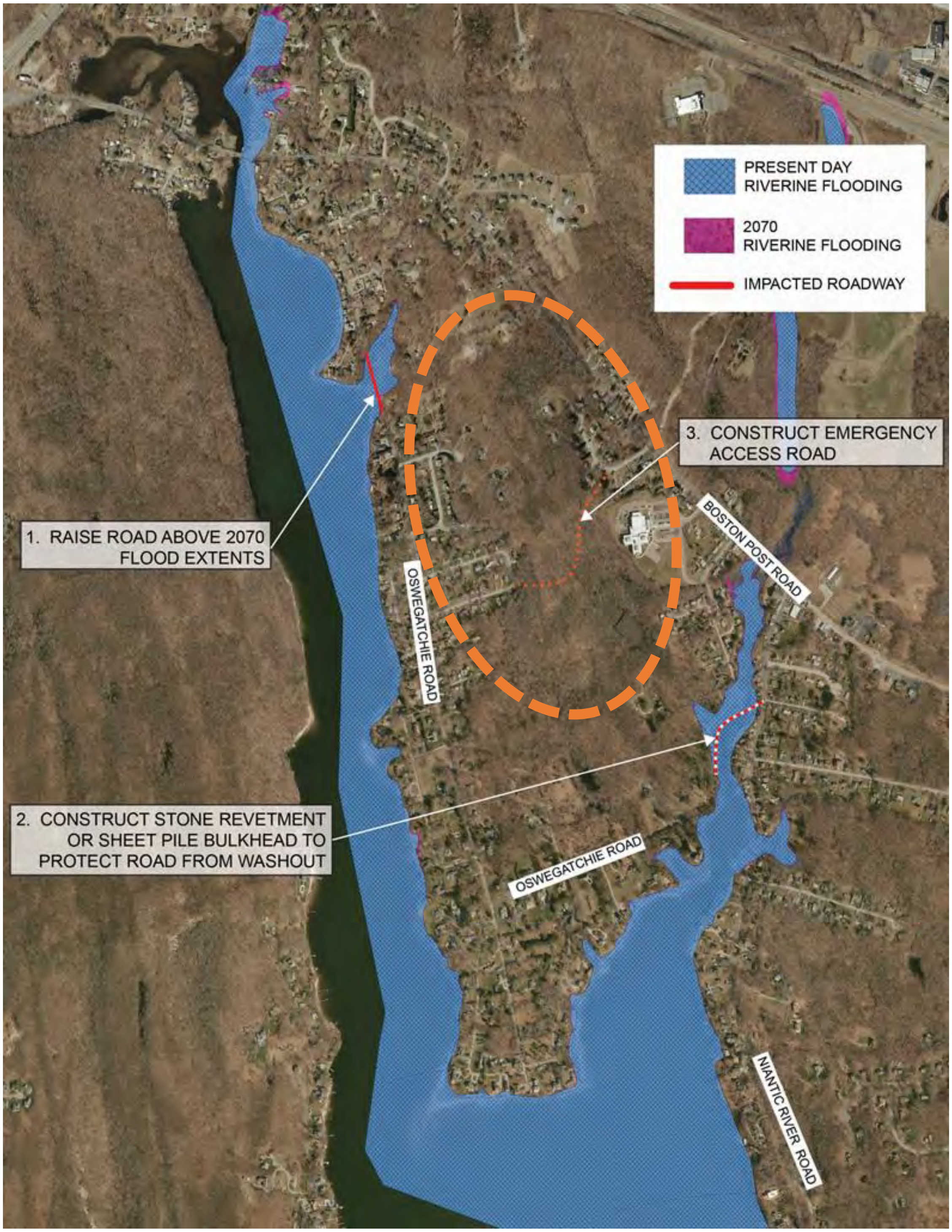


Figure 30 - Proposed Conceptual Road Improvements at Oswegatchie Road – 2070, 100-Year Riverine Flood Scenario

Adaptation Strategy – Rope Ferry Road / Avery Lane / Great Neck Road

The intersection of Rope Ferry Road, Avery Lane and Great Neck Road currently floods from riverine flooding during 100-year storms in the present, 2030 and 2070 timeframes. This is an important intersection in Waterford, and ideally should be protected from flooding. This will help to minimize damage to the roadway infrastructure, including underground and overhead utilities. The proposed strategy described below, will offer protection for a 100-year riverine flood in 2070.

Adaptation Strategy – Raise Elevation of Intersection - Estimated Range of Construction Costs: $2,079,000 - $3,466,000

As illustrated in Figure 31, this strategy proposes to raise the elevation of the intersection a maximum of 4.50 feet to a Design Flood Elevation of 16.50 corresponding to the 2070 (riverine) flood elevation with no additional freeboard. The proposed lengths of road modification are estimated to be as follows:

- Rope Ferry Road: 990 feet
- Avery Lane: 420 feet
- Great Neck Road: 320 feet

Please note that these lengths of road are estimates suitable for long-term planning purposes based on engineering judgement. No roadway geometry, engineering, traffic or environmental studies or utility investigations were conducted as part of this project to determine actual geometry and code-related issues that will affect the length of work and associated costs.

A number of driveways serving adjacent properties would also need to be adjusted to accommodate the raised roadway.

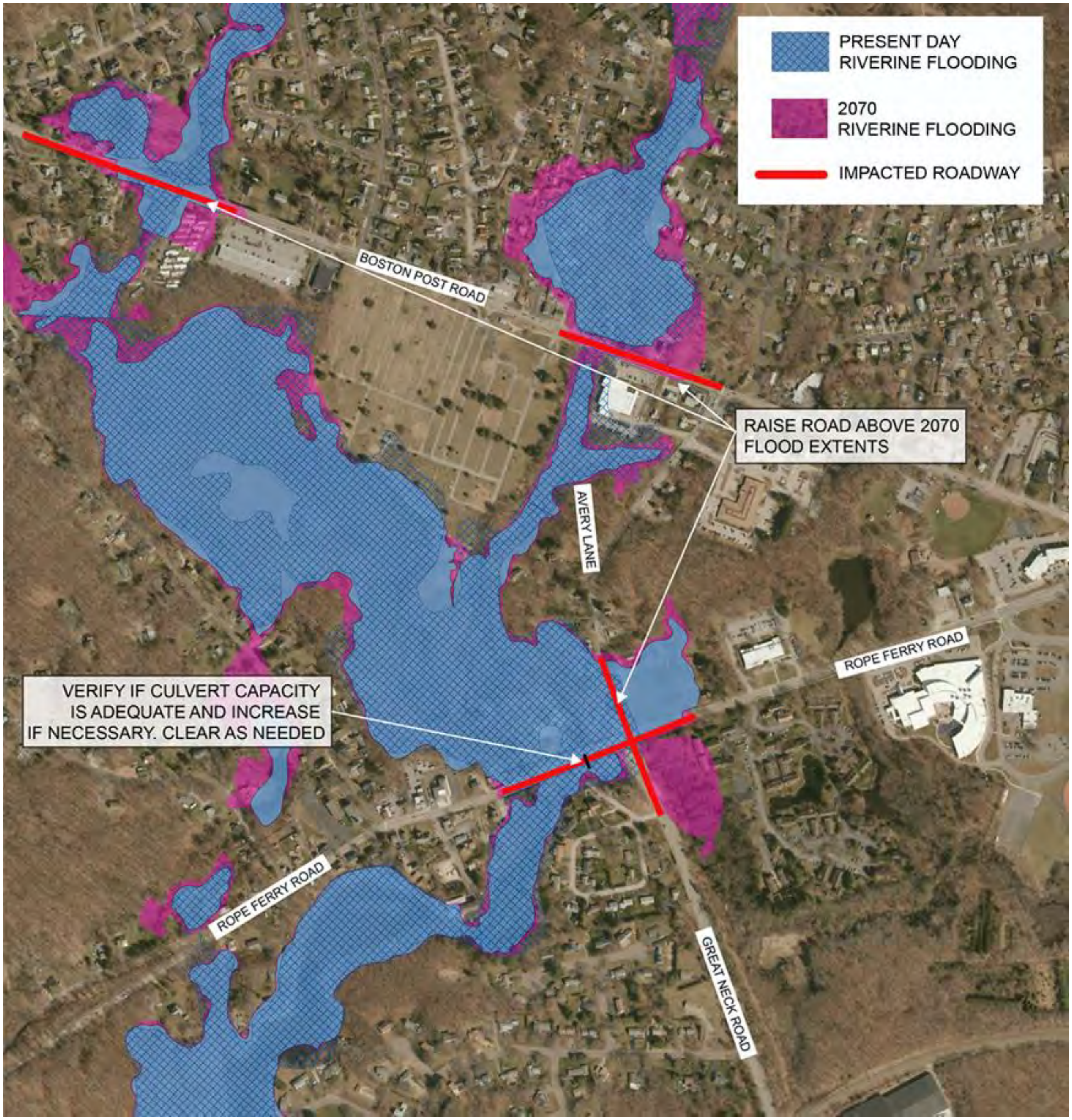


Figure 31 - Proposed Conceptual Road Improvements at Rope Ferry/Avery Lane/Great Neck Road – 2070, 100-Year Riverine Flood Scenario Shown

Adaptation Strategy – Niantic River Road

Adaptation Strategy – Reinforce Roadway Embankments- Estimated Range of Construction Costs: $187,000 - $311,000

Much of Niantic River Road is shown to flood for a present day 1% storm event for both coastal (El. 10.03) and riverine (El. 12.0) storms. For the 2070 timeframe, the predicted water elevations for a 1% storm event are El. 13.27 and El. 13.2 for coastal and riverine storms, respectively. The lowest road elevation is El. 3.30 with several other low spots averaging closer to El. 6.0.

Niantic River Road is a relatively long road subject to flooding with numerous homes and driveways directly adjacent to the road. Therefore, raising the road, even to only meet present-day flood levels, is not practically feasible.

It is also not practical to install permanent flood walls or other flood prevention devices because the height would effectively block most water views from the roadway as well as many of the homes. There would also need to be too many openings in the wall required for access to driveways that would be difficult to seal up in advance of a major storm.

Therefore, we do not believe that it is reasonably feasible to prevent flooding of Niantic River Road. Instead we recommend that the embankments of two of the lowest sections of road directly adjacent to the water be reinforced with additional stone revetment or sheet pile cut-off walls to prevent erosion of the road embankment during a major storm. Although the road would be out of service during a major flood, the goal is to return it to service as quickly as possible after the water recedes. If sections of the road collapse, reopening the road would be greatly delayed. The total length of revetment reinforcement is estimated to be 540 feet. The total estimated cost to construct this revetment reinforcement is in the range of $187,000 to $311,000.

Adaptation Strategy – Evacuation

As mentioned above, there are many roads in Waterford that will flood in a major flood event. It would be cost prohibitive to raise all affected roads. Another strategy is for the Town to purchase an amphibious vehicle to assist with evacuations in the event that neighborhoods become isolated due to severe flooding. Figure 32 shows two examples of such vehicles. One is similar to the “Duck Boat Tour” boats in Boston. These amphibious vehicles can drive on roads, but when the roads are flooded they can drive into the water and turn into boats. They seat about 20 people, which would make them an excellent rescue vehicle. Another option is a large-wheeled ex-military type vehicle.

The cost to purchase these type of vehicles is difficult to predict. A good source of amphibious vehicles is from surplus military equipment, which is often auctioned off through the Department of Homeland Security or made available to Public Safety Departments under various grants. A budgetary estimate would be in the range of $75,000 to $100,000. In addition, to the capital purchase cost, the cost of annual maintenance and storage should be factored in.

Figure 32 - Examples of Potential Rescue Vehicles

<u>Adaptation Strategy – Waterproofing Wastewater Manholes</u>

The Town of Waterford has already waterproofed all wastewater manholes located within the current FEMA 100-year mapped floodplain. The purpose for waterproofing the wastewater manholes is to prevent surcharging and flooding wastewater pump stations from floodwater entering leaking manholes. However, based on the flood mapping generated by this project, the floodplain will likely expand beyond the current FEMA 100-year floodplain in the future.

As discussed with the Working Group, we recommend that wastewater manholes located within the current FEMA 500-year floodplain be waterproofed with gasketed, bolted-down manhole covers with sealed rims to help minimize infiltration of flood water into the wastewater pump stations during a major flood.

Using the GIS layer of manhole locations provide by Town staff, we estimate that there are 229 manholes in the zone between the 100-year and 500-year flood plains that should be waterproofed. Table 7 shows the distribution of these manholes by pump station area, and Figure 33 shows the distribution graphically. At an estimated cost of $2,500 per manhole, the estimated cost to waterproof 229 manholes is approximately $573,000. We recommend prioritizing the waterproofing of wastewater manholes based on the same risk-prioritization of the pump stations to which the manholes drain to.

Table 7 - Recommended Wastewater Manholes to be Waterproofed

Sewer Drainage Area	No. of Manholes Between Current 100-Year and 500-Year FEMA Floodplains
Mago Point	49
Niantic River Road	1
Oil Mill Road	1
Gardiners Wood Road	15
Quaker Hill	5
Seaside	14
Shore Road	8
Stony Brook	5
Bolles Court	1
Dock Road	19
East Neck Road	14
Cross Road	12
Evergreen	47
Harvey Ave./Blue Hills	18
Oswegatchie Road	1
Richards Grove	1
Ridgewood	18
Total	**229**
LEGEND	
(red)	High Priority
(orange)	Medium Prioirty
(yellow)	Lower Priority
(green)	Low Priority

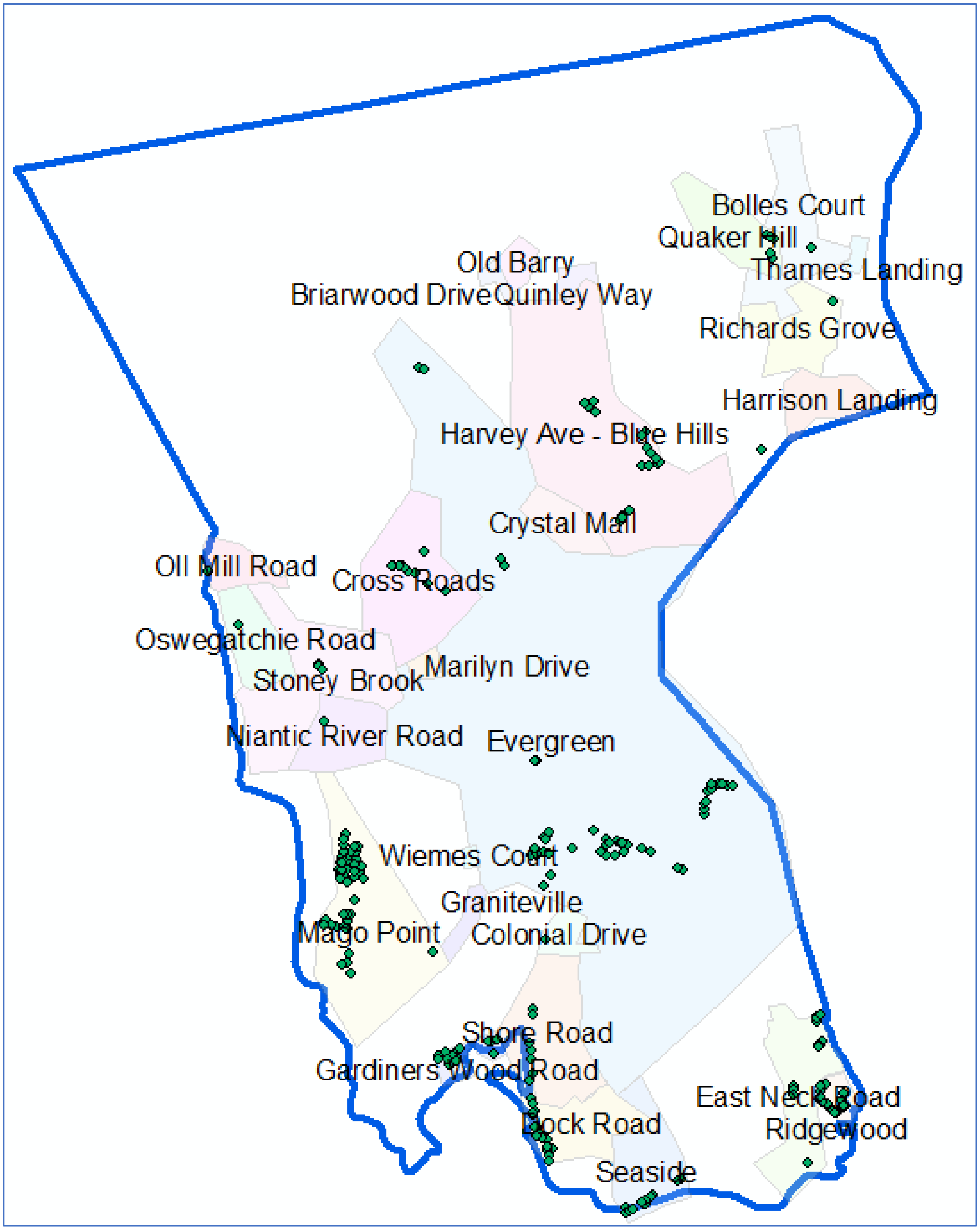


Figure 33 - Distribution of Recommended Wastewater Manholes to be Waterproofed Overlaid on Service Areas Associated with Each Pump Station

G. ADAPTATION STRATEGIES - NATURAL RESOURCES

Coastal estuaries contain a mix of important habitats. Salt marsh and associated tidal flats are important eco-systems. The salt-tolerant vegetation of the salt marsh is at the heart of complex food chains in both estuarine and marine environments. Low marsh, high marsh, subtidal and intertidal flats and tidal creeks, important components of the salt marsh ecosystem, are differentiated by slight differences in elevation.

These rich ecosystems, which support numerous species, also absorb storm surge and wave energy, which helps to protect coastal environments from severe erosion. Loss of salt marsh has been shown to accelerate rates of coastal and beach erosion.

Survival of tidal salt marsh depends on a balance between creation of salt marsh through processes of deposition via mineral and organic sediment accumulation versus the forces leading to deterioration of salt marsh from sea-level rise, wave erosion and subsidence. The sustainability of a salt marsh is dependent on the rate of vertical development, or accretion, compared to the local relative rate of sea-level rise, defined as the combination of the change in sea level (water surface) and the change in marsh ground elevation. Figure 34 illustrates some of the climate and environmental factors that can influence vertical and horizontal wetland development.

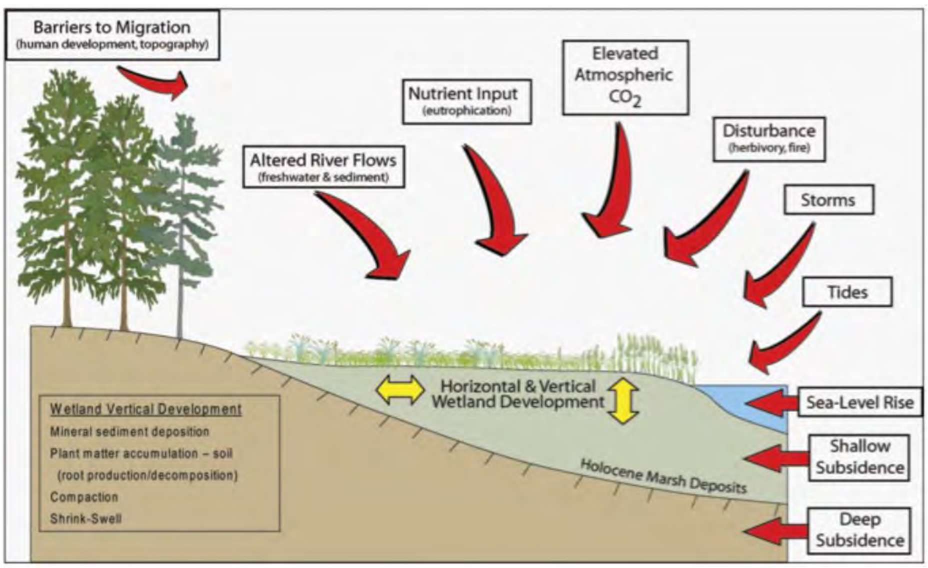


Figure 34 - Climate and Environmental Drivers Influencing Vertical and Horizontal Wetland Development (Source: USGS and Cahoon and others 2009)

If the rate of sea level rise exceeds the rate of accretion, the marsh elevation gradually lowers with respect to mean high water, which leads to increased frequency, depth and duration of flooding. If the marsh elevation falls below the optimum growth range of plants, the plants will die. As the marsh vegetation dies, the marsh habitat converts to intertidal mud flats or sub tidal open water. This change in marsh structure can negatively affect the health and biodiversity of the marsh ecosystem.

Possible adaptation solutions to protect salt marsh include thin-layer deposition to raise the marsh platform and oyster/clam shell bags to protect against marsh edge erosion and hold sediment on the marsh platform (see Figure 35).

Figure 35 - Examples of Thin-Layer Deposition (left) and Ouster/Clam Shell Bags for Marsh Edge Protection (right)

The scope of this project did not include performing detailed studies of salt marshes in Waterford that might be negatively affected by the effects of climate change and sea level rise. We have identified seven natural resource areas in Waterford that might warrant further studies to determine the sustainability of the marsh system. Not all these areas are owned by the Town of Waterford. In those cases where the Town does not fully control the property, the Town can work collaboratively with the property owner/s to help obtain grants and permits to help increase the sustainability of these natural resource areas.

The time frame used for natural resource impacts is 2070, as the primary impacts to salt marsh will be due to daily tides caused by sea level rise, which are not predicted to be substantially different in the 2030-time frame. The substantially higher sea levels in the 2070-time frame will likely effect marsh systems much more significantly.

Town Beach and Marsh

The salt marsh, beach and estuary constituting the Town Beach is shown schematically in Figure 36. This natural resource is under full control of the Town of Waterford. There is a tidal inlet passing from Long Island Sound to Alewife Cove.

According to a report prepared by the American Littoral Society, dated December 17, 2012, titled *Assessing the Impacts of Hurricane Sandy on Coastal Habitats*, “the barrier dune protecting low lying developed areas and tidal wetlands was breached. Continuing erosion will force sand into adjacent Alewife Cove, obstructing the cove’s outlet to Long Island Sound.” This is evidence that the barrier beach and estuary system, which was damaged during Hurricane Sandy, is vulnerable to future damage from the combined effects of sea level rise and coastal storm surge. Continued erosion of the beach surrounding the inlet could cause silting problems for Alewife Cove, which could negatively affect water quality and health of the marsh ecosystem. In addition, breaching of the barrier beach and dune system could change the dynamics and location of marsh resources behind the beach.

We recommend that a coastal processes study of Town Beach be performed to better understand how to stabilize the barrier beach structure and the inlet to enhance tidal exchange into Alewife Cove and to support the salt marsh to the north of Town Beach. There does appear to be room for controlled marsh migration to the north of the barrier beach as shown in Figure 37.

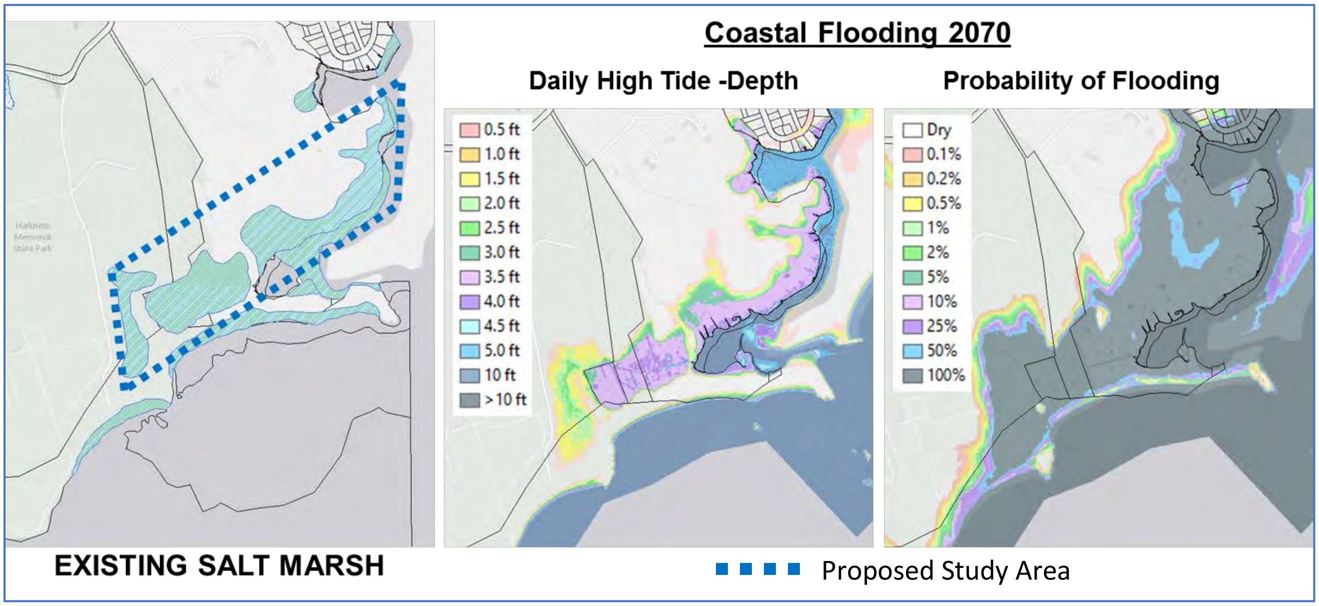


Figure 36 - Town Beach and Marsh

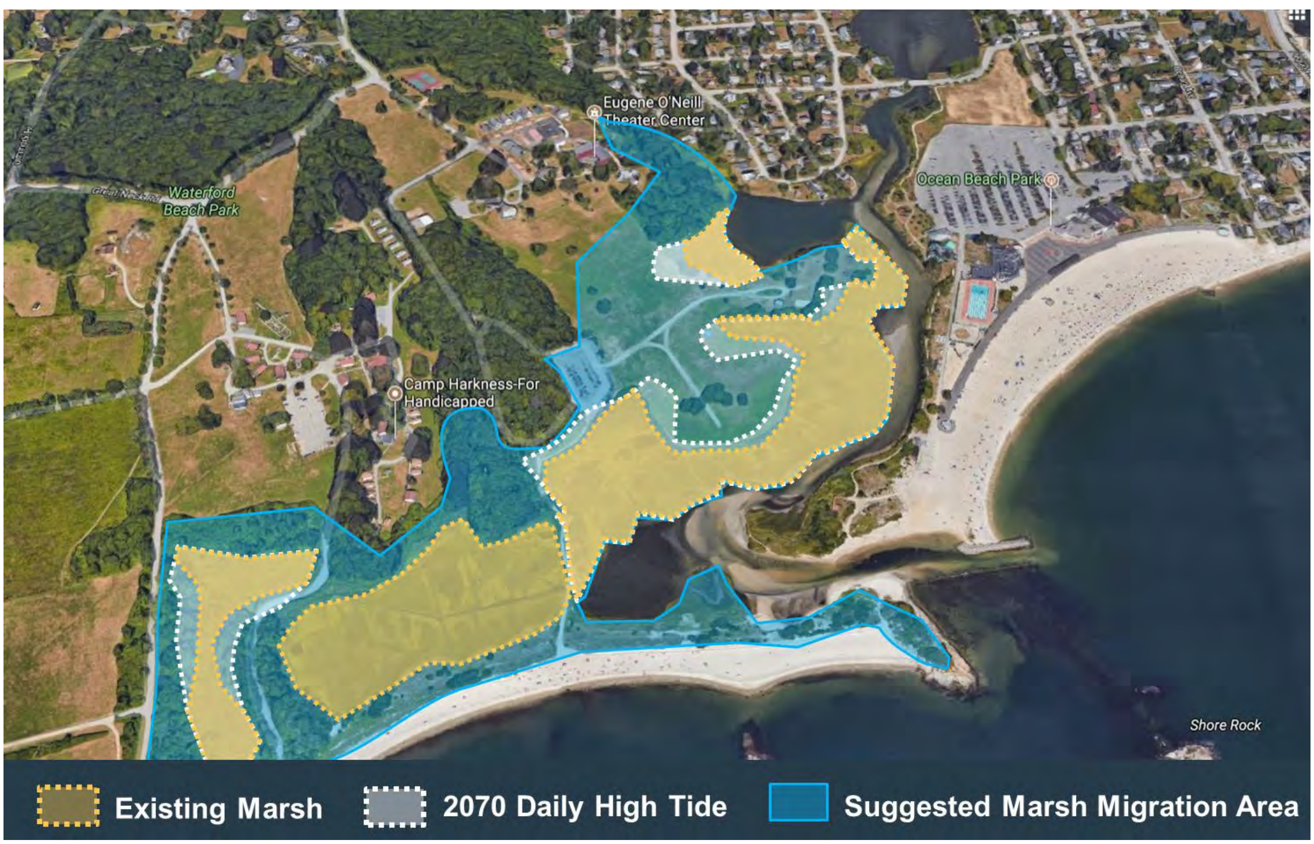


Figure 37 - Areas of Potential Marsh Migration at Town Beach

Much of the modeling data that was used by Woods Hole Group in the development of their 2015 study titled, *Stabilization of Goshen Cove Outlet Feasibility Study at Harness Memorial State Park* could be reusable for this coastal processes study, which would help to reduce the cost. A coastal processes study should include:

- Site-specific data collection, including observations of wave data, tides and currents; grain size sampling of beach sands and marsh sediments; marsh categorization; and research regarding historical and geological changes.
- Development of a hydrodynamic model to simulate overall coastal processes in the area for a range of conditions including normal tides, storms and future sea level rise.
- Wave transformation modeling required to simulate refraction, diffraction shoaling and breaking of waves, as well as wave-induced near-shore currents that drive coastal sediment transport.
- Sediment transport modeling to determine net sediment transport potential along the beach.
- Conceptual restoration alternatives to provide improved resilience of the beach/marsh system, including beach nourishment and dune enhancement to help strengthen the barrier beach system and methods to encourage controlled marsh migration.

The cost to perform a coastal processes study of Town Beach could range from $50,000 to $100,000, depending on the scope of work and the applicability of data from the Goshen Cove study. As the coastal models would also incorporate the adjacent Ocean Beach Park and Neptune Park Association located in New London, there might be an opportunity for both the Town of Waterford and the City of New London and perhaps other private associations and property owners to jointly participate in the study, which will benefit all parties.

We further recommend that the Town develop a Beach Management and Habitat Conservation Plan, with the following goals:

- Serve as a reference document for use by existing and future managers of Town Beach.
- Provide a management program consistent with federal, state and local laws and regulations for the various existing and potential uses of the beach.
- Provide a document that serves as the basis for the on-going management of wetland resources, including regulatory and reporting requirements.
- Describe the management structure of the beach and the role of various parties.
- Provide management guidelines that are flexible enough to be adapted, refined and implemented by the beach’s on-site management staff.
- Provide management guidelines to protect endangered and protected species and their habitats.
- Provide an outline of annual beach restoration and maintenance programs, including invasive species management, optimal beach and dune profiles and dune vegetation to be maintained, as well as a coastal storm response program.
- Define public education and outreach programs to help educate the public about the key role that the beach plays for the Town of Waterford.

A Beach Management and Habitat Conservation Plan can generally be prepared in-house with minimal cost, except for staff and committee time. If a consultant were to prepare the Beach Management Plan, the cost might be in the range of $25,000 to $50,000, depending on the scope and level of public engagement required.

Pleasure Beach/White Point Marsh

This natural resource area, which includes both beach and salt marsh, is shown schematically in Figure 38. It is partially owned by the Town of Waterford and private entities. This marsh appears to have room for some very limited migration. We recommend that a marsh assessment study be performed of this marsh resource to determine the processes affecting vertical and horizontal wetland development. Possible adaptation techniques that might be applicable include:

- Thin layer deposition to accelerate accretion rates
- Possible widening of drainage channels to enhance tidal flow into marsh.
- Beach nourishment and dune enhancement with dune grass planting at Pleasure Beach

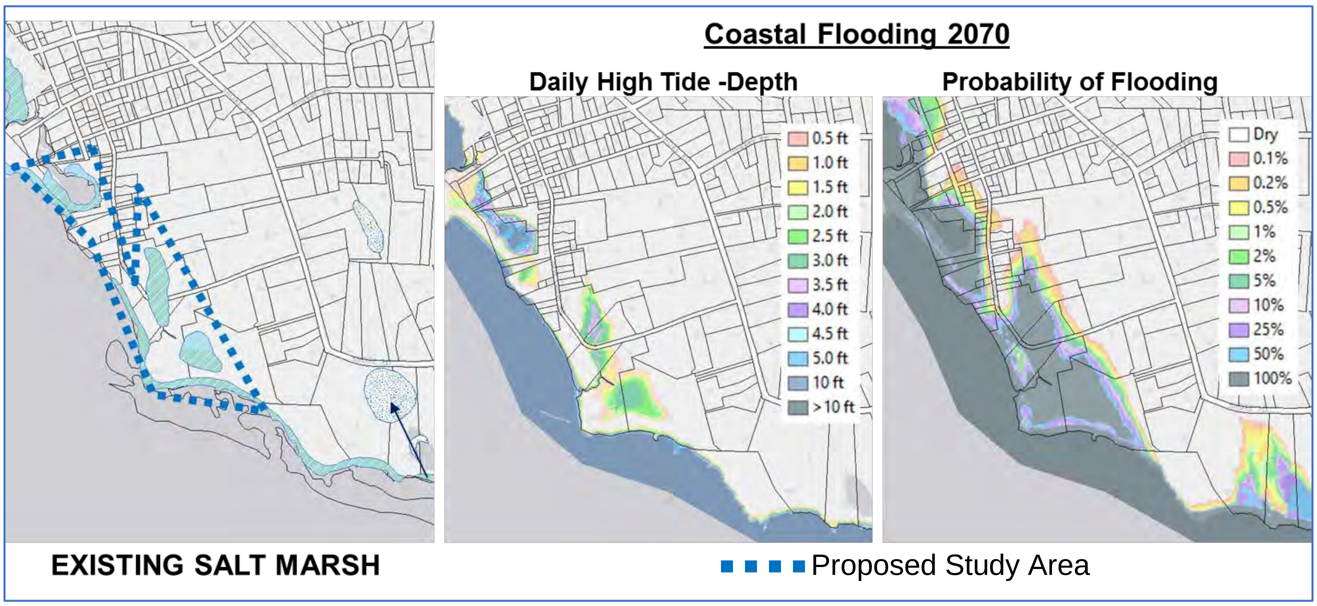


Figure 38 - Pleasure Beach/White Point Marsh

The primary benefit of preserving this marsh system is habitat preservation and erosion control of waterfront property. The cost to perform a limited marsh assessment for this area, as well as the other marsh areas described in this report would be in the range of $20,000 to $40,000, depending on the scope of work requested. As the Town does not fully control this marsh system, this should be considered a medium priority from a funding perspective. The Town should encourage other affected property owners to participate in funding the study or participating in securing grant funding.

Mago Point Marsh

The Mago Point Marsh area is generally shown in Figure 39. The ownership is a mix of private land and railroad right-of-way. Existing tidal exchange infrastructure includes several culverts under the road and railroad embankment that bisect the area. The steep embankments and dense development surrounding the smaller marsh to the north generally limit any possible landward migration. This smaller marsh is dominated by the invasive common reed. The larger marsh area to the south is higher quality marsh and helps to protect the railroad embankment. To better understand the potential for future loss of salt marsh in these areas, we recommend that a marsh assessment study be performed of this marsh resource to determine the processes affecting vertical and horizontal wetland development. Possible marsh restoration techniques that might be applicable include:

- Improve the tidal exchange to the marsh area on the north side of the railroad embankment by expanding the cross-culvert and keeping it free of vegetation and debris.
- Thin layer deposition to accelerate accretion rates
- Oyster/clam shell bags to minimize edge erosion and to help hold sediment on the marsh platform.

The cost to perform a limited marsh assessment for this area, as well as the other marsh areas described in this report would be in the range of $20,000 to $40,000, depending on the scope of work requested. As the Town does not own this property, and the primary beneficiary of the marsh is Amtrak, because the marsh helps protect the railroad embankment, this should be considered a lower priority from a funding perspective. However, the Town could encourage Amtrak to fund a study or contribute to an overall Town-wide marsh assessment study.

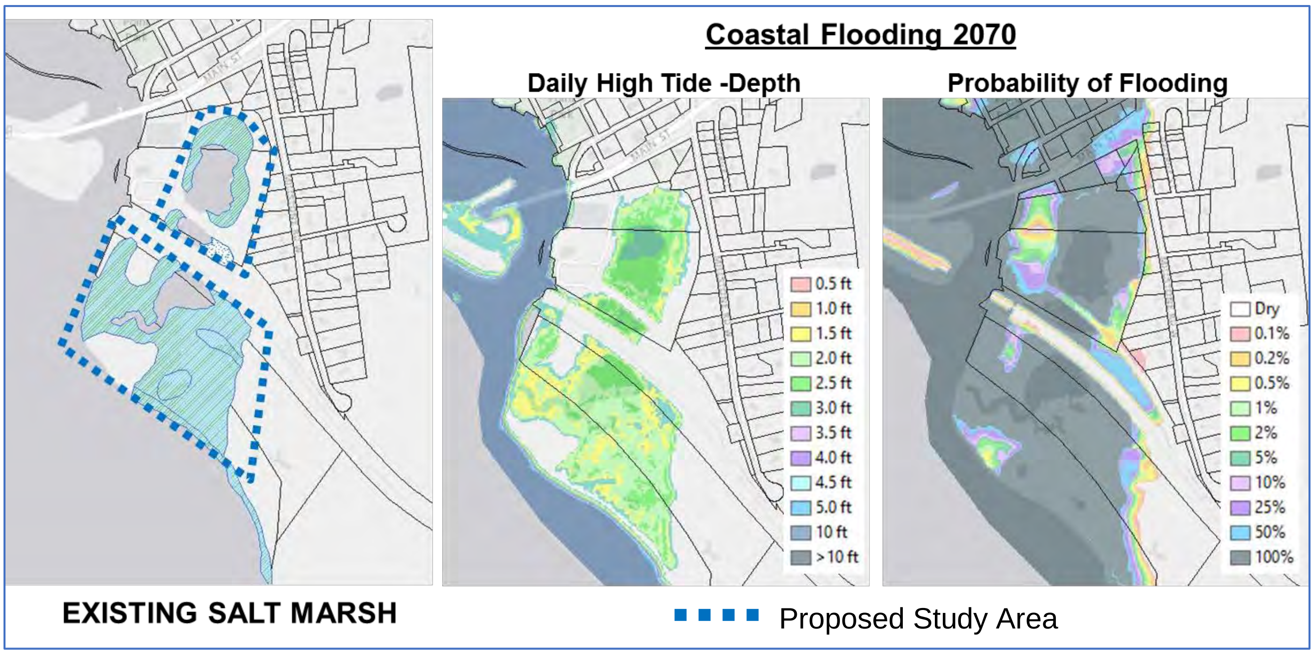


Figure 39 - Mago Point Marsh Area

Millstone/Jordan Cove Marsh

This marsh is shown schematically in Figure 40 below. It is another non-municipally-owned marsh, owned by Millstone. This marsh has some potential room for migration, especially north of the railroad tracks. The Town should encourage Millstone and the railroad companies to perform a marsh assessment study to determine the processes affecting vertical and horizontal wetland development and to improve tidal flow under the railroad embankment to improve the health of the marsh north of the tracks. The primary benefit of preserving this marsh system is habitat preservation, but it could also potentially improve flood storage.

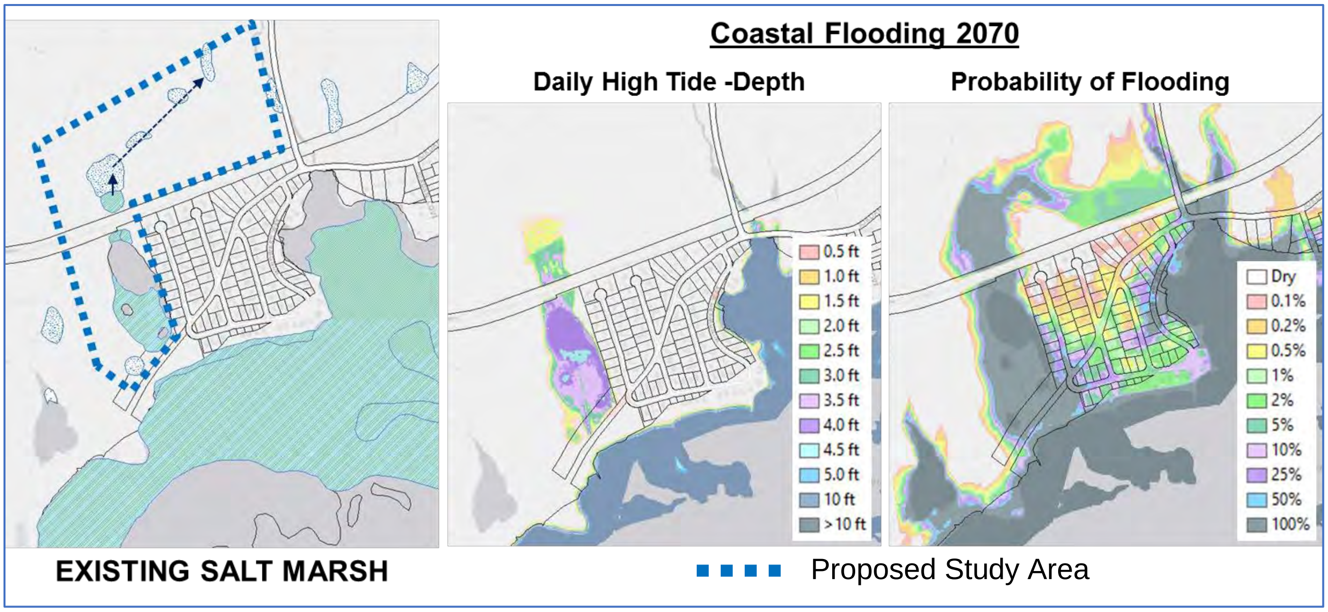


Figure 40 - Millstone/Jordan Cove Marsh

The cost to perform a limited marsh assessment for this area, as well as the other marsh areas described in this report would be in the range of $20,000 to $40,000, depending on the scope of work requested. As the Town does not own this property, and the primary beneficiary of the marsh is Millstone and Amtrak, because the marsh helps protect the railroad embankment, this should be considered a lower priority from a funding perspective. However, the Town could encourage Millstone and Amtrak to fund a study or to contribute to a Town-wide marsh assessment study.

Goshen Cove Marsh

This marsh, owned by the State of Connecticut and a private interest, is schematically shown in Figure 41 below. This marsh and its outlet to Long Island Sound were the subject of a 2015 study performed by the Woods Hole Group titled, "*Stabilization of Goshen Cove Outlet Feasibility Study at Harness Memorial State Park.*" We recommend that the Town encourage and support State efforts to implement recommendations in the report, including:

- Stabilizing the inlet to the cove in its present location
- Utilizing dredge material to enhance beach and dune resources to the west of the inlet to improve resiliency of the natural beach system and protect the marsh landward of the barrier beach.
- Utilizing dredge material to restore ecological habitat in the marsh plains through thin-layer deposition, making the system more resilient to sea level rise.

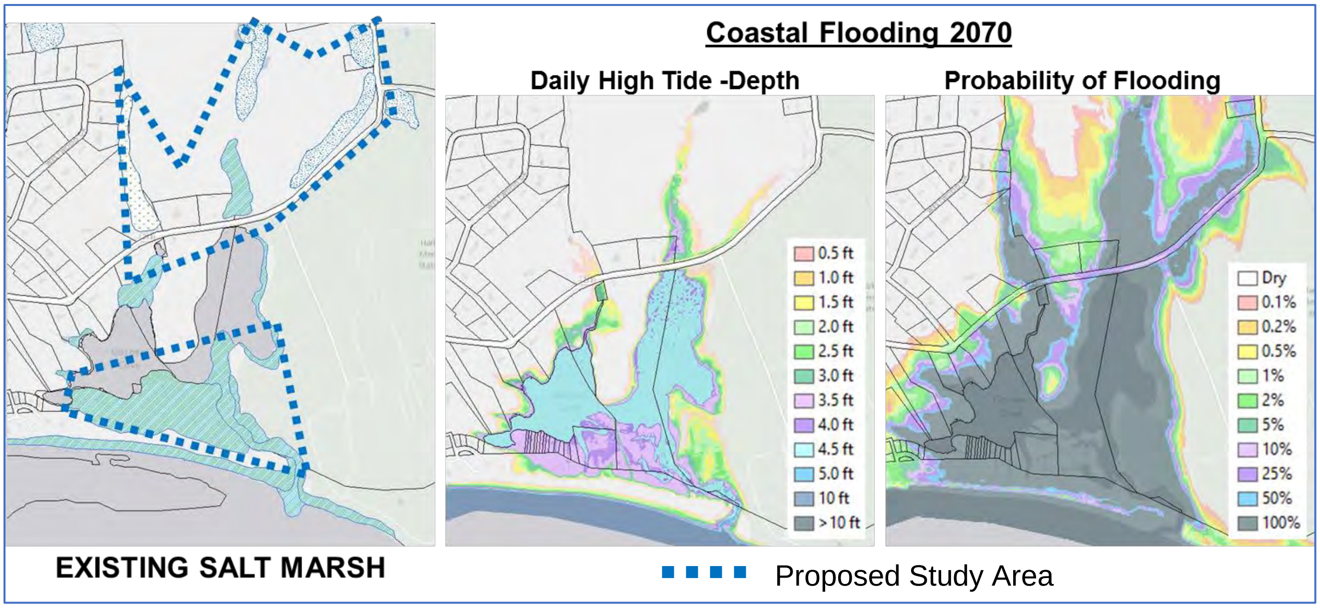


Figure 41 - Goshen Cove Marsh

Ridgewood Marsh

The Ridgewood marsh area is shown schematically in Figure 42. There is a small marsh area along the inlet to Alewife Cove. There are several properties along Wilson Avenue, which might be potentially susceptible to flooding in the 2070 timeframe. The Town might explore the possibility of acquiring some of these parcels via simple fee acquisition or rolling easement with the intent of developing more marsh buffer along Alewife Cove. There is not a lot of potential for marsh migration given the number of residences in the area.

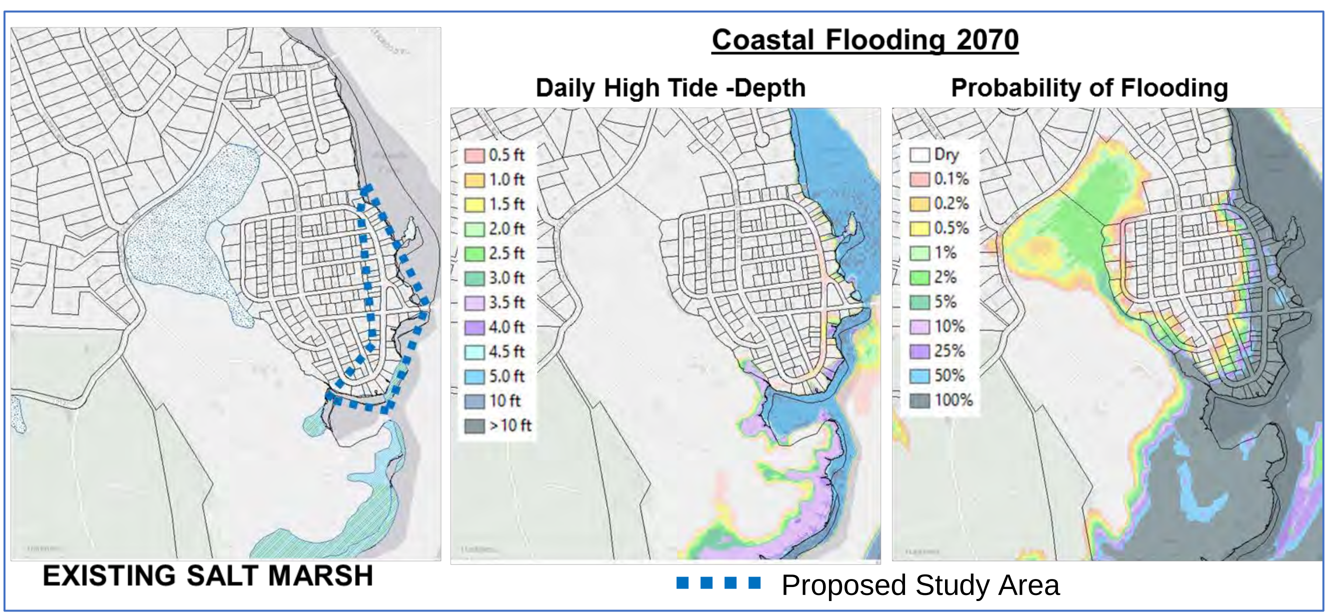


Figure 42 - Ridgewood Marsh Area

Assigning costs associated with property acquisition is beyond the scope of this study. This should be considered as a lower priority in terms of public funding.

Mamacoke Cove Marsh

The Mamacoke Cove marsh area is shown schematically in Figure 43. There are several properties along Wilson Avenue and Benham Avenue, which might be potentially susceptible to flooding in the 2070 timeframe. The Town might explore the possibility of acquiring some of these parcels via simple fee acquisition or rolling easement with the intent of developing more marsh buffer in this area. There is some potential for marsh migration in the area.

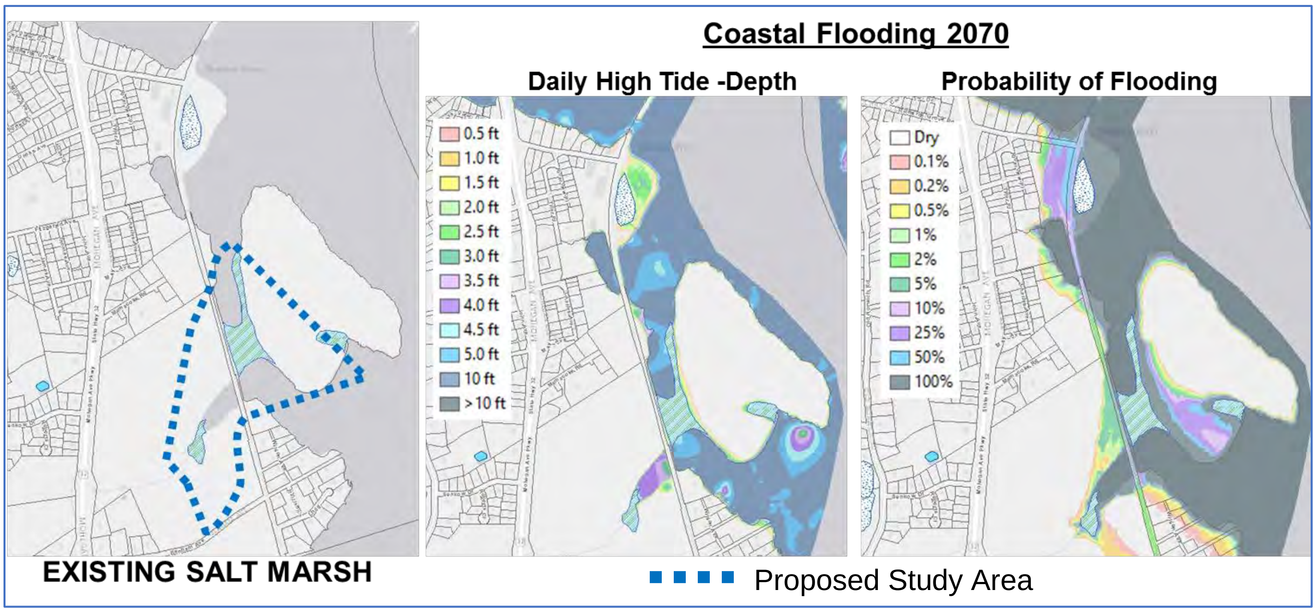


Figure 43 - Mamacoke Cove Marsh Area

Assigning costs associated with property acquisition is beyond the scope of this study. This should be considered as a lower priority in terms of public funding.

POLICY RECOMMENDATIONS

A. ZONING REGULATIONS

Potential changes to the Town of Waterford Zoning Regulations are as follows:

1. Section 1 (Definitions): Consider adding the following definition:

   Sea Level Rise - Consider adding a definition for sea level rise and how it is defined, calculated and at what time periods. For example, you may want to establish a standard that the "Highest" curve from the U.S. National Climate Assessment (Global Sea Level Rise Scenarios for the United States National Climate Assessment, NOAA Technical Report OAR CPO-1, December 12, 2012) (see Figure 44) shall be used as the basis for all sea level rise determinations. This will ensure consistency, and will prevent developers from developing projects using a lower standard.

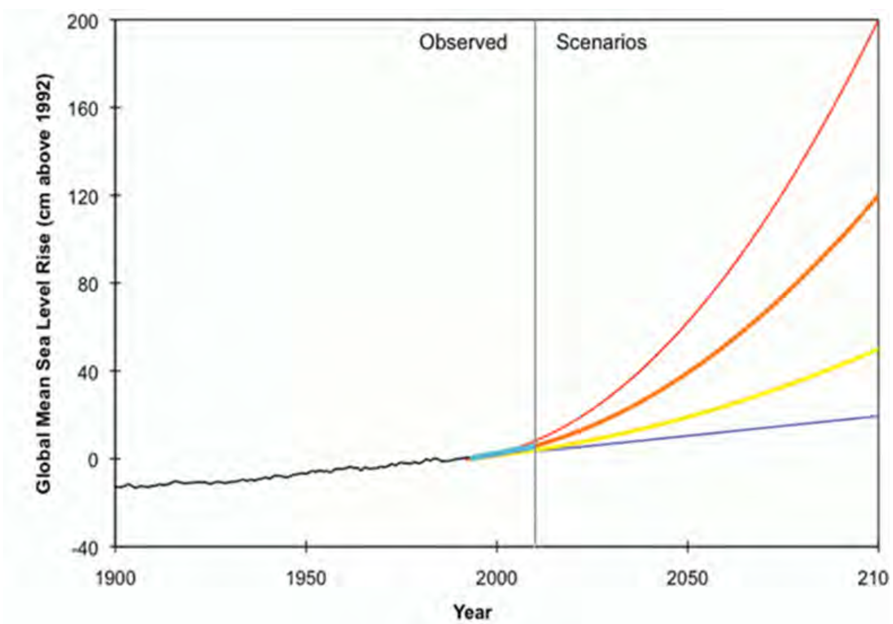


Figure 44 - U.S. National Climate Assessment Sea Level Rise Curves (NOAA 2012)

2. Section 3.6 (Modification of Maximum Building Height Requirements): Consider amending this section to allow increasing maximum building height in the case of structures being elevated to improve flood protection above the minimum 2-foot freeboard above Base Flood Elevation (BFE). A 2-foot freeboard should be considered the minimum safe clearance above the BFE. Consideration should be given to allowing freeboards up to 5 feet. Consider adopting a freeboard incentive for residential and commercial building elevation projects. For example, the Town of Hull, MA adopted a $500 permit fee reduction for an additional 2 feet of freeboard.

3. Section 3.34.3.a (Lot Design Standards – Minimum Buildable Area and Square): The fourth bullet states that no areas within a 100-year flood hazard area can be included within the Minimum Buildable Square (MBS). This seems to conflict with the requirements described in Section 25.3 (Development in Flood Hazard Areas) that address building standards in flood hazard areas. This should be coordinated.

4. Section 3.39.2.4 (Maximum height of accessory dwelling): Clarify if the height is measured from the Base Flood Elevation (BFE) plus two (2) feet per the definition of Building Height in Section 1.11.2.

5. Section 23.5 (Special Permits – Findings): Consider adding another approval condition as follows:

   23.5.10 Protection from the Effects of Flooding

   In addition to meeting the requirements of Sections 25.3 and 25.4, developments located entirely or partially within Flood Hazard Areas shall demonstrate that the infrastructure and structures located on the site are designed to safely withstand the effects of future sea level rise and storm surge over the design life of the development.

6. Section 24.6.G (Special Permit – Flood Plain Compliance): Section 24.6.G requires that a non-conforming structure must be elevated two (2) feet above the base flood elevation, and that the structure cannot be located more than twelve (12) feet above existing ground. Consider allowing more than 2 feet, as 2 feet should be considered the minimum. The 12- foot maximum clearance above the ground is a good limit to retain. Also, clarify where these measurements are taken.

7. Section 25.3 (Development in Flood Hazard Areas – Introduction): Consider modifying the second paragraph as follows:

   *These flood losses are caused by the cumulative effect of obstructions in floodplains causing increases in flood heights and velocities, **sea level rise and storm surge**, and by the occupancy in flood hazard areas by uses vulnerable to floods hazardous to other lands which are inadvertently elevated, floodproofed, or otherwise unprotected from flood damages.*

8. Section 25.3 (Development in Flood Hazard Areas): This section only refers to Base Flood Elevations established by FEMA on approved FIRM maps. These maps do not take into account the effects of future sea level rise. Consideration should be given to establishing higher minimum freeboard than 1 ft. used in Sections 25.3.5.D.1 and 25.3.5.D.2 to account for future sea level rise. Establish performance criteria for sea level rise, such as curves to be used, time frames relative to the expected life of the project, and acceptable methodologies. For projects located within flood hazard areas, the applicant should provide a discussion on how the proposed project addresses flooding from the combined effects of sea level rise and storm surge and precipitation. Include information on how sea level rise is included in the project design, what

temporary and permanent measures are used to control potential flooding, and any adverse effects these measures may have on adjacent properties.

9. Section 25.3.2 (Development in Flood Hazard Areas – Definitions): Consider adding a definition for sea level rise and how it is to be determined. For example, you may want to establish a standard that the "Highest" curve from the U.S. National Climate Assessment (Global Sea Level Rise Scenarios for the United States National Climate Assessment, NOAA Technical Report OAR CPO-1, December 12, 2012) shall be used as the basis for all sea level rise determinations. This will ensure consistency, and will prevent developers from developing projects using a lower standard.

10. Temporary Flood Protection: Consider adding a section about how to treat temporary flood protection measures such as flood protection barriers that can be deployed in advance of a flood to protect a structure. Examples of temporary flood protection are shown in Figures 45. Consideration should be given as to flood zones where deployment of such barriers is permitted, egress issues, and design standards.

Figure 45 - Temporary Flood Panels (left) and Flood Wall with Temporary Flood Gate (right)

B. SUBDIVISION REGULATIONS

Potential changes to the Town of Waterford Subdivision Regulations are as follows:

1. Section 2.2.3 (Preliminary Subdivision Plan – Content): Consider adding the requirement to submit flood hazard map data required per Section 25.3 in the Zoning Regulations.

2. Section 4.3 (Lot Layout/Topographic Map): This section should require submission of flood hazard data described in Section 25.3 (Development in Flood Hazard Areas) of the Zoning Regulations.

3. Section 5.2 (Land Subject to Flooding): This section should be updated to reference the requirements of Section 25.3 (Development in Flood Hazard Areas) of the Zoning Regulations. For projects located within flood hazard areas, provide a discussion on how the proposed project addresses flooding from the combined effects of sea level rise and storm surge and precipitation. Include information on how sea level rise is

included in the project design, what temporary and permanent measures are used to control potential flooding, and any adverse effects these measures may have on adjacent properties.

C. INLAND WETLAND AND WATERCOURSES REGULATIONS

Potential changes to the Town of Waterford Inland Wetland and Watercourses Regulations are as follows:

1. Consider adding the requirement to submit flood hazard map data required per Section 25.3 in the Zoning Regulations.

D. LAND/RESOURCE ACQUISITION

1. Consider acquiring land adjacent to coastal resource areas to accommodate changing conditions of natural resource areas such as salt marsh, especially those areas identified in this study as areas of potential resource change and/or migration. The natural resource information provided in this study can be used to identify priority areas for acquisition through easements, fee interest or purchase of development rights (conservation restrictions) to accommodate future effects of sea level rise.

2. Investigate obtaining a FEMA Hazard Mitigation Assistance (HMA) grant for property acquisition and structure demolition projects, which involves purchase of structures and underlying land in a hazard-prone area and the removal of the structure, thus converting the land to open space. The owner of the acquired property must voluntarily agree to sell the land, and the property must be deed-restricted in perpetuity to open space that restores and/or conserves the natural floodplain functions.

3. Investigate the possibility of implementing a rolling easements program in which the Town can purchase an easement from a property owner today in exchange for a promise to surrender the property to the Town once it is substantially damaged by a flood event. This program would be part of a “retreat” policy to be implemented in areas subject to severe and repeated flooding. Rolling easements are a potential way to provide cash to a property owner today with the understanding that when the property is substantially damaged, it will not be rebuilt and will be turned over to the Town. Based on information provided in the “*Hazard Mitigation Plan Update Annex for the Town of Waterford”* dated November 20, 2012, there are a total of seven “repetitive loss” properties in Waterford, each having had at least two or more flood claims of $1,000 or more in any given 10-year period since 1978. Four are related to inland riverine flooding and three are related to coastal flooding. These properties might be ideal candidates for such a program as they have already experience repeated flood damage in the past. It is likely that these properties will experience

more claims in the future unless they have been elevated or otherwise protected from flooding.

E. POTENTIAL POLICIES FOR PUBLIC PROJECTS

1. Develop policies for public projects that incorporate the anticipated effects of long-term sea level rise and promote more sustainable practices throughout the community.
   a. Require that all Town-funded projects consider predicted impacts of long-term sea level rise.
   b. Update the Town's Hazard Mitigation Plan in the context of this study and amend as appropriate. Include a documentation requirement/goal to build data on the impacts of coastal storms to inform implementation of future adaptation measures.
   c. Set up a Town resiliency web site that can be used to disseminate helpful information to the public regarding flooding vulnerabilities, adaptation information for homeowners and businesses, and reports such as this study.
   d. Publish and post to the Town resiliency web site an annual inventory/report of actions taken by the community to improve resilience to climate change, sea level rise and coastal storm surge and extreme precipitation.

F. COASTAL FLOOD AND EMERGENCY OPERATIONS PLAN

1. Consider developing a Flood Operations Plan to prepare for and minimize flood damage due to coastal and riverine flooding as a result of extreme weather events. The plan will help to institutionalize flood prevention actions that need to be performed before, during and after a major storm.
   a. The plan should utilize actual maximum predicted water elevations for a storm and should clearly define what the sources of the data are and who makes the decision to implement the plan.
   b. The plan should clearly define actions to be taken based on the maximum predicted water elevations, parties responsible to perform the actions and timelines required to implement the actions. The plan should include protocols and procedures for pre-storm mobilization, public notification or warnings, monitoring during the storm, and post-storm recovery.
   c. The plan should identify training, storage, and maintenance needs for any specific equipment such as temporary flood barriers.

d. Each facility being protected should have facility-specific instructions located on-site for easy access during pre-storm mobilization.

e. The plan should be incorporated into the Town’s overall emergency response planning documents, including the Town’s Hazard Mitigation Plan.

G. NATIONAL FLOOD INSURANCE PROGRAM COMMUNITY RATING SYSTEM

1. The National Flood Insurance Program’s (NFIP) Community Rating System (CRS) recognizes and encourages community floodplain management activities that exceed the minimum NFIP standards. Depending upon the level of participation, flood insurance premium rates for policyholders in the community can be reduced up to 45%, depending on the credit level achieved by the community. Most communities do not reduce flood insurance premiums by more than 15%. Besides the benefit of reduced insurance rates, CRS floodplain management activities enhance public safety, reduce damages to property and public infrastructure, avoid or reduce economic disruption and losses, reduce human suffering, and protect the environment. Technical assistance on designing and implementing some activities is available at no charge from the NFIP. Participating in the CRS provides an incentive to maintaining and improving a community's floodplain management program over the years. Implementing some CRS activities can also help the Town qualify for Flood Mitigation Assistance (FMA) funding through the NFIP. FEMA provides FMA funds to assist communities with implementing measures that reduce or eliminate the long-term risk of flood damage to buildings, homes and other structures insurable under the NFIP.

   To participate in the program, the Town of Waterford can choose to undertake some or all of the 19 public information and floodplain management activities, which fall under the following four broad categories:

- *Series 300 - Public Information Activities:*
  This series credits programs that advise people about flood hazards, flood insurance, and ways to reduce flood damage. The activities also provide data that insurance agents need for accurate flood insurance rating. It includes the possible following activities:
    - 310 Elevation Certificates (*Required*)
    - 320 Map Information Service
    - 330 Outreach Projects
    - 340 Hazard Disclosure
    - 350 Flood Protection Information
    - 360 Flood Protection Assistance
    - 370 Flood Insurance Promotion

- *Series 400 - Mapping and Regulations*:
  This series credits programs that provide increased protection to new development. It includes the possible following activities:

- 410 Floodplain Mapping
- 420 Open Space Preservation
- 430 Higher Regulatory Standards
- 440 Flood Data Maintenance
- 450 Stormwater Management

- *Series 500 - Flood Damage Reduction Activities*:
  This series credits programs that reduce the flood risk to existing development. It includes the possible following activities:

  - 510 Floodplain Management Planning (*required*)
  - 520 Acquisition and Relocation
  - 530 Flood Protection
  - 540 Drainage System Maintenance

- *Series 600 - Warning and Response*:
  This series credits flood warning, levee safety, and dam safety projects. It includes the possible following activities:

  - 610 Flood Warning and Response
  - 620 Levee Safety
  - 630 Dam Safety

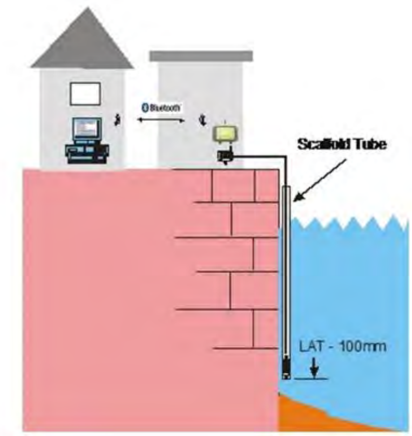
More detailed descriptions of each of the above activities is described in the *CRS - A Local Official's Guide to Saving Lives, Preventing Property Damage and Reducing the Cost of Flood Insurance* published by FEMA's National Flood Insurance Program.

Many of the recommendations in this study, if implemented, will qualify toward the above CRS activities.

It should be noted that there are annual costs that the Town would have to expend to administer this program. Some communities find that costs and personnel time required to administer the program outweigh the benefits of the program, and therefore choose not to participate.

H. TIDE GAUGE INSTALLATION

1. Consider installing automated tide gauge recorders in Waterford to monitor actual sea level rise locally. This information will be very valuable for longer-term planning as a database of tidal data is collected. Locally collected tidal data will be invaluable for calibrating future coastal flood modeling. Suitable locations would include Niantic River (Mago Point), Jordan Cove, Smith Cove, and Alewife Cove. With the amount of existing and proposed development along the Niantic River, we suggest Mago Point be considered a priority location. Tide gauges can also be incorporated into the educational curricula to help educate students and the public on sea level rise.



The cost to install an automated tide gauge recorder might be in the range of $15,000 to $25,000, depending on the type of recorder selected and the site-specific mounting details.

I. POTENTIAL FUNDING SOURCES

The costs for the Town of Waterford to become more resilient and adapt to the impacts of climate change, including sea level rise, increased storm surge and increased precipitation, are enormous, and likely beyond the means of the Town to fund within normal budgetary appropriations. The Town will need to explore external funding sources to implement many of the recommendations described in this study.

The following are some federal, state and private funding sources that the Town can potentially pursue:

Connecticut Institute for Resilience and Climate Adaptation (CIRCA) Municipal Resilience Grant Program

CIRCA is a partnership of the University of Connecticut and the Connecticut Department of Energy and Environmental Protection. The mission of CIRCA is to assist Connecticut towns and cities to adapt to a changing climate and to enhance the resilience of their infrastructure. This program is focused on implementation and proposals must review and consider integration of CIRCA's research products (see following link to CIRCA Research Projects report http://circa.uconn.edu/crest/wave-research/). CIRCA has made up to $100,000 in funds available to municipal governments for the execution of resilience initiatives. In the past, CIRCA has awarded 2 – 5 projects per round of funding. CIRCA has indicated that future funding of grant opportunities is likely.

Project proposals should develop knowledge or experience that is transferable to multiple locations in Connecticut and have well-defined and measurable goals. Projects should be implemented in no more than a 12-month time frame. Preference will be given to projects that leverage multiple funding sources and that involve collaboration with CIRCA to address at least on the following priority areas:

- Develop and deploy natural science, engineering, legal, financial dn policy best practices for climate resilience;
- Undertake or oversee pilot projects designed to improve resilience and sustainability of the natural and built environment along Connecticut's coast and inland waterways;
- Foster resilient actions and sustainable communities – particularly along the Connecticut coastline and inland waterways – that can adapt to impacts and hazards of climate change; and
- Reduce the loss of life and property, natural system and ecological damage, and social disruption from high-impact events.

National Oceanic and Atmospheric Administration (NOAA) Regional Coastal Resilience Grants

The objective of the NOAA Coastal Resilience Grants program, jointly administered by NOAA's National Ocean Service and National Marine Fisheries Service, is to implement projects that build resilient U.S. coastal communities, economies and ecosystems. Resilience is the ability to prepare and plan for, absorb, recover from, and successfully adapt. This program is intended to build resilience by reducing the risk to coastal communities, economies and ecosystems from extreme weather events and climate related hazards. Projects that build resilience include activities that protect life and property, safeguard people and infrastructure, strengthen the economy, and/or conserve and restore coastal and marine resources.

The NOAA Coastal Resilience Grants Program, is a competitive grant, which typically support two categories of activities:

1) Strengthening Coastal Communities: activities that improve capacity of multiple coastal jurisdictions (states, counties, municipalities, territories and tribes) to prepare and plan for, absorb impacts of, recover from, and/or adapt to extreme weather events and climate-related hazards; or

2) Habitat Restoration: activities that restore habitat to strengthen the resilience of coastal ecosystems and decrease the vulnerability of coastal communities to extreme weather events and climate-related hazards. Proposals focused on restoring habitat should strengthen the resilience of coastal ecosystems and decrease the vulnerability of communities to extreme weather events and climate-related hazards.

Preference is typically given to proposals that demonstrate collaboration among stakeholders and leverage recommendations or strategies outlined in previous multi-stakeholder studies or vulnerability assessments related to community resilience.

Municipalities in Connecticut are eligible for funding. In 2017, the total amount for funding was up to $15 million, with typical awards ranging from $250,000 up to $1,000,000. Federal funds awarded under this program must be matched with non-federal funds (recipient contributions or third-party in-kind cost share) at a 2:1 ratio of federal to non-federal contributions. Funding for this grant program in future years is subject to federal appropriations.

Federal Emergency Management Agency (FEMA)

FEMA administers a number of potential grants that the Town of Waterford might be eligible for, including the following:

Flood Mitigation Assistance (FMA) Program

The FMA program has the goal of reducing or eliminating claims under the National Flood Insurance Program (NFIP). FMA provides funding to states, territories, federally-recognized tribes and local communities for projects and planning that reduce or eliminate long-term risk of flood damage to structures insured under the NFIP. Future funding is subject to federal appropriation by Congress.

A condition of this competitive grant program is that a municipality must develop and adopt a hazard mitigation plan. FMA grant applications must be submitted to FEMA through the State of Connecticut. Local communities can sponsor applications on behalf of homeowners and businesses, and then submit the applications through the State.

In 2017, $70 million of the $160 million available under FMA was prioritized for community flood mitigation projects using proven techniques that integrate cost-effective natural floodplain restoration solutions and improvements to NFIP-insured properties that benefit communities with high participation and favorable standing in the NFIP. Participation in the NFIP Community Rating System would help when applying for this program.

Pre-Disaster Mitigation (PDM) Program

The PDM Grant program provides resources to assist states, tribal governments, territories and local communities in their efforts to implement a sustained pre-disaster natural hazard mitigation program.

A condition of this competitive grant program is that a municipality must develop and adopt a hazard mitigation plan. PDM grant applications must be submitted to FEMA through the State of Connecticut. Acquisition, elevation and mitigation reconstruction projects related to flood mitigation activities are not as highly rated as non-flood hazard mitigation projects, so the likelihood of receiving a PDM grant is probably fairly low.

Hazard Mitigation Grant Program (HMGP)

The purpose of the HMGP is to help communities implement hazard mitigation measures following a Presidential Major Disaster Declaration in the areas of the state requested by the Governor. The key purpose of the grant is to enact mitigation measures that reduce the risk of loss of life and property from future disasters.

A condition of this competitive grant program is that a municipality must develop and adopt a hazard mitigation plan. HMGP grant applications must be submitted to FEMA through the State of Connecticut. Funding under this highly-competitive program can only be applied for and received after a disaster, so this grant opportunity is not available to fund projects pro-actively in advance of a storm.

US Army Corps of Engineers (USACE)

The USACE Continuing Authorities program allows the USACE to plan, design and construct smaller projects without specific authorization from Congress. The non-Federal sponsor, which can include a municipality, must request the USACE to investigate potential flood risk management issues that might fit the program. Once the USACE determines that the project fits the program, the District will request funds to initiate a reconnaissance effort to determine potential Federal interest in proceeding to a feasibility study. There are three authorities available under this program:

Section 14 – Emergency Streambank and Shoreline Protection

Authorized by Section 14 of the Flood Control Act of 1946, this program authorizes the USACE to construct emergency shoreline and streambank protection projects to protect public facilities such as bridges, roads, public buildings, sewage treatment plants, water wells, and non-profit public facilities such as churches, hospitals and school. Some recommendations in this report could potentially be eligible for this program, but more than likely the small scale of the stream bank protection involved would make it unlikely to be successful for funding.

Section 205 – Small Flood Risk Management Projects

Authorized by Section 205 of the Flood Control Act of 1948, this program authorizes the USACE to study, design and construct small flood control projects in partnership with non-Federal government agencies. The recommendations made in this report do not appear to be eligible for funding under this program.

Section 208 – Clearing and Snagging of Waterways

Authorized by Section 208 of the Flood Control Act of 1954, this program authorizes the USACE to perform channel clearing and excavation with limited embankment construction to reduce nuisance flood damage caused by debris and minor shoaling of rivers. The recommendations made in this report do not appear to be eligible for funding under this program.

U. S. Department of Housing and Urban Development (HUD)

The Connecticut Department of Housing administers Connecticut's CDBG program. The Town of Waterford has had past success in securing CDBG funding (this study was funded by a CDBG grant).

Community Development Block Grant (CDBG)

It is possible that CDBG funding could be available for floodproofing and elevating residential and non-residential buildings, provided that the buildings being protected meet the overall CDBG program goals to provide or improve affordable housing as well as expanded economic opportunities, principally for persons of low and moderate income. More than likely, the recommendations made in this report would not fit these goals, and therefore the likelihood of obtaining CDBG funding to implement the recommendations in this report are low.

CDBG Disaster Recovery Assistance

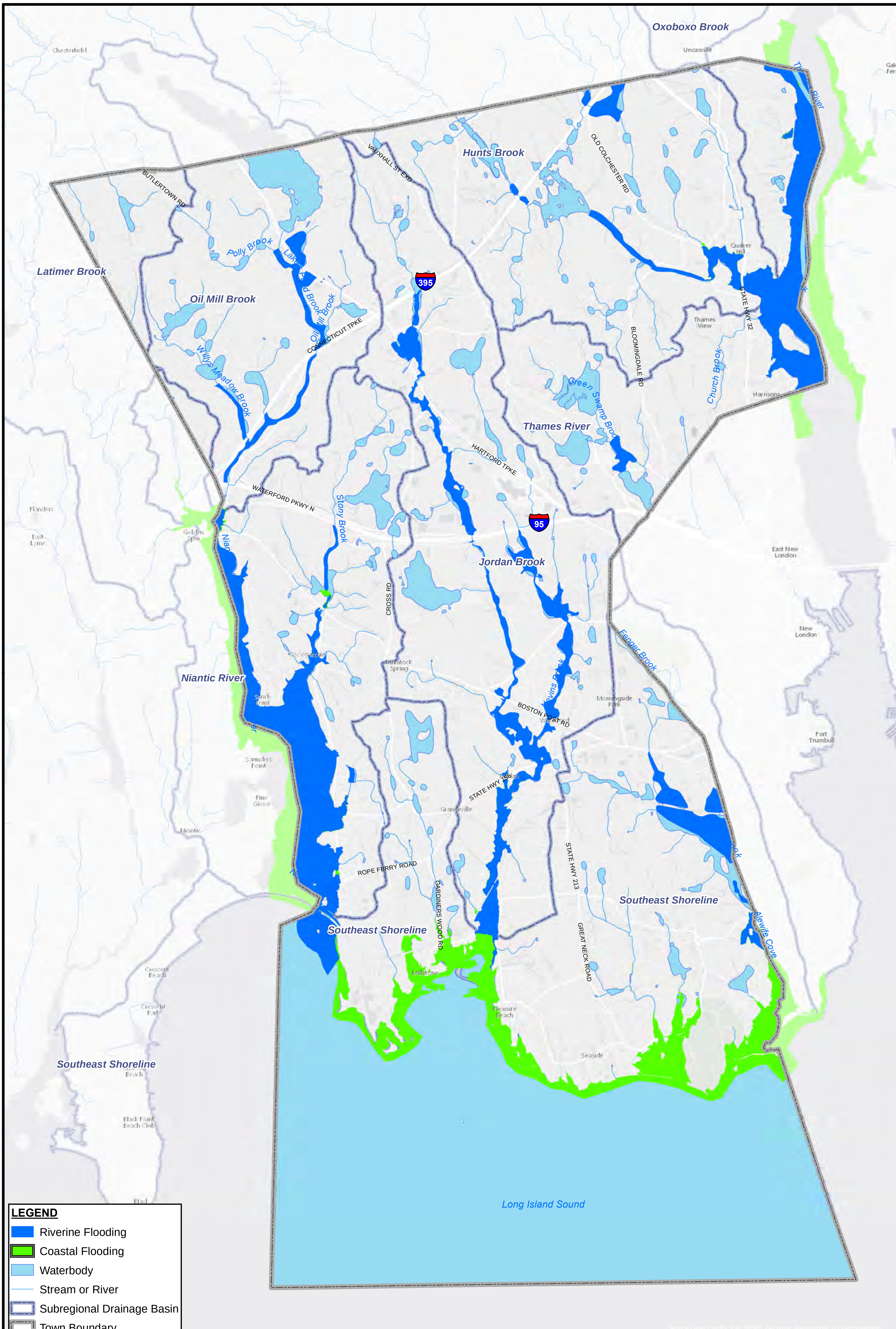
HUD, through the Connecticut Department of Housing, provides flexible grants to help cities and states recover from Presidentially-declared disasters, especially in low income areas. Funding under this highly-competitive program can only be applied for and received after a disaster, so this grant opportunity is not available to fund projects pro-actively in advance of a storm.

Natural Resources Conservation Service (NRCS)

Emergency Watershed Protection Program (EWP)

The EWP program is designed to help people and conserve natural resources by relieving imminent hazards to life and property caused by floods, fires, windstorms and other natural occurrences. EWP is an emergency recovery program. Allowable activities include: removing debris from stream channels, road culverts and bridges; reshaping and protecting eroded banks; correcting damaged drainage facilities; and repairing levees and structures. NRCS may purchase EWP easements "in lieu of recovery" on any floodplain lands that have been impaired within the last 12 months or that have a history of repeated flooding (i.e. flooded at least two times during the past 10 years). If it is more cost effective, EWP – Floodplain Easement (FPE) can be used as an alternative to EWP. NRCS may bear up to 75% of the construction cost of emergency measures. The remaining 25% must come from local sources and can be in the form of cash or in-kind services. Funding under this highly-competitive program can only be applied for and received after a disaster, so this grant opportunity is not available to fund projects pro-actively in advance of a storm.

APPENDIX A
FLOOD MAPS



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Feet

Locations are approximate

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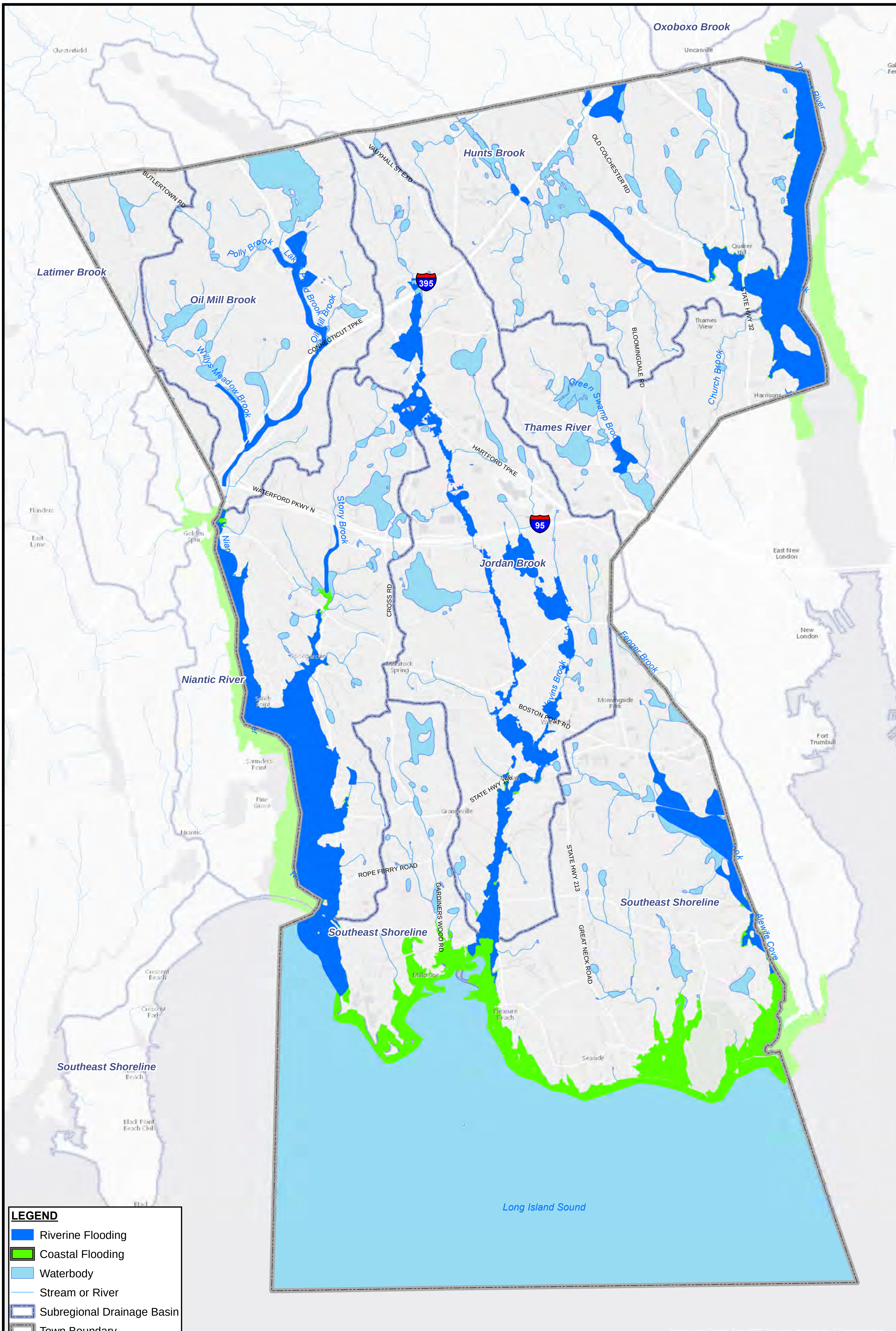
FLOODING EXTENTS
PRESENT

Climate Change Risk Assessment Study
Town of Waterford, CT

MAP

A1



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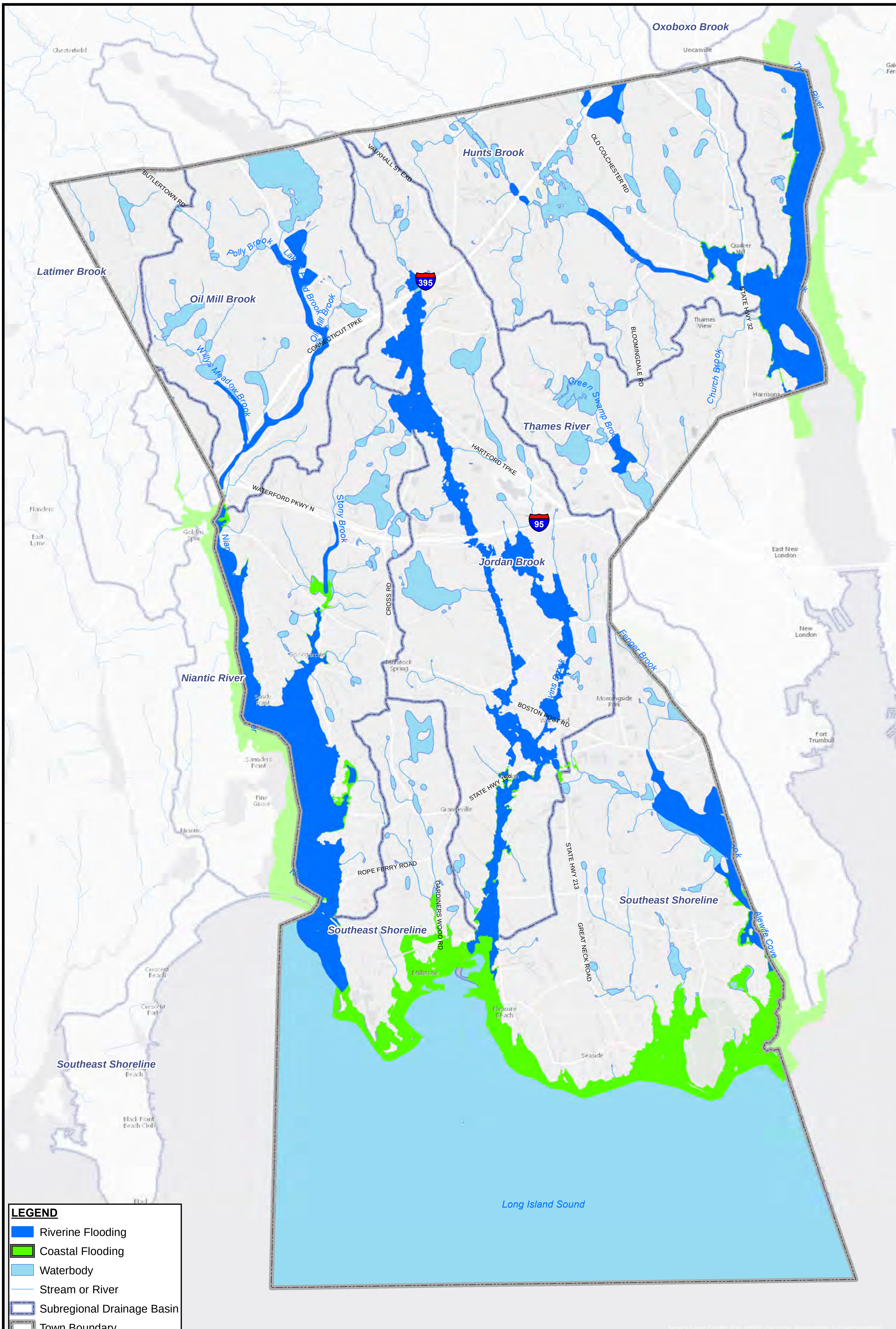
FLOODING EXTENTS 2030

Climate Change Risk Assessment Study
Town of Waterford, CT

MAP
A2



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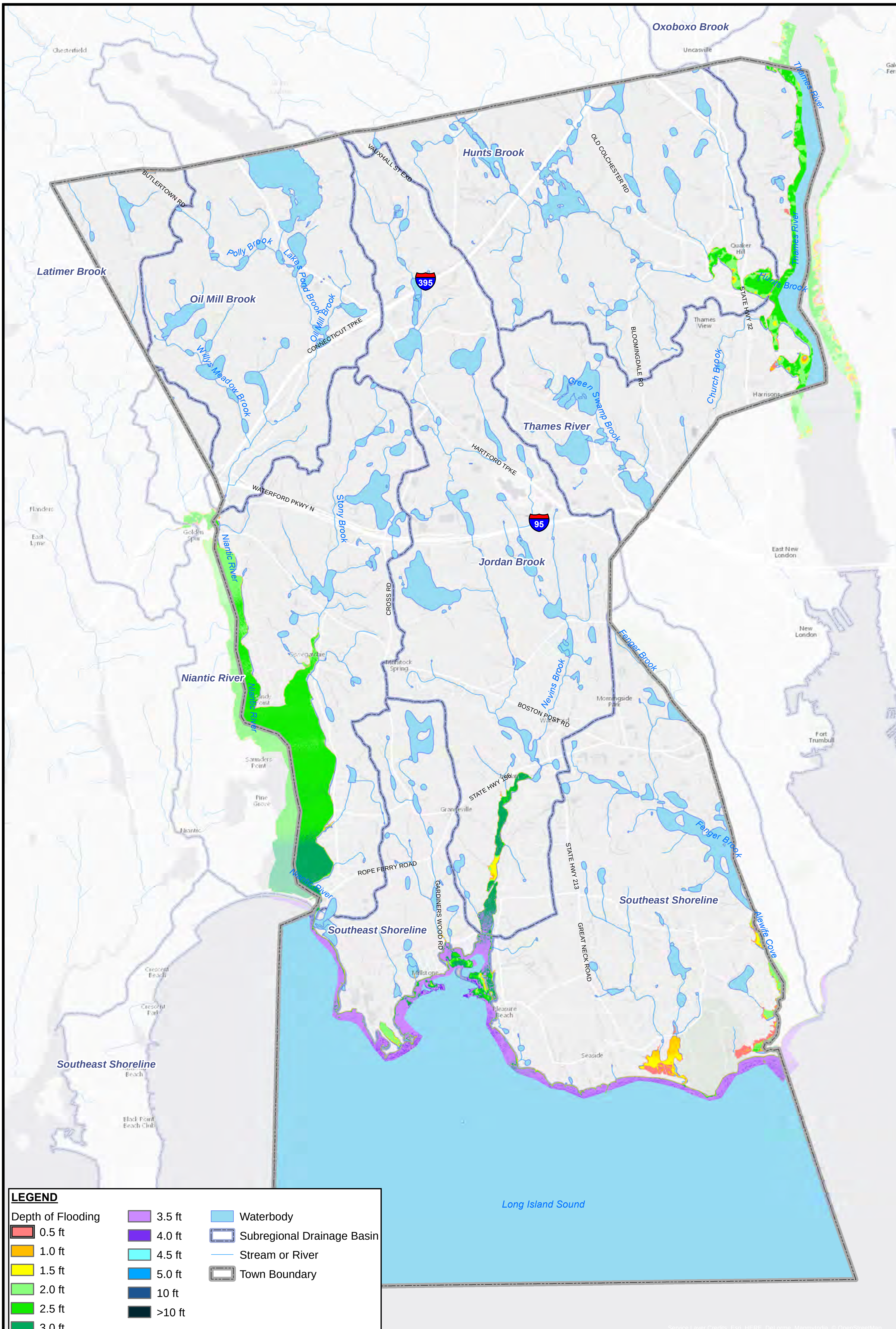
FLOODING EXTENTS
2070

Climate Change Risk Assessment Study
Town of Waterford, CT

MAP **A3**



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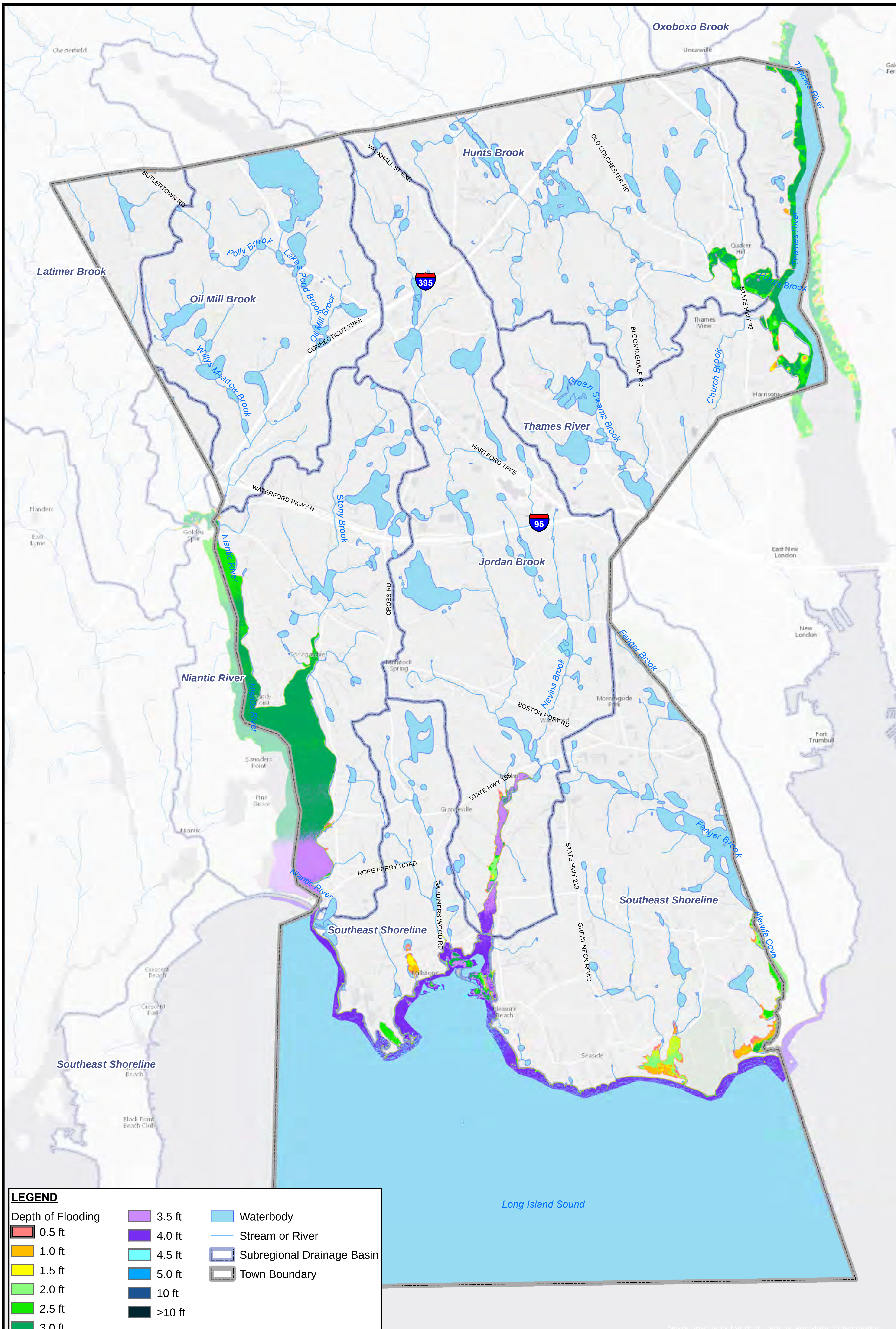
COASTAL FLOODING DEPTH MHHW - PRESENT

Climate Change Risk Assessment Study
Town of Waterford, CT

MAP
A4



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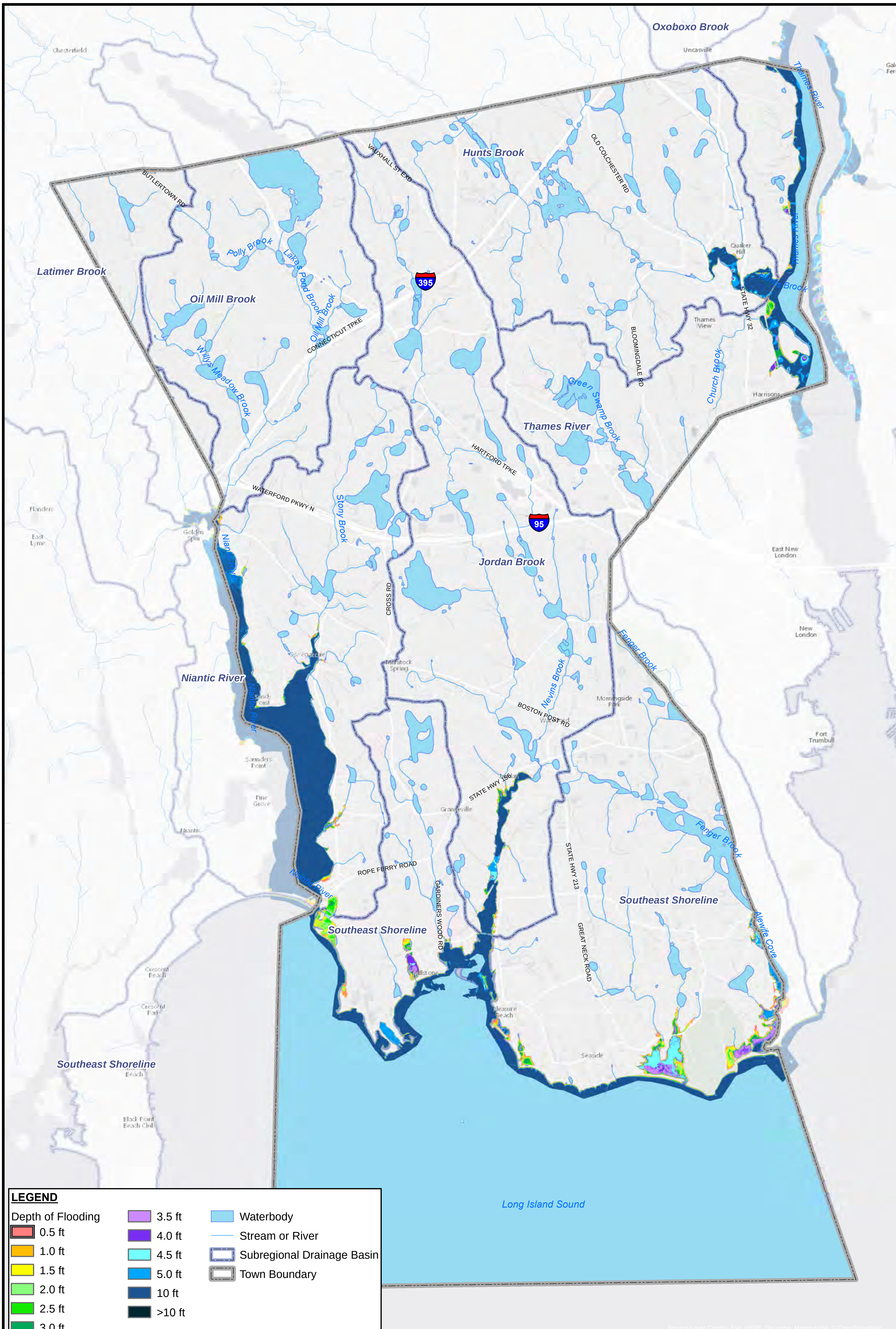
COASTAL FLOODING DEPTH MHHW - 2030

Climate Change Risk Assessment Study
Town of Waterford, CT

MAP
A5



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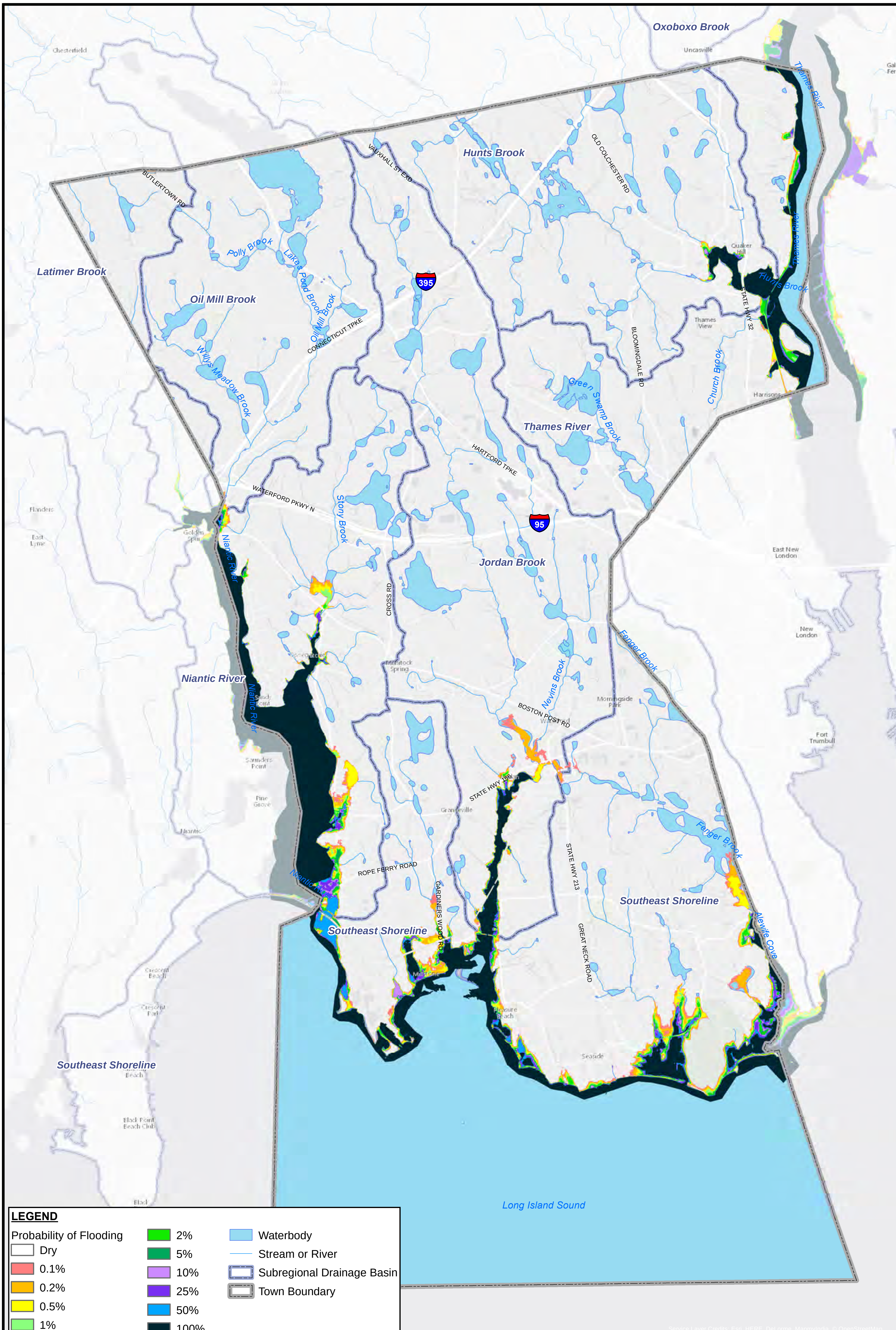
COASTAL FLOODING DEPTH MHHW - 2070

Climate Change Risk Assessment Study
Town of Waterford, CT

MAP

A6



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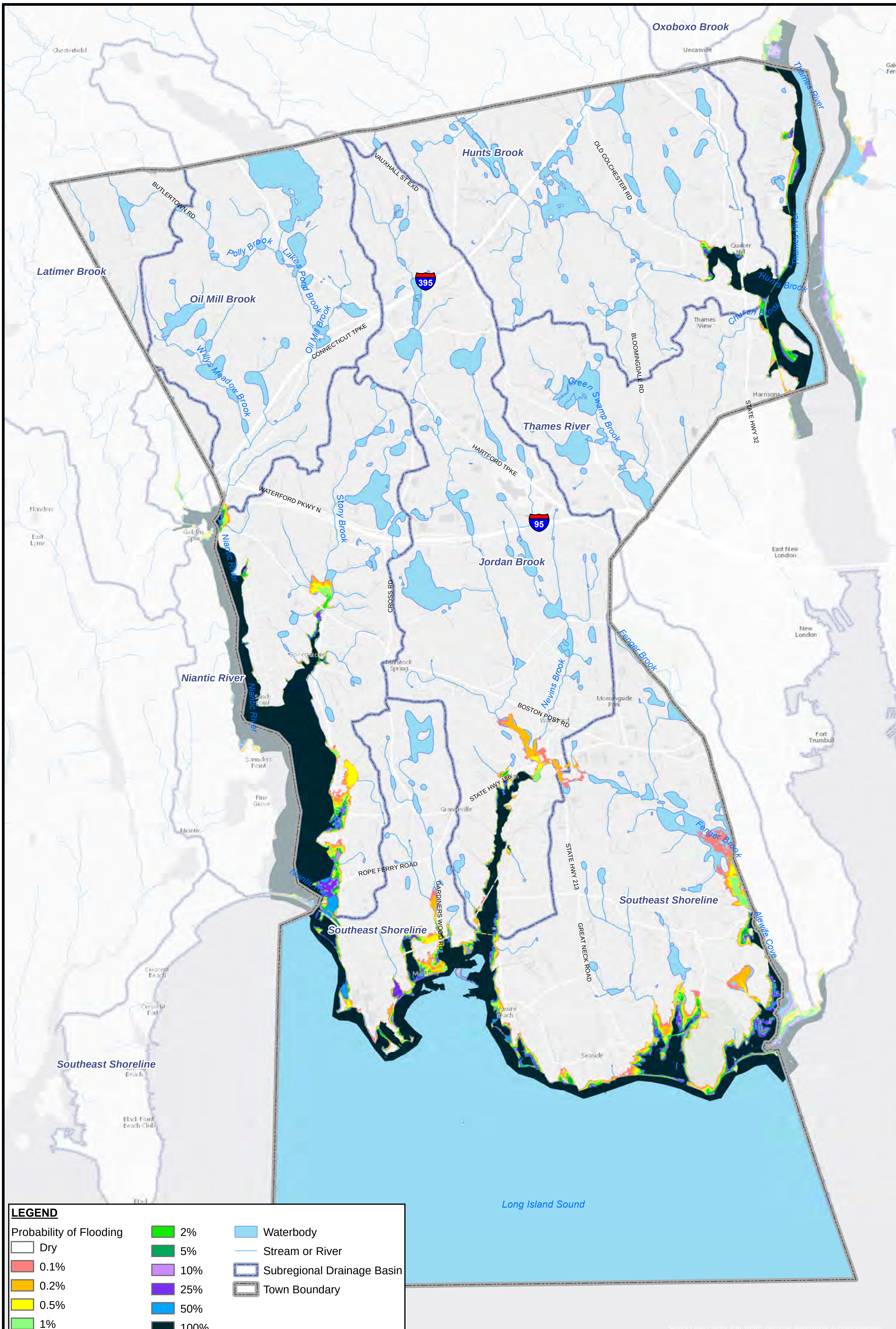
COASTAL FLOODING PROBABILITY - PRESENT

Climate Change Risk Assessment Study
Town of Waterford, CT

MAP
A7



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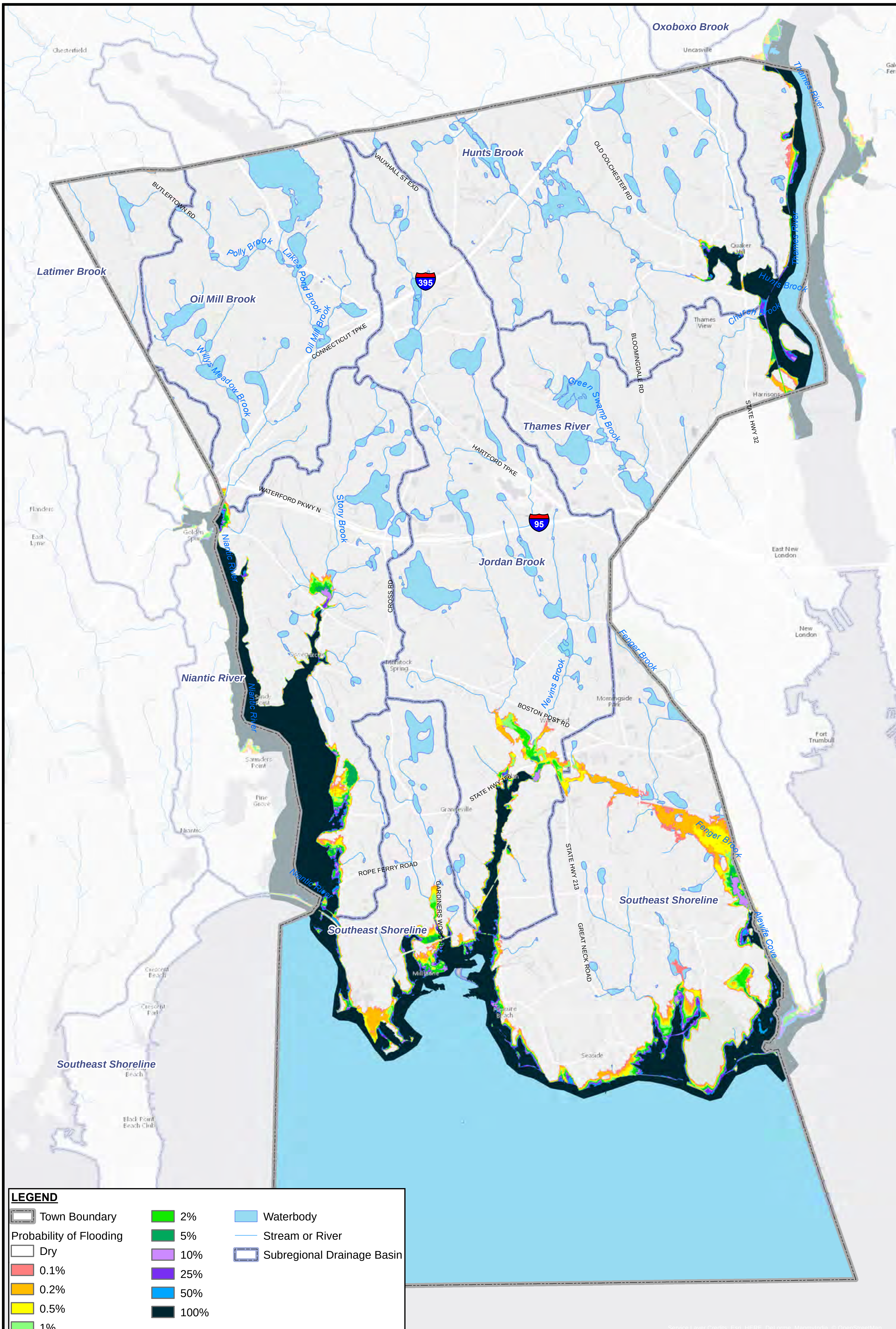
COASTAL FLOODING PROBABILITY - 2030

Climate Change Risk Assessment Study
Town of Waterford, CT

MAP
A8



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Feet
Locations are approximate

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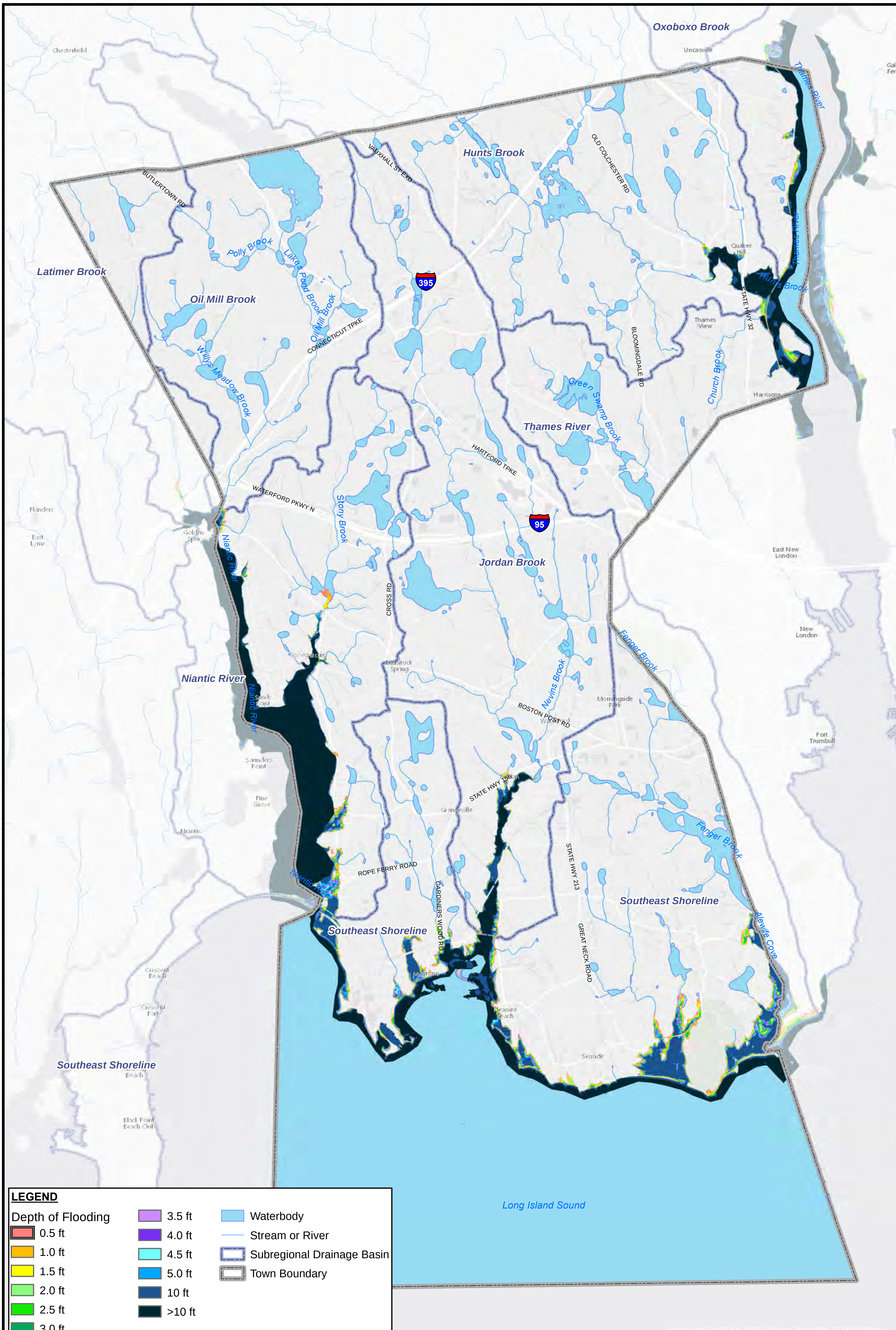
PROJECT NO.	20172200
DRAWN:	02/01/2017
DRAWN BY:	KFH
CHECKED BY:	IG
FILE NAME:	Probability_2070.mxd

COASTAL FLOODING PROBABILITY - 2070

Climate Change Risk Assessment Study
Town of Waterford, CT

MAP
A9



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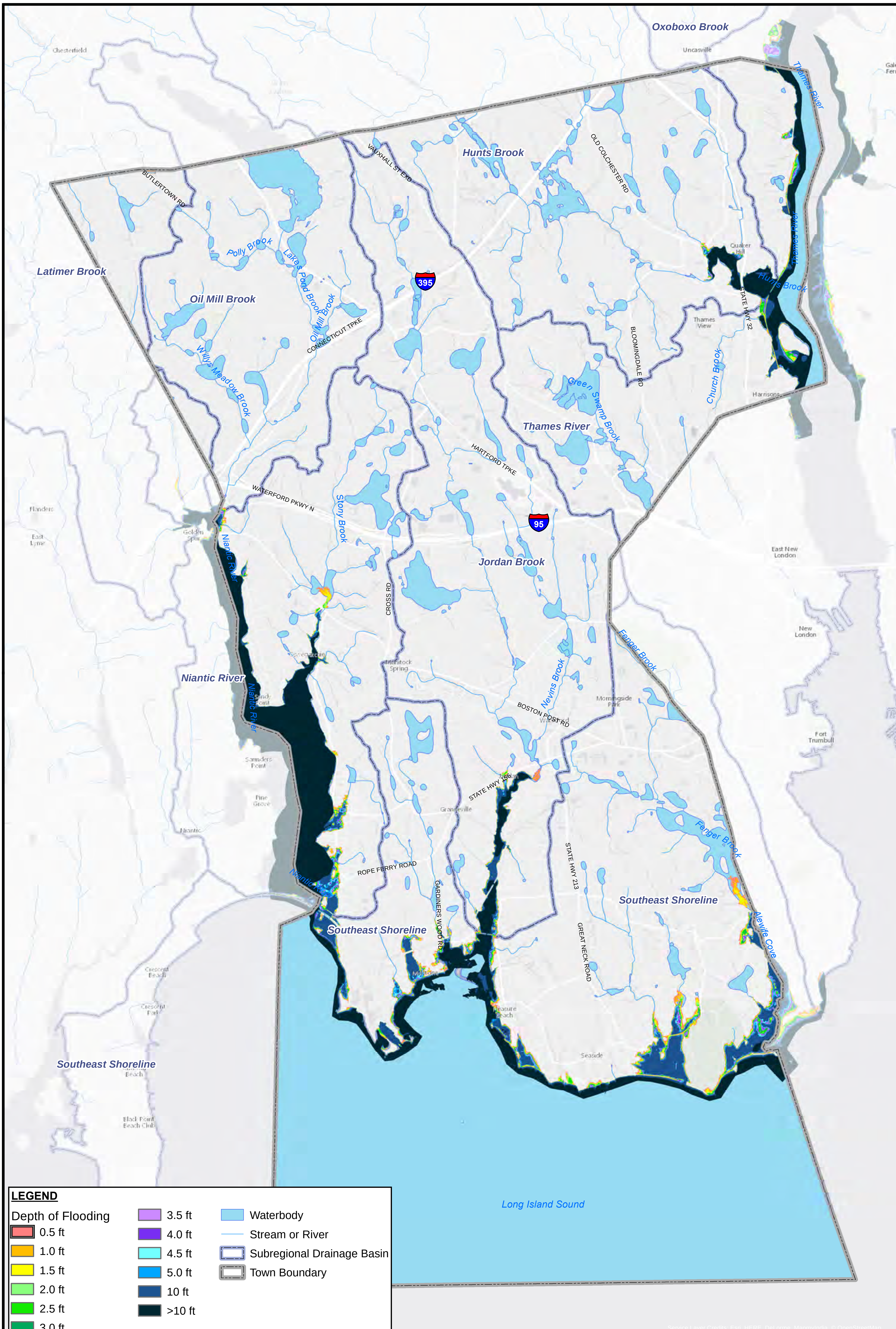
PROJECT NO.	20172200
DRAWN:	02/01/2017
DRAWN BY:	KFH
CHECKED BY:	IG
FILE NAME:	Depth1Pct_present.mxd

COASTAL FLOODING
DEPTH 1% - PRESENT

Climate Change Risk Assessment Study
Town of Waterford, CT

MAP
A10



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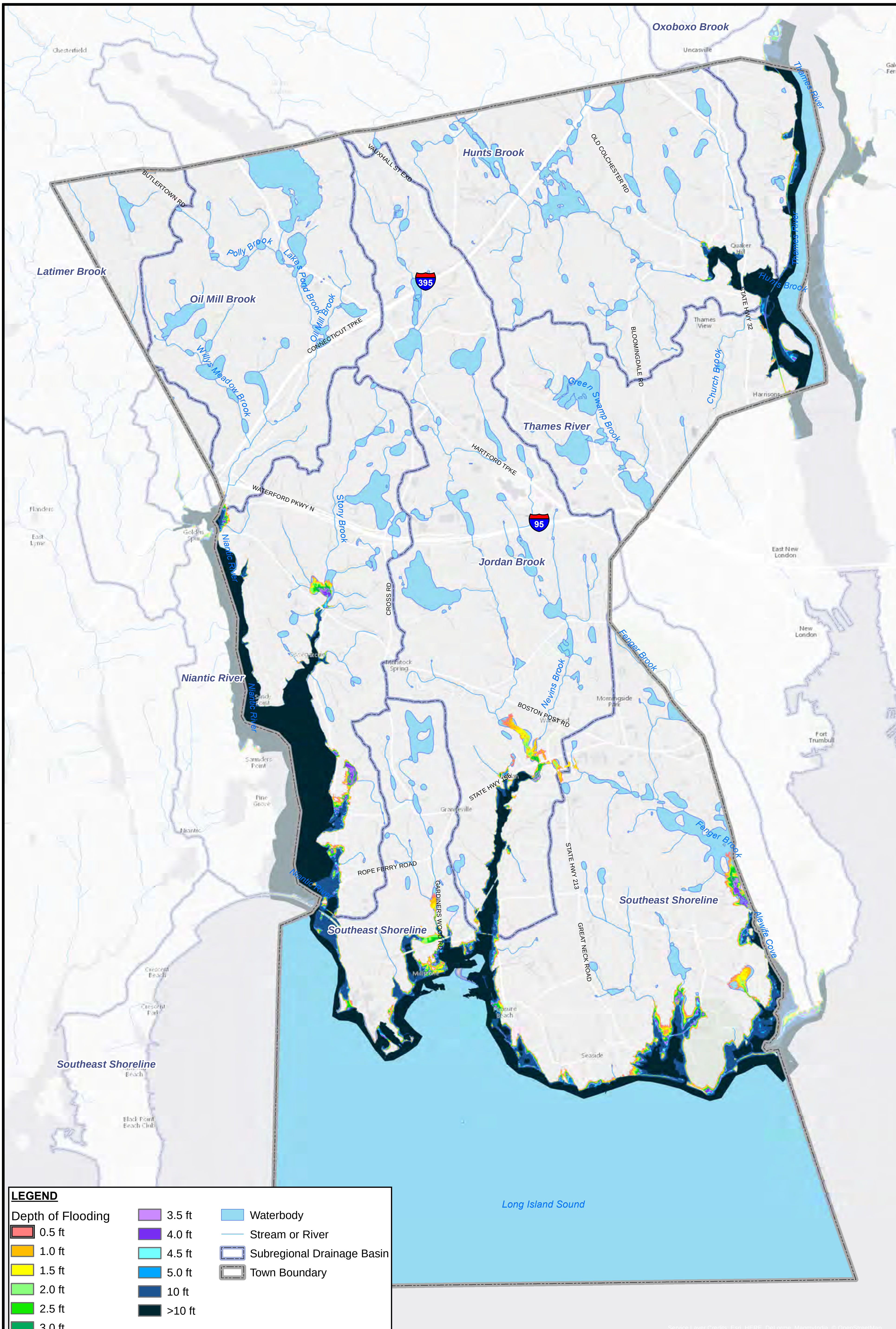
PROJECT NO.	20172200
DRAWN:	02/01/2017
DRAWN BY:	KFH
CHECKED BY:	IG
FILE NAME:	Depth1Pct_2030.mxd

COASTAL FLOODING DEPTH 1% - 2030

Climate Change Risk Assessment Study
Town of Waterford, CT

MAP

A11



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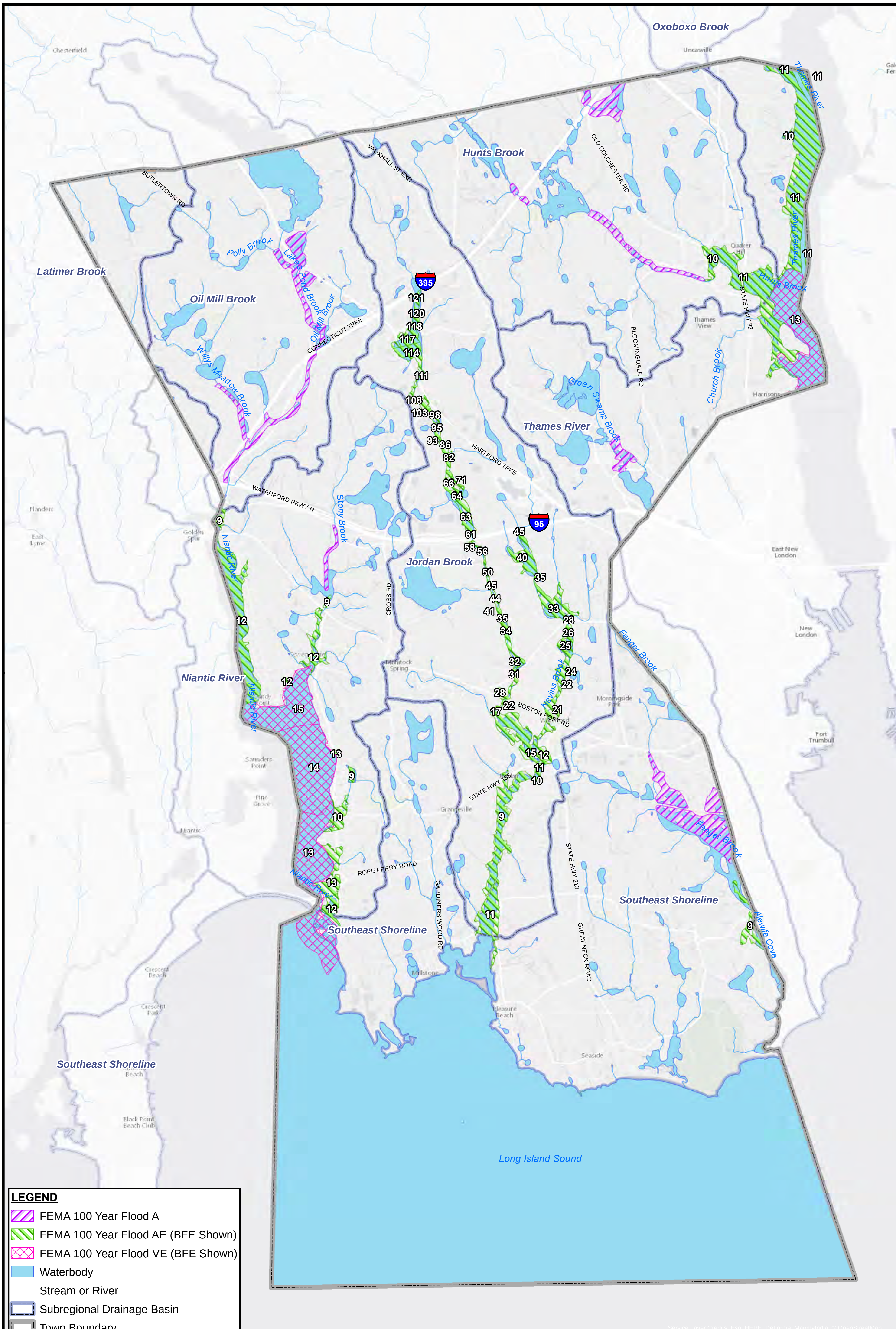
PROJECT NO.	20172200
DRAWN:	02/01/2017
DRAWN BY:	KFH
CHECKED BY:	IG
FILE NAME:	Depth1Pct_2070.mxd

COASTAL FLOODING DEPTH 1% - 2070

Climate Change Risk Assessment Study
Town of Waterford, CT

MAP
A12



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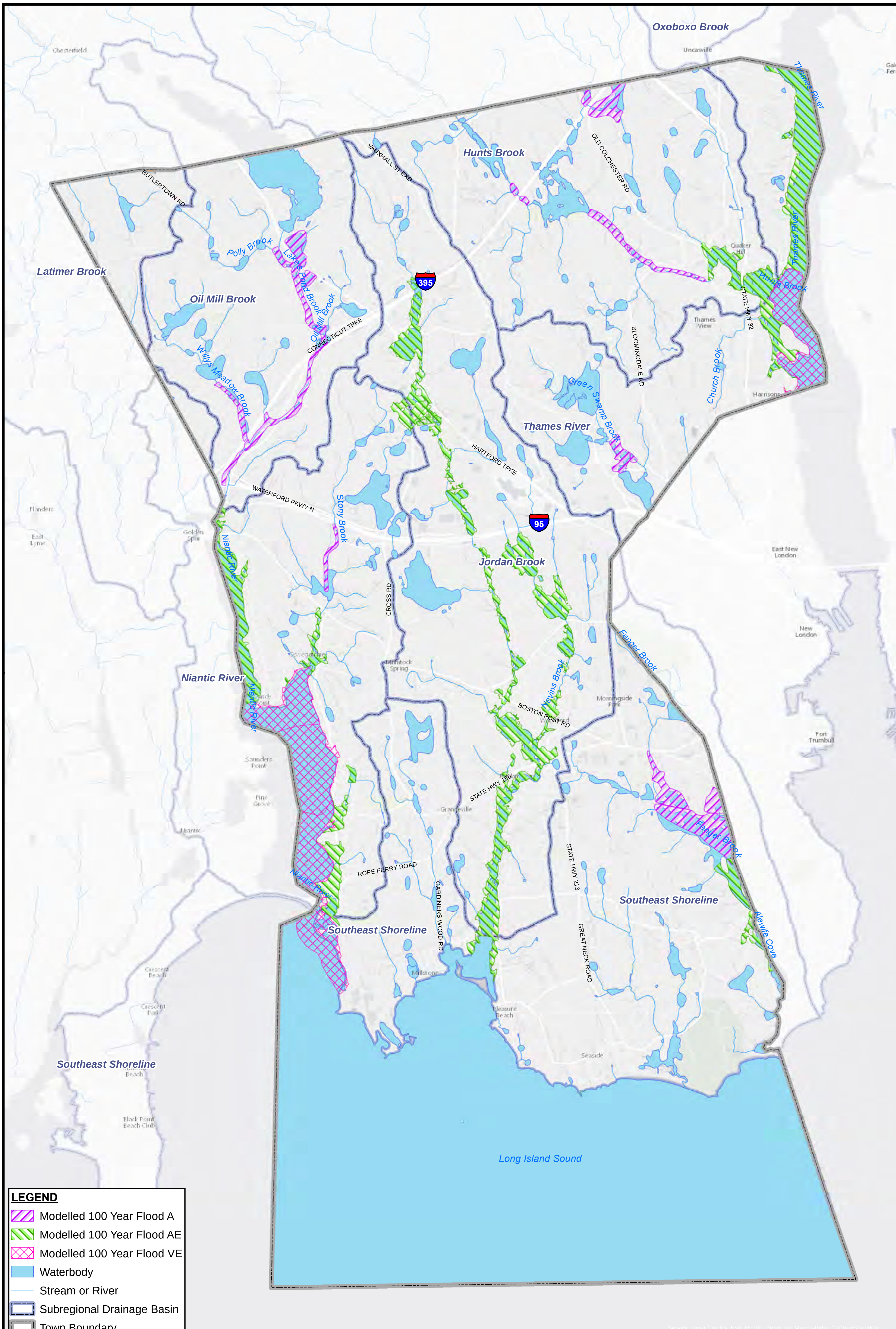
PROJECT NO.	20172200
DRAWN:	02/01/2017
DRAWN BY:	KFH
CHECKED BY:	IG
FILE NAME:	Riverine_present.mxd

RIVERINE FLOODING PRESENT

Climate Change Risk Assessment Study
Town of Waterford, CT

MAP
A13



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Locations are approximate

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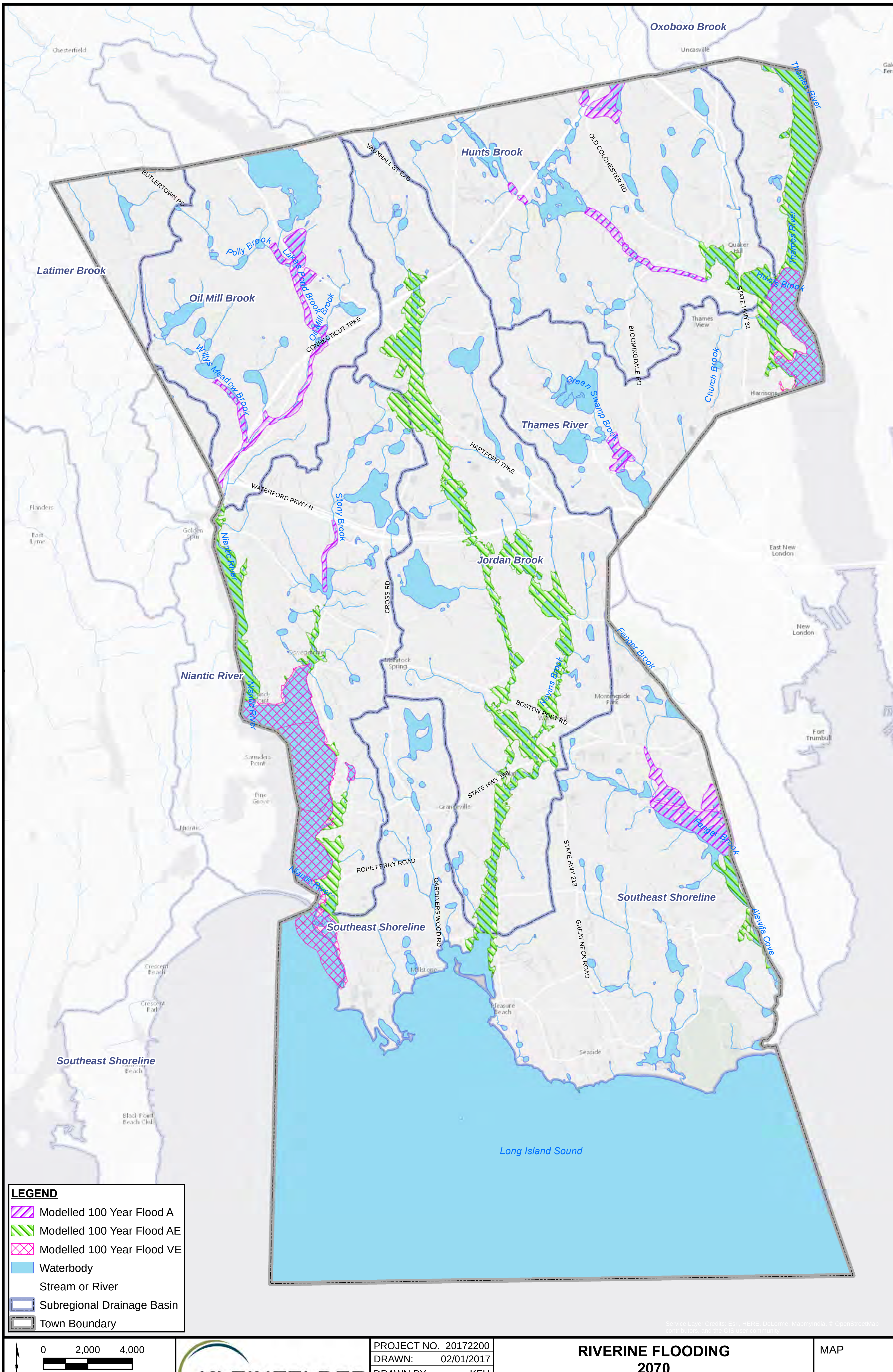
PROJECT NO.	20172200
DRAWN:	02/01/2017
DRAWN BY:	KFH
CHECKED BY:	IG
FILE NAME:	Riverine_2030.mxd

RIVERINE FLOODING
2030

Climate Change Risk Assessment Study
Town of Waterford, CT

MAP
A14



Locations are approximate

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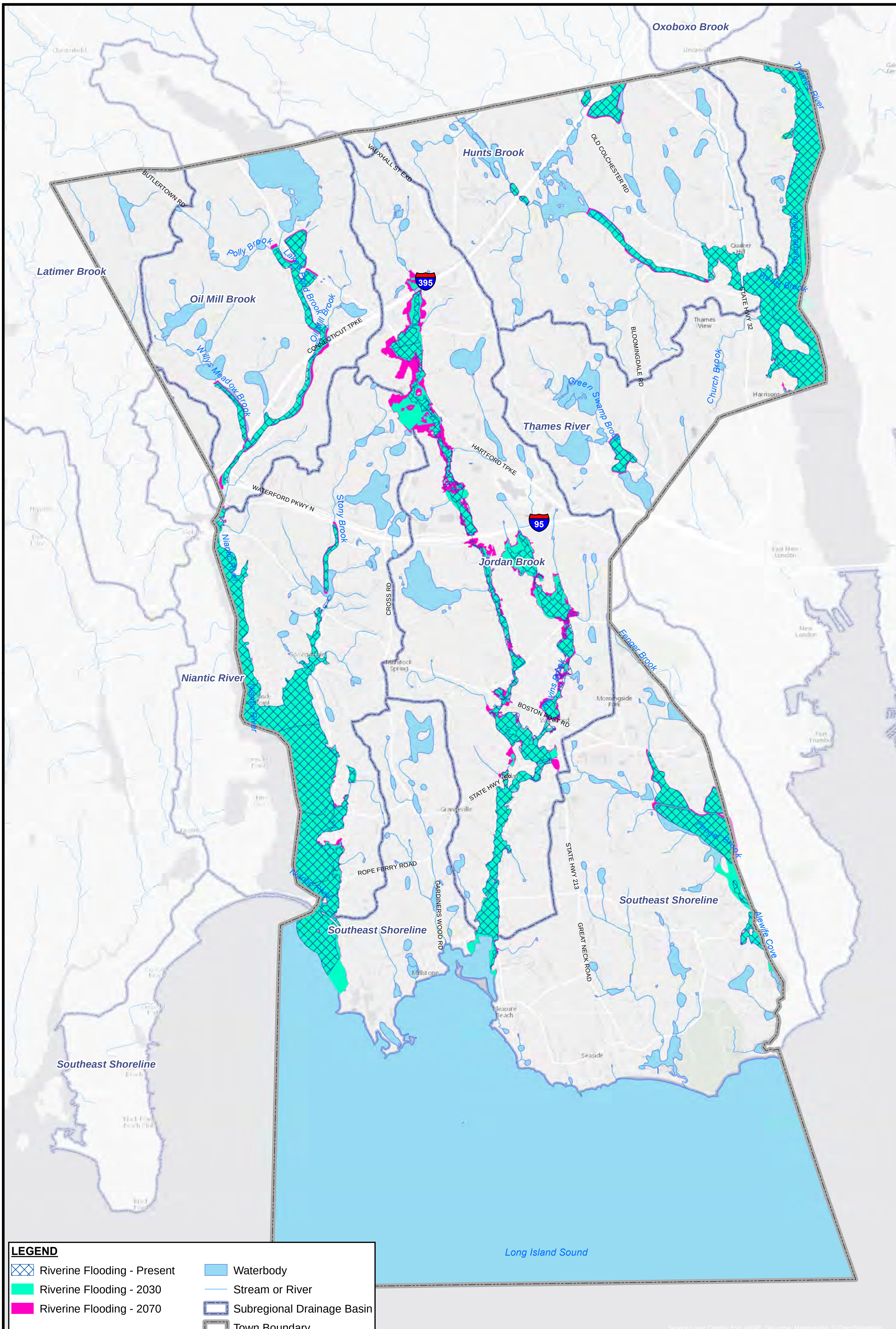
PROJECT NO.	20172200
DRAWN:	02/01/2017
DRAWN BY:	KFH
CHECKED BY:	IG
FILE NAME:	Riverine_2070.mxd

RIVERINE FLOODING 2070

Climate Change Risk Assessment Study
Town of Waterford, CT

MAP
A15



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Feet
Locations are approximate

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PROJECT NO.	20172200
DRAWN:	02/01/2017
DRAWN BY:	KFH
CHECKED BY:	IG
FILE NAME:	Riverine_comparison.mxd

RIVERINE FLOODING COMPARISON - PRESENT, 2030, 2070

Climate Change Risk Study
Town of Waterford, Connecticut

MAP
A16

APPENDIX B

LIST OF ROADWAYS VULNERABLE TO FLOODING

APPENDIX B

A. VULNERABLE ROADWAYS

Name	Type	Coastal (≥0.1% Probability)			Riverine (1% Probability)		
		Present	2030	2070	Present	2030	2070
I- 395	I						
I- 95	I						
Waterford Pkwy N	I						
Waterford Pkwy S	I						
E Neck Rd	S						
Boston Post Rd	S						
Connecticut Tpke	S						
Great Neck Rd	S						
Hartford Tpke	S						
Rope Ferry Rd	S						
Mohegan Ave	S						
1st Ave	M						
1st St	M						
2nd Ave	M						
2nd St	M						
3rd Ave	M						
4th Ave	M						
4th St	M						
5th Ave	M						
6th Ave	M						
7th Ave	M						
8th Ave	M						
9th Ave	M						
10th Ave	M						
Ave A	M						
Ave B	M						
Avery Ln	M						
B Ln	M						
Back St	M						
Baldwin Dr	M						
Bayside Ave	M						
Beach St	M						
Beach Rd	M						

Colors indicate the time horizon of vulnerability: = Present = 2030 = 2070

		Coastal (≥0.1% Probability)			Riverine (1% Probability)		
Name	Type	Present	2030	2070	Present	2030	2070
Bella Vista Dr	M						
Benham Ave	M						
Birch St	M						
Bishop St	M						
Bloomingdale Rd	M						
Bolles Ct	M						
Brook St	M						
Circle St	M						
Cliff St	M						
Chapman Ave	M						
Cross Rd	M						
Daniels Ave	M						
Dimmock Rd	M						
Division St	M						
Dock Rd	M						
Donna St	M						
Douglas Ln	M						
E Bishop St	M						
E Brook Dr	M						
E Wharf Rd	M						
E Wood St	M						
Ellen Ward Rd	M						
Evergreen Ave	M						
Fog Plain Rd	M						
Forest St	M						
Gardiners Wood Rd	M						
Glenwood Ave	M						
Glenwood Rd	M						
Greenfield St	M						
Gun Shot Rd	M						
Gurley Rd	M						
Highland Ave	M						
Highway Pt	M						
James St	M						
Jordan Cove Cir	M						
Jordan Cove Rd	M						
Lanyard Ln	M						

Colors indicate the time horizon of vulnerability: = Present = 2030 = 2070

Name	Type	Coastal (≥0.1% Probability)			Riverine (1% Probability)		
		Present	2030	2070	Present	2030	2070
Laurel St	M	■	■	■			
Logger Hill Rd	M			■			
Lower Bartlett Rd	M			■			
Mago Blvd	M			■			
Mill Ln	M			■			
Millstone Rd W	M	■	■	■	■	■	■
New Shore Rd	M	■	■	■			
Niantic River Rd	M	■	■	■	■	■	■
Niles Hill Rd	M				■	■	■
North Rd	M						■
Oil Mill Rd	M	■	■	■	■	■	■
Old Colchester Rd	M	■	■	■	■	■	■
Old Great Neck Rd	M	■	■	■	■	■	■
Old Mill Rd	M				■	■	■
Old Norwich Rd	M	■	■	■	■	■	■
Oswegatchie Rd	M	■	■	■	■	■	■
Palmer Rd	M	■	■	■			
Parkway	M	■	■	■			
Peninsular Ave	M	■	■	■			
Quaker Ln	M	■	■	■	■	■	■
Reynolds Ln	M				■	■	■
Race Rock Rd	M	■	■	■			
Reed Ave	M	■	■	■			
Richards Grove Rd	M	■	■	■	■	■	■
Ridgewood Ave	M	■	■	■			
River St	M	■	■	■	■	■	■
School House Ln	M			■			
Scotch Cap Rd	M			■			
Sea Meadow Ln	M			■			
Shore Dr	M	■	■	■			
Shore Rd	M	■	■	■	■	■	■
Stoney Brook Dr	M			■			
Sunshine Rd	M	■	■	■	■	■	■
The Strand	M	■	■	■			
Valley St	M	■	■	■			
Wadington St	M	■	■	■	■	■	■
Wadsworth Ln	M	■	■	■	■	■	■

Colors indicate the time horizon of vulnerability: ■ = Present ■ = 2030 ■ = 2070

Name	Type	Coastal (≥0.1% Probability)			Riverine (1% Probability)		
		Present	2030	2070	Present	2030	2070
Way Hill Rd	M						
Westcot Rd	M						
Wilcox Ct	M						
Willow St	M						
Wilson Ave	M						
Windward Way	M						
Wood St	M						
Woodbine St	M						
Woodland Rd	M						
Woodlawn Ave	M						
Woodlawn Ct	M						
Woodworth Dr	M						
Yorkshire Dr	M						

Colors indicate the time horizon of vulnerability: = Present = 2030 = 2070

APPENDIX C

CITIZEN'S PARTICIPATION PLAN

TOWN OF WATERFORD, CONNECTICUT

CLIMATE CHANGE VULNERABILITY, RISK ASSESSMENT AND ADAPTATION PLAN

COMMUNITY DEVELOPMENT BLOCK GRANT – DISASTER RECOVERY PROJECT

CITIZEN PARTICIPATION PLAN

The Town of Waterford has adopted the following Citizen Participation Plan to provide a framework for citizen participation in the planning and implementation of the Town's Climate Change Vulnerability, Risk Assessment and Adaptation Plan (the Project). The Project is being implemented by the Town of Waterford Planning Department and coordinated through a Project Working Group, with financial support provided by the Community Development Block Grant – Disaster Recovery (CDBG-DR) Program. The CDBG-DR Program is administered by the State of Connecticut Department of Housing on behalf of the US Department of Housing and Urban Development.

The Citizen Participation Plan sets forth the Town of Waterford's policies and procedures to accomplish the following objectives:

1) Provide for and encourage citizen participation, with particular emphasis on participation by persons of low and moderate income who reside in areas that are potentially exposed to flooding impacts;

2) Provide citizens with reasonable and timely access to local meetings, information, and records relating to the Project;

3) Provide for a minimum of two (2) public meetings to share Project information, obtain citizen views, and respond to questions at all stages of the Project process; these meetings shall be held after adequate notice, at times and locations convenient to potential or actual beneficiaries, and with accommodations for persons with disabilities;

4) Identify how the needs of non-English speaking citizens will be met in the case of the public meeting where a significant number of non-English speaking citizens can be reasonably expected to participate;

5) Provide citizens with reasonable time prior to the finalization of the Project to submit comments; and identify how the Town of Waterford will give opportunity so that affected citizens will have sufficient opportunity to review and provide comments;

6) Provide technical assistance to groups representative of persons of low and moderate income that may request assistance to participate in the Project;

7) Provide for a timely written answer to complaints and grievances, within 15 working days where practical; and

8) Provide citizens with reasonable notice of, and opportunity to comment on, any proposed amendments to the Project scope.

I. PARTICIPATION

The Town will provide for and encourage citizen participation, particularly by low- and moderate-income persons who reside in areas that are potentially exposed to flooding impacts, by:

1) Providing timely public notice of Project activities by advertising in The Day, by posting at Waterford Town Hall, Community Center and Library, and by posting on the Town of Waterford website “Upcoming Events” calendar.
2) Carrying out special outreach in areas potentially exposed to flooding impacts and through community organizations including Waterford Senior Services, Youth Services and Waterford Public Schools.
3) Whenever possible, holding Project public meetings within or near areas potentially exposed to flooding impacts, affording participation by the most affected residents.

II. ACCESS TO MEETINGS, INFORMATION, AND RECORDS

The Town will ensure that citizens will be given reasonable and timely access to local meetings, information, and records relating to the Project. Such documents may include the following:

1) All meetings and promotional materials;
2) Records of meetings;
3) All key documents, including prior applications, letters, grant agreements, citizen participation plans, and proposed applications;
4) Copies of the regulations (final statements) concerning the program; and,
5) Documents regarding other important requirements, such as Procurement Procedures, Fair Housing, Equal Employment Opportunity, Uniform Act, Labor Provisions, and Environmental Procedures.

Citizens will be afforded timely and adequate notice of any public meetings regarding the Project through notices that will be published at least seven (7) days prior to each public meeting in The Day; and by posting at Waterford Town Hall, Library, Community Center, and Youth Services; and by posting on the Town of Waterford website “Upcoming Events” calendar.

Records and information pertaining to the Project may be obtained at the Planning and Development Department offices, 15 Rope Ferry Road, Waterford, Connecticut 06385 (Telephone: 860-444-5813) during normal business hours (8:00 am to 4:00 pm, Monday through Friday). Records and Information may also be obtained via the Town’s Planning and Development webpage: http://www.waterfordct.org/planning-development

III. PUBLIC MEETINGS

The Town will provide for a minimum of two (2) Project public meetings to share Project information, obtain citizen views, and respond to proposal and questions at all stages of the Project process. These meetings will address the parameters to be investigated in the project, the vulnerabilities to flooding that have been identified, and the potential strategies proposed to reduce such vulnerabilities. There will be reasonable notice of all meetings, which will be scheduled for times and locations convenient to the potential and actual beneficiaries and which will accommodate persons with disabilities. Accessibility for persons with disabilities will be considered in the selection of meeting sites.

In order to inform the public and obtain citizens' views on the Project goals, scope, schedule, and proposed Citizen Participation Plan, a presentation will be made during a public meeting of the Board of Selectmen on October 31, 2016. The meeting will be held in a formal Board of Selectmen meeting, regularly held at 5:00 on the first and third Tuesdays of each month at Waterford Town Hall. Additional presentations may be made during other regularly scheduled public meetings of various Town Boards and Commissions. Public participation will be encouraged at these meetings.

The first Project public meeting will be held at the end of the Vulnerability Assessment phase. This meeting will focus on familiarizing members of the public with the project goals, scope, and schedule; reviewing climate change parameters and flood modeling results; identifying vulnerable critical municipal infrastructure and natural resources within areas subject to flooding; seeking public feedback; and initiating preliminary discussions on opportunities to reduce vulnerabilities.

A second Project public meeting will be held at the end of the Adaptation Strategies phase. This meeting will focus on reviewing proposed adaptation strategies for vulnerable municipal infrastructure and natural resources; reviewing proposed regulatory changes; seeking public feedback; sharing educational materials developed by the Project; and notifying the public of the public comment period for the Project Summary Report.

In order to give adequate notice of the public meetings listed above, notice will be published at least seven (7) days prior to each public meeting by advertising in The Day; by posting at Waterford Town Hall, Community Center, and Library; and by posting on the Town of Waterford website "Upcoming Events" calendar.

Written minutes of the meetings and an attendance roster will be maintained by the Town of Waterford.

IV. NEEDS OF NON-ENGLISH SPEAKING CITIZENS

According to the 2014 Census data, only a small percentage of the residents of the Town of Waterford speak English not well or not at all (estimated 5.8%). Therefore, at this time, no special arrangements are anticipated to accommodate non-English speaking residents at Project public meetings, as the numbers do not warrant it.

However, every effort will be made to accommodate the needs of any non-English speaking citizens who wish to participate in public meetings. The Town of Waterford requires that it be given sufficient notification of at least three (3) calendar day(s) prior to the meeting to address the request.

V. PUBLIC COMMENTS

In order to give adequate notice of the public comment period for the Project Summary Report – Draft for Public Comment, notice will be published at least seven (7) days prior the opening of the public comment period in The Day; by posting at Waterford Town Hall, Community Center, and Library; and by posting on the Town of Waterford website "Upcoming Events" calendar; informing the citizens of the following:

1) Proposed opening and closing date for the submittal of public comments on the Project Summary Report – Draft for Public Comment;
2) Overview of the project and Summary Report contents; and

3) Location and hours the document is available for review and comment.

In addition, the notice shall state "all citizens, particularly persons of low and moderate income and residents of areas potentially exposed to flooding as well as those affected by the proposed project, are encouraged to review the Project Summary Report – Draft for Public Comment and submit any written comments on the application to:"

Copies of the Project Summary Report – Draft for Public Comment will be available for review and comment at the Town of Waterford Planning and Development Department website www.waterfordct.org/planning-development and at Waterford Town Hall, 15 Rope Ferry Road, Waterford, Connecticut 06385, during normal business hours (8:00 am to 4:00 pm, Monday through Friday).

A reasonable number of free printed copies will be provided to groups that request it. Materials in a form accessible to persons with disabilities will be made available upon request.

The views of citizens, public agencies, and other interested parties will be considered in the preparation of the final Project Summary Report. A summary of these comments or views not accepted and the reasons therefore, shall be attached to the final Project Summary Report.

VI. TECHNICAL ASSISTANCE

Technical assistance will be provided, upon request, to citizens or groups representative of low-and moderate-income persons to participate in the Project.

The level and type of assistance to be provided is at the discretion of the Town of Waterford Board of Selectmen and does not necessarily include providing funding to such groups.

Local officials will conduct informational meetings with the residents of the low to moderate income areas if a written request is received by the Town of Waterford with at least a one (1) week notification. The persons who conduct the technical assistance meetings will disseminate information on the program and answer all pertinent questions.

VII. COMPLAINTS AND GRIEVANCES

Citizens may submit written comments concerning the Project to the Town of Waterford Department of Planning and Development, 15 Rope Ferry Road, Waterford, Connecticut 06385 (Telephone: 860-444-5813) during normal business hours (8:00 am to 4:00 pm, Monday through Friday). Response to the comments will be provided in writing by Department of Planning and Development staff and returned to the citizen within fifteen (15) working days, where practicable.

Citizens may submit written complaints and grievances concerning the Project to the Town of Waterford Board of Selectmen, 15 Rope Ferry Road, Waterford, Connecticut 06385 (Telephone: 860-444-5834) during normal business hours. Resolution of the complaints or grievances shall be determined by the First Selectmen and a written response returned to the citizen within 15 working days, where practicable.

It is the policy of the Town of Waterford to review all complaints received. The following procedures will be followed on all complaints received by the Town of Waterford relative to this project:

1) The complainant shall notify the Planning Director of the complaint. The initial complaint may be expressed orally or by written correspondence.
2) The Planning Director will notify the First Selectman of the complaint within three (3) working days.
3) The Planning Director will investigate the complaint and will report the findings to the First Selectman within five (5) working days.
4) The Planning Director will notify the complainant of the findings in writing or by telephone within five (5) working days.

If the complainant is aggrieved by the decision, he or she may forward the complaint in writing (if previously submitted orally) to the First Selectman. **VIII. AMENDMENTS**

Project scope amendments, which substantially alter the Project from that approved in the original application, shall not be submitted to the State without publication of notice in the official newspaper, if applicable, or in a newspaper having general circulation within the municipality, informing citizens of the following:

1) Proposed submittal date of the amendment;
2) Proposed objectives;
3) Proposed activities;
4) Location of proposed activities;
5) Dollar amount of proposed activities; and
6) Location and hours the application is available for review and comment.

In addition, the notice shall state "all citizens, particularly persons of low and moderate income and residents of slum and blighted areas as well as those affected by the proposed project, are encouraged to review the proposed application and submit any written comments on the application to: Town of Waterford, Planning and Development Department, 15 Rope Ferry Road, Waterford, CT 06385."

No less than seven (7) days will be provided for review and comment on proposed Substantial Amendments. Comments will be accepted electronically or in writing. Any comments received including the responses will be submitted with the request for the amendment.

Citizens may, at any time, contact DOH directly to register comments, objections, or complaints concerning the subrecipient's CDBG-DR application(s), amendment(s), and/or performance. Citizens are encouraged, however, to attempt to resolve any complaints at the local level as outlined above prior to contacting DOH.

Persons wishing to object to approval of an application or amendment by the State may make such objection known via email to CT.Housing.Plans@ct.gove or be mailed to:

Program Coordinator
CDBG-DR Program
Department of Housing
505 Hudson Street
Hartford, CT 06106-7106

APPENDIX D
PUBLIC COMMENTS AND RESPONSES

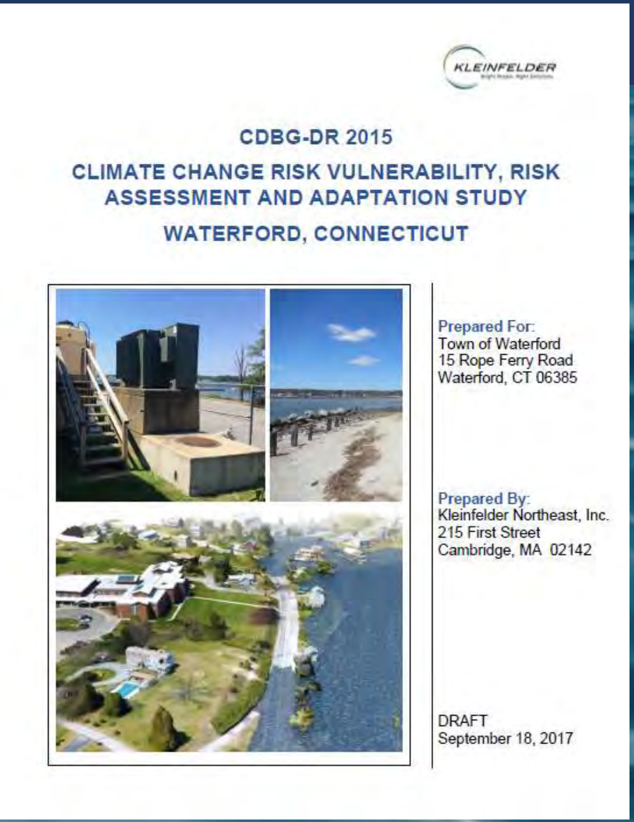
Town of Waterford, CT

Municipal Resilience Project

AN INVITATION FOR PUBLIC COMMENT

The Town of Waterford Planning and Development Department seeks public comments on the draft *"Climate Change Risk Vulnerability, Risk Assessment and Adaptation Study,"* which is available for review at the Waterford Town Hall Planning Department (8:00am to 4:00 pm), Community Center, Library and online at www.waterfordct.org/planning-development.

All citizens, particularly persons of low and moderate income and residents of areas potentially exposed to flooding as well as those affected by the proposed project, are encouraged to review the Draft Study and submit any written comments to Abby Piersall, Planning Director (apiersall@waterfordct.org no later than October 12, 2017. If you have any questions, please call Abby Piersall at 860-444-5813.


KLEINFELDER

CDBG-DR 2015

CLIMATE CHANGE RISK VULNERABILITY, RISK ASSESSMENT AND ADAPTATION STUDY

WATERFORD, CONNECTICUT

Prepared For:
Town of Waterford
15 Rope Ferry Road
Waterford, CT 06385

Prepared By:
Kleinfelder Northeast, Inc.
215 First Street
Cambridge, MA 02142

DRAFT
September 18, 2017