Riverside Drive/Ash Creek Resilience Study

Fairfield, Connecticut

June 2017

Revised September 2017

MILONE & MACBROOM®

Engineering | Planning | Landscape Architecture | Environmental Science

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Fairfield, Connecticut
June 2017
Revised September 2017

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ACRONYMS

ADCIRC	Advanced Circulation
ASCE	American Society of Civil Engineers
ASFPM	Association of State Floodplain Managers
BFE	Base Flood Elevation
CDBG-DR	Community Development Block Grant – Disaster Recovery Program
CGS	Connecticut General Statutes
CIRCA	Connecticut Institute for Resilience and Climate Adaptation
CISA	Climate Informed Science Approach
CJL	Coastal Jurisdiction Line
CRS	Community Rating System
CSPR	Coastal Site Plan Review
CTDEEP	Connecticut Department of Energy & Environmental Protection
CWA	Clean Water Act
CZM	Coastal Zone Management
DEM	Digital Elevation Model
DOH	State Department of Housing
EO	Executive Order
EPA	Environmental Protection Agency
FECB	Flood & Erosion Control Board
FEMA	Federal Emergency Management Agency
FFRMS	Federal Flood Risk Management Standard
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FVA	Freeboard Value Approach
GIS	Geographic Information System
HUD	U.S. Department of Housing and Urban Development
IP	Individual Permit
IPCC	Intergovernmental Panel on Climate Change
LiDAR	Light Detection and Ranging
LIMWA	Limit of Moderate Wave Action (zone)
LMSL	Local Mean Sea Level
LOMR	Letter of Map Revision
LWRD	Land and Water Resources Division
MHW	Mean High Water
MHHW	Mean Higher High Water
MetroCOG	Connecticut Metropolitan Council of Governments
MSL	Mean Sea Level
NACCS	North Atlantic Coast Comprehensive Study (USACE)
NDDB	Natural Diversity Data Base
NFIP	National Flood Insurance Program
NFPC	National Flood Proofing Committee
NFWF	National Fish and Wildlife Foundation
NOAA	National Oceanic and Atmospheric Administration
NWP	Nationwide Permit
PCN	Preconstruction Notification

PFA	Percent Floodplain Approach
SFHA	Special Flood Hazard Area
SHPO	State Historic Preservation Office
SP	Special Permit
SRT	Self-Regulating Tide Gate
SV	Self-Verification
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey

Executive Summary

A broad coastal floodplain lies south of downtown Fairfield extending from the Pine Creek estuary to Ash Creek. Much of this floodplain is occupied by hundreds of residential properties located within the 1% annual chance flood zone as mapped by the Federal Emergency Management Agency (FEMA). The area located west of Ash Creek and north of Jennings Beach experienced flooding during Hurricane Sandy[1] in 2012 and Tropical Storm Irene in 2011. During Hurricane Sandy, the storm surge reportedly washed over the west bank of Ash Creek, overtopping the lower areas among isolated locations of higher ground and traveling upstream along Turney Creek and Riverside Creek to flood adjacent lands. The storm surge also overtopped several sections of Fairfield Beach to the south of Jennings Beach and southwest of Penfield Beach although there were pockets of high ground, dunes, and coastal structures that dampened some of the flooding along Fairfield Beach. After Hurricane Sandy, floodwaters were trapped north of Jennings Beach in the South Benson Road area, leaving many people's homes inundated for extended periods of time.

The Town of Fairfield has taken steps to address flood risk. The town maintains a FEMA-approved hazard mitigation plan along with the other communities in the Metropolitan Council of Governments[2], and the Fairfield Flood and Erosion Control Board developed a Flood Mitigation Plan subsequent to storms Irene and Sandy. In addition, Fairfield has taken regulatory land use steps to reduce flood risk with a designated Flood Plain District Zone that limits development in the Pine Creek area and regulations that limit uses such as assisted living facilities and manufactured homes within any Special Flood Hazard Area (SFHA). The Flood Mitigation Plan envisions a comprehensive coastal flood protection system extending from Ash Creek to the Pine Creek tidal marshes, with individual components that can be pursued in phases, along with other flood mitigation actions such as a pumping station to remove floodwaters. Furthermore, the United States Army Corps of Engineers (USACE) has been evaluating components of a flood protection system for the area surrounding Pine Creek.

> The town has received grants to advance design and construction of individual projects, but the Riverside Drive/Ash Creek/Jennings Beach corridor remained a significant "unmet need." As an unmet need, this study was an ideal candidate for grant funding from the U.S. Department of Housing and Urban Development's (HUD) Community Development Block Grant Disaster Recovery Program (CDBG-DR). These CDBG-DR funds were allocated to Connecticut through the 2013 Disaster Relief Appropriations Act that followed Hurricane Sandy.

The goal for the Ash Creek/Riverside Drive/Jennings Beach study is identification of a comprehensive flood mitigation strategy that will reduce the risk of flooding to the west of Ash Creek. In the context of flood resiliency, reducing the frequency of flooding will directly reduce the flood risk. However, it is understood that flood frequency may be increasing because sea level is rising, causing a higher base level when storm surges occur. Therefore, the damage from rare storm surges will occur more frequently unless steps are taken to reduce flooding or flood damage.

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[1] Hurricane Sandy was the 18th named tropical cyclone of the 2012 Atlantic hurricane season. The storm transitioned into a post-tropical cyclone just prior to moving onshore near Atlantic City, but the term "Hurricane" is used in this report to preserve consistency with the terminology of the Disaster Appropriations resulting from Public Law 113-2.

[2] http://www.ctmetro.org/programs/environmental-programs/regional-natural-hazard-mitigation-program/#.WXsx92eWzcs

In the context of flood protection, the Town of Fairfield has two options for reducing risk in the study area. The town could pursue a moderate level of protection that would protect properties from the "next Hurricane Sandy" or a similar magnitude storm in the next few decades. This moderate level of protection would not position the town for pursuing a FEMA map revision, and property owners on the landward side of the flood protection system would need to maintain flood insurance as current practice. The top elevation of this moderate flood protection system may be in the range of 10 to 15 feet NAVD88. The second option is to pursue a higher level of protection that would make the system eligible for accreditation and allow the town to request a FEMA map revision. The top elevation of this higher flood protection system may be in the range of 15 to 18 feet NAVD88, or possibly higher. The town's flood protection system for the Water Pollution Control Facility (wastewater treatment plant) is likely within this higher range as is the proposed flood protection system for Staten Island, New York.

Three sets of flood protection systems were conceptually designed with top elevations of 12, 15, and 18 feet NAVD88 and associated preliminary grading to understand where impacts to private property, roadways, circulation, and public access to the shoreline would be affected. In general, the layout follows the alignment of Riverside Drive across Turney Creek to the bend in the road, then crosses Riverside Creek at the existing dike, turning west along town open space and then south through the marina, and then extending into Jennings Beach. The higher elevations require wider base widths for the flood protection system, consistent with USACE and FEMA design criteria for earthen systems.

Fortunately, most of the properties that would be directly affected by construction or grading are owned by the Town of Fairfield. Direct impacts to private properties would be concentrated at the bend in Riverside Drive. At the 12' elevation, an elevated roadway may allow homes to remain. However, the 15' and 18' elevations would be successively more disruptive to private properties. As an alternative, layouts were evaluated on the inside of the bend in the road (located in backyards and side yards) and on the outside of the bend (located waterward of private properties). However, private property impacts would be associated with both options. An alternate option for the bend of Riverside Drive would be to install a floodwall along the east side of the road and avoid the grading needed to elevate the road; however, the wall would likely be elevation 12 or lower to avoid significant visual impacts.

A completely separate alternative would be to avoid the Riverside Drive corridor and elevate Turney Road to 12' or 15' NAVD88. This flood protection alignment would protect the majority of the South Benson Road area from Ash Creek flooding but would place the Riverside Drive corridor on the water side of the protection. This would be least disruptive to private properties on Riverside Drive but may be disruptive to some of the properties along Turney Road.

All flood protection system options are disruptive to the town marina. Parking and internal access would be negatively affected to progressively higher degrees for the 12', 15', and 18' options. Only the 12' option would allow motorists to travel between the northern and southern sections of the marina. Maintaining two access points to the marina will help alleviate some of the impacts associated with all three elevations.

The flood protection system options are least disruptive at Jennings Beach because the top of the dune ridge appears to already meet elevations of 12' to 15' in several locations. The 15' and 18' options would require adding height to the ridge. The primary disruptions at Jennings Beach include reconfiguring pedestrian access over the ridge and through the pavilion. The pavilion would likely need to be relocated or modified extensively to provide flood protection at the gap in the dune ridge.

A subset of the study focused on the tide gate systems where Riverside Drive crosses over Turney Creek and where the Ash Creek Open Space dike crosses Riverside Creek. Conceptual designs were prepared for modification of both tide gate systems. The design for Turney Creek envisions a decoupling of the tide gate structure from the bridge, with the space between the two "daylit." The tide gate structure could be elevated to provide flood protection, allowing the bridge to remain at a lower elevation. The design for Riverside Creek envisions adding a second culvert and tide gate.

None of the flood protection system components will eliminate risk. Residual risk will always exist behind a flood protection system. Furthermore, without pursuing flood protection at Fairfield Beach (between Jennings Beach and Penfield Beach, and south of Penfield Beach) and Pine Creek, flooding of a long duration will allow floodwaters to travel from these areas toward South Benson Road and Turney Road. Therefore, the study evaluated the possibility of not pursuing a flood protection system. In this case, individual property owners would continue to elevate structures as they have been doing in recent years. The primary three options are summarized in the graphic below.

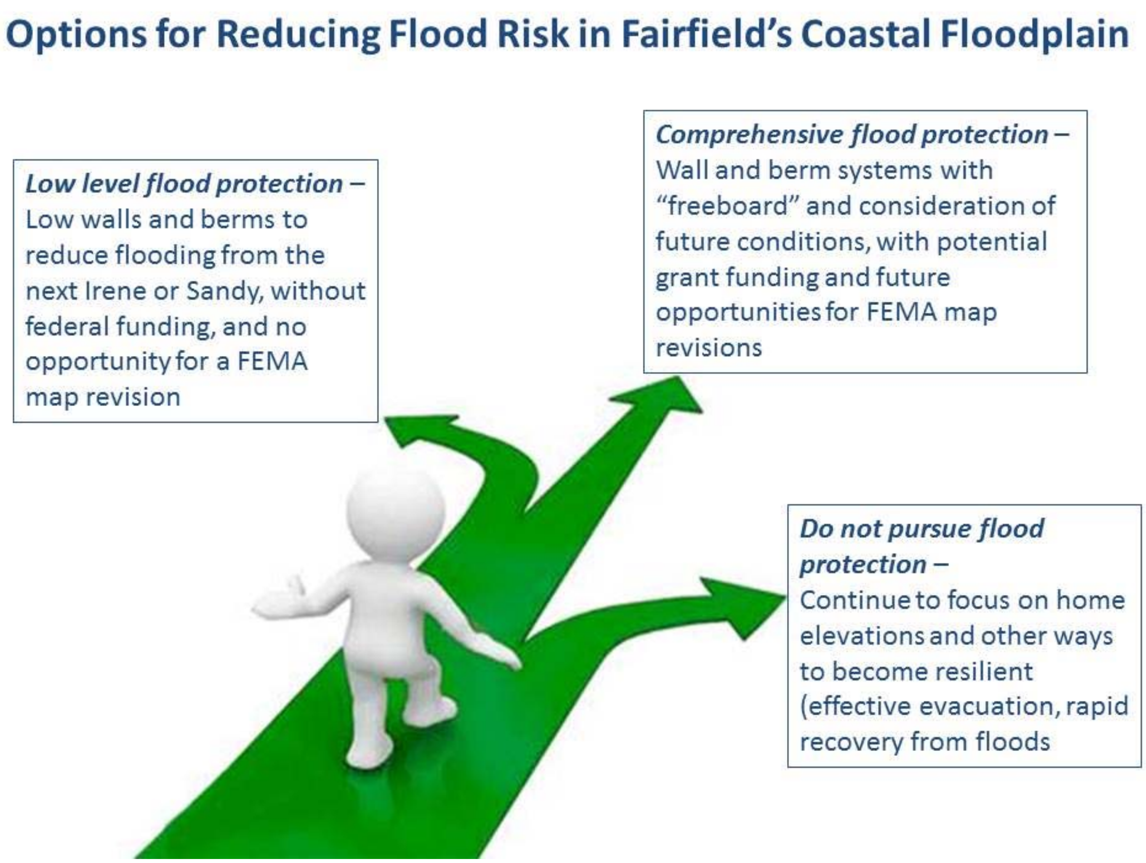

Figure ES-1

If the town cannot generate wide consensus for either comprehensive flood protection or low-level flood protection, the town could instead pursue individual specific projects such as enhancing flood protection where it is least disruptive such as at Jennings Beach, at the Turney Creek tide gate, and at the Riverside Creek tide gate. These individual projects would, at the very least, help reduce the movement of storm surge into the town's coastal floodplain, thereby increasing coastal resiliency.

1. Introduction

The Town of Fairfield was flooded by the storm surges associated with Tropical Storm Irene and Hurricane Sandy. The coastal floodplain consists of the residential area bounded by Pine Creek, Penfield Beach, Jennings Beach, and Ash Creek. In order to better understand future flood risk challenges related to sea level rise and to examine potential resiliency options for the town, a limited area located west of Ash Creek and bounded loosely by Riverside Drive, Turney Road, and Jennings Beach has been selected for focused study and assessment of alternatives. This area is depicted in the Flood Insurance Rate Map (FIRM) below. A larger copy of the FIRM can be found in Appendix A.

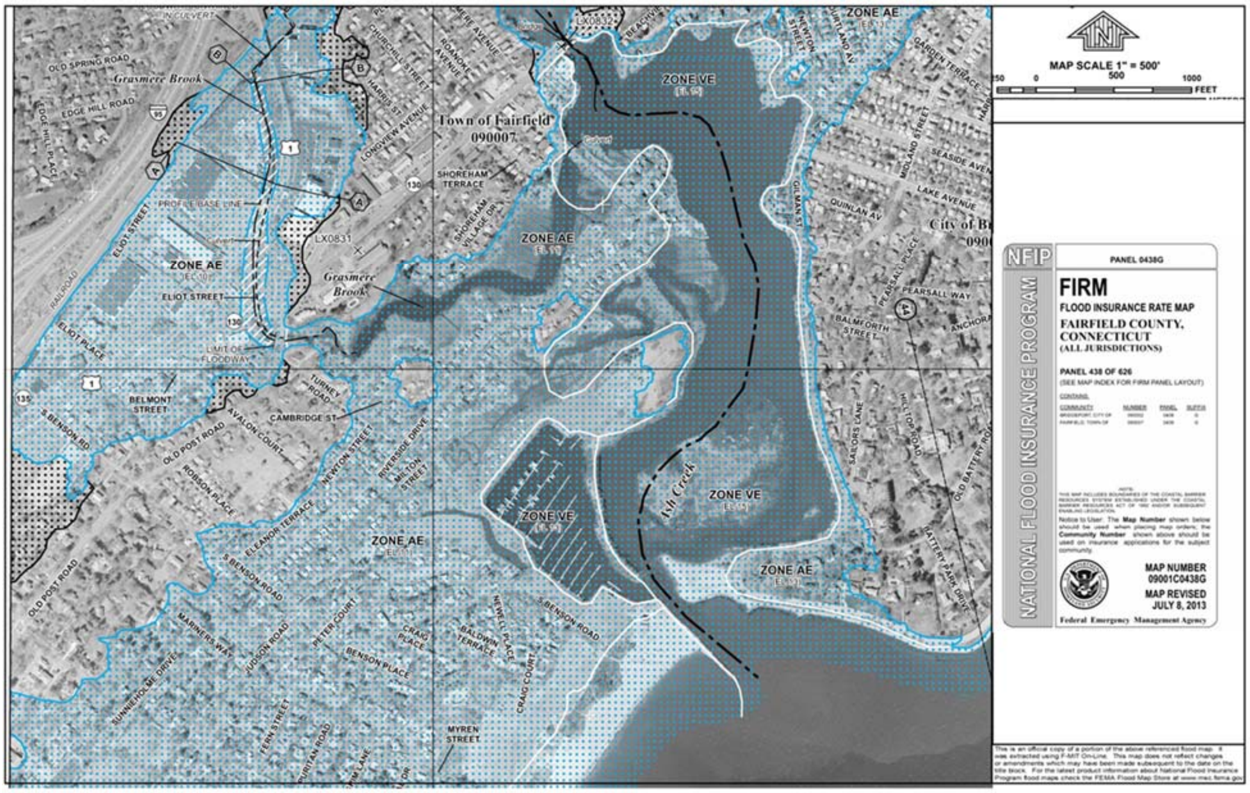

Figure 1-1
FEMA – Flood Insurance Rate Map (FIRM) for Riverside Drive/Ash Creek Area

The limited geography of the study area allows in-depth review of existing flood mitigation infrastructure (dikes and flood gates), existing natural systems, properties and public infrastructure at risk, and the feasibility of future flood mitigation infrastructure alternatives (conceptual designs) that correspond to various projected combinations of sea level rise scenarios and storm surge elevations. The scenarios are cross referenced with summaries of regulatory permitting requirements and challenges and estimated costs relative to these potential construction options.

1.1 Study Priorities

The Riverside Drive/Ash Creek Resiliency Study provides a framework for understanding the risks to this targeted area of Fairfield's shoreline and potential modification options that can be made (with future funding) to existing public infrastructure to lower the overall risks to this area. The Town of Fairfield Flood & Erosion Control Board (FECB) and town staff have indicated that the study provides an initial model for understanding the types of risks to a specific area (in this case, the Ash Creek/Riverside Drive/Jennings Beach area), the types of mitigation projects that might be possible, and the potential for linking into future development of a comprehensive flood protection system for the town. The town can utilize the study approach as a template for evaluating whether similar measures might be appropriate in other high flood risk locations bounded by Fairfield Beach and Pine Creek.

In the context of flood resiliency, reducing the frequency of flooding will directly reduce the flood risk (risk is proportional to frequency *and* vulnerability). However, it is understood that flood frequency may increase due to the effects of sea level rise, causing a higher base level when storm surges occur from nor'easters or tropical storms. Therefore, the damage from a rare storm surge is now occurring more frequently than it was in the past. Because frequencies are changing, risk is increasing. In order to reduce risk, vulnerabilities must be decreased. A flood protection system and/or flood mitigation framework in Fairfield will necessarily reduce vulnerabilities in order to reduce risk.

Many flood-related challenges in Fairfield are already being addressed. Components of a comprehensive flood protection system and/or flood mitigation system in Fairfield have been developed in the "Fairfield Mitigation Plan" by the town's FECB. The USACE has reportedly been evaluating components of a flood protection system for the area surrounding Pine Creek. Meanwhile, the town has applied for various grants to advance planning and design of sections of a comprehensive flood protection system, but securing FEMA and National Fish and Wildlife Foundation (NFWF) grants has been unsuccessful.

1.2 Study Funding

The Town of Fairfield was awarded a CDBG-DR through the State Department of Housing's (DOH) Post-Sandy disaster relief allocation through HUD for $200,000 in planning funds for a Riverside Drive Flood Mitigation Study. The money was allocated to HUD through the 2013 Disaster Relief Appropriations Act, which designated aid assistance for communities affected by Hurricane Sandy. This grant is intended for planning and conceptual design purposes only. Construction funding for any of the alternatives identified in this study or further developed by the Town of Fairfield will need to be identified and applied for independently of this study.

1.3 Study Area and Mapping

The area located west of Ash Creek and bounded loosely by Riverside Drive suffered significant flood damage during the Irene and Sandy storm events. The storm surge reportedly washed over the west bank of Ash Creek, traveling upstream along smaller estuaries and overtopping higher ground, and flooded the vast FEMA-delineated 1% annual chance floodplain occupied by hundreds of residential properties. The residential houses in the area are largely in the SFHA AE with a Base Flood Elevation (BFE) of 11. A portion of Riverside Drive and some of Ash Creek, particularly where the footpath is located, are in the High Velocity Flood zone – VE-15. Although the storm surge also overtopped several sections of Fairfield Beach to the south and southwest, there were pockets of high ground, dunes, and coastal structures that dampened some of the surge flooding along Fairfield Beach.

Following the Irene and Sandy flood events, floodwaters had a difficult time draining from the area, leaving many people's homes inundated for extended periods of time as pictured above (photo courtesy of the Flood & Erosion Control Board). When floods occur, extended floodwater exposure, particularly salt water exposure, has a direct correlation to property damage and resulting costs incurred. Longer periods of time in floodwaters will equal much greater losses.

Existing Geographic Information System (GIS) data were compiled from the Town of Fairfield and Connecticut Metropolitan Council of Governments (MetroCOG) to provide detailed base mapping of the study area. Data such as structures (buildings), parcels, utilities, stormwater infrastructure, town-owned land, open space, tide gates, and topography were added to base mapping. The map on the next page depicts this information. Base maps were later used to help with assessment of existing dike and tide gates, described in Section 2 of this report.

Review of base mapping shows that the study area can be generally divided into two different settings: a residential northern area, which includes Riverside Drive and the Ash Creek Open Space, and a southern nonresidential area, which includes the Fairfield Marina and Jennings Beach. The north section spans from Ash Creek where Riverside Drive meets Old Post Road/Fairfield Avenue toward the Ash Creek Open Space land adjacent to the Fairfield Marina. A number of properties and infrastructure fall within the FEMA AE and VE Zones. AE Zones are areas inundated by 1% annual chance flooding, for which BFEs have been determined as elevation 11. VE Zones are areas inundated by 1% annual chance flooding with velocity hazard (wave action). BFEs have been determined in VE mapping as elevation 15.

The southern section extends from the Fairfield Marina to Jennings Beach. Jennings Beach is located in the SFHA VE-13 where velocity hazard (wave action) is anticipated.

Source:
ESRI

Figure 1-2: Base Map

Location:
Fairfield, CT

N

Riverside Drive/ Ash Creek Resiliency Study

Map By: MER
MMI#: 1342-18
MXD: Y:\1342-18\Maps\base3.mxd
1st Version: 9/05/2017
Revision: none
Scale: 1 in = 350 ft

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2. Assessment of Existing Dike and Tide Gate Systems

Reconnaissance-level visual inspections were conducted to characterize the existing dikes and raised grade that may be serving as flood protection. These areas include Jennings Beach, the dike at Ash Creek Open Space south of Riverside Drive, and the grade of the Riverside Drive roadway. One of the primary reasons for this study is to provide information about how these existing "structures" have historically provided flood protection and then describe how they may provide flood protection in the future. To accomplish this, four segments were delineated focusing on topography and function served of the existing dike and tide gate systems. Segment 1 refers to the Riverside Drive residential area north of Ash Creek Open Space, Segment 2 refers to the dike at the Ash Creek Open Space, Segment 3 refers to the remainder of the Ash Creek Open Space and the Fairfield Marina in the vicinity of South Benson and Turney Roads, and Segment 4 is Jennings Beach. A fifth segment (Turney Road) was added subsequent to commencing the study.

Appendix B (Assessment of Existing Dike and Tide Gate Systems) describes the five segments and their capacity relative to their ability to provide flood protection in their current forms. Additionally, separate visual inspections were performed for the two primary tide gate systems in the study area, including those beneath Riverside Drive (located at Turney Creek) and in the earthen dike in Ash Creek Open Space (Riverside Creek). Appendix C contains specific observations for the two tide gate systems in the study area.

Many years ago, the study area was not characterized by berms, raised grade, and dikes. Appendix D contains aerial photography that depicts the historical layouts of estuaries and landforms in the study area. As with many coastal towns, low-lying areas were filled to allow some development, and tidal creeks were modified to benefit construction of roads and bridges as well as water-based transportation. These changes contributed to some level of coastal flood risk as buildings and infrastructure were constructed in coastal areas.

3. Parcel-Based Evaluation of Available Land

The information obtained from the compiled base mapping and the assessment of existing dike and tide gate systems was used to develop a matrix, map, and summary of existing parcels and rights-of-way that may be available for flood protection and flood protection techniques. In the Riverside Drive and Ash Creek study area, the Town of Fairfield appears to have most of the land available for flood protection system components, but several private properties would be impacted by driveway/access modifications related to a berm or levee system, depending on the project's elevation, height, and location. The higher the proposed elevation where more significant grading is required the more significant is the impact on adjacent private property driveways and structures. A significant amount of additional land also appears available for shoreline protection components along Ash Creek. These parcels are explained in detail in Appendix E.

Overall, the review of available land determined that the Town of Fairfield appears to own much of the land available for development of flood protection system components, but several private properties on Riverside Drive and up to 25 private properties on Turney Road could be impacted by driveway and access modifications related to a berm, levee, or elevated roadway system.

4. Evaluation of Flood Protection Options

Flood protection can be achieved in many ways. This section of the report focuses on providing an overview and explaining the differences between protective infrastructure such as hard shoreline protection, soft shoreline protection, bank protection, living shorelines, and also community infrastructure protection of stormwater systems. In Section 5, the report turns to the specific design criteria for flood protection systems. In Section 6, the report addresses other methods of flood mitigation and resilience.

4.1 Protective Infrastructure

Protective infrastructure includes resilience options designed to protect against flood events. This may include hard shoreline protection, soft shoreline protection, bank protection and stabilization, and living shorelines. These are conceptually introduced below and subsequently discussed.

4.1.1 Hard Shoreline Protection

Hard Flood Protection and Bank Protection

The first category generally includes long-lasting structures parallel to the shoreline.

- Levees are engineered berms that protect land from flooding.
- Floodwalls are designed to stop floodwaters from reaching a specific area and can be used for inland or coastal flooding; they are generally not designed for use directly on the shorefront.
- Seawalls are engineered barriers at the shorefront that protect land from waves and flooding.
- Bulkheads are engineered structures that retain soil and reduce erosion.
- Revetments protect against erosion by dissipating wave energy. They may be constructed of piles of large stones (riprap), mesh cages of smaller rocks (gabions), or other materials.

✓ *The primary hard structures of interest to the study are levees/berms and floodwalls. The study considers their use along Riverside Drive, in the Ash Creek Open Space, around the marina, and at Jennings Beach.*

Hard Sediment Management Structures

Additional hard protections that are not necessarily parallel to the shoreline or that are parallel but offshore may include the following:

- Jetties and groins are built perpendicularly to the beach to interrupt the flow of sand along the shoreline. Over time, sand builds up on one side (the "updrift" side) and is eroded from the other (the "downdrift" side).
- Breakwaters are built parallel to the beach in the water offshore. They are designed to block waves, reducing wave energy at the shoreline. Over time, sand can accumulate toward the breakwater, eventually causing a similar effect as a groin.

✓ *The primary sediment and wave management structure of interest to the study is the breakwater. Possible locations are within Ash Creek or offshore from Jennings Beach.*

Hurricane Barriers

Several hurricane barriers are located in New England, including barriers in Stamford Harbor to the west and New London to the east. A map of the Stamford hurricane barrier provided by subconsultant GEI can be found in Appendix F along with cross section figures from the associated levee. The hurricane barrier primarily protects areas upstream of the East Branch of Stamford Harbor, with a physical barrier for the channel that can be deployed. The sections of the barrier on dry land consist of levees and berms that extend to the east and west to meet high ground.

✓ *A hurricane barrier at the mouth of Ash Creek was considered as part of this study.*

Applicability of Hard Structures to Study Area

Because an existing system of dikes, road embankments, and high elevation areas already helps to protect the southeastern portion of Fairfield from flooding from Ash Creek, the use of floodwalls and levees/berms to provide additional protection is similar to existing conditions. This is a key point because the construction of levees, berms, or walls beginning at or near sea level would be a significant undertaking. Such structures would need to be designed for frequent exposure to water whereas a system of berms, levees, and walls built on the existing grade would typically be dry.

FEMA P-259, "Engineering Principles and Practices for Retrofitting Flood-Prone Residential Structures, Third Edition" (2012) states that a levee is "compacted soil used to provide protection to a limited number of residential buildings" and provides the following criteria for levee design:

TABLE 4-1
FEMA Criteria for Levee Design

✓	Impervious Fill Material: CH, CL, or SC used as defined by ASTM Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) Designation D2487-10 (ASTM, 2010).
✓	Soils compacted to at least 95 percent of the Standard Laboratory density as determined by ASTM Standard D698-07el (ASTM, 2007)
✓ 2 ft	Overall compacted/settled height: < 6 feet
✓ 4:1	Waterward side slope: < 2.5H : 1V
✓ 3:1 – 4:1	Landward side slope: < 3H : 1V (Foundation soils are clays.) or < 5H : 1V (Foundation soils are sands.)
✓ 1.2 ft	Freeboard: > 1 foot, design 5 percent higher than required for settlement
✓	Cutoff trench: 4 feet deep by 2 feet wide
✓ n/a	Drainage toe on landward side if levee > 3 feet height
✓ V = 0 ft/sec 0.5 in stone (or grass)	Scour protection on waterward side: < 2 ft/sec velocity 0.5 in dia stone < 5 ft/sec velocity2 in dia stone <8 ft/sec velocity 9 in dia stone
✓	Interior drainage to have backflow prevention

A levee schematic is provided in the FEMA publication; a copy is provided below.

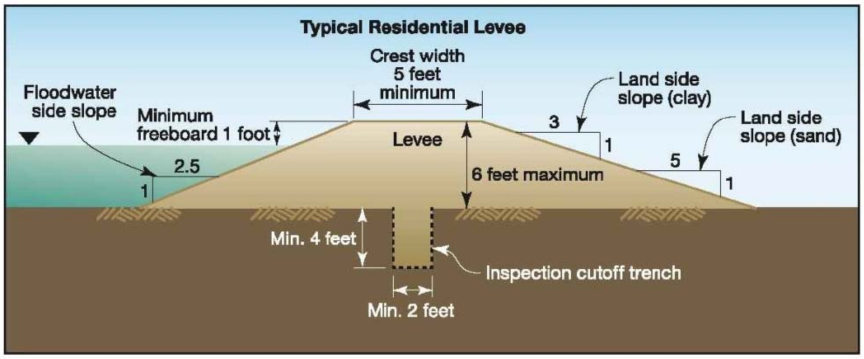


Figure 5F-28. Typical residential levee
ADAPTED FROM: FEMA P-259: "ENGINEERING PRINCIPLES AND PRACTICES FOR RETROFITTING FLOOD-PRONE RESIDENTIAL STRUCTURES"

TYPICAL FLOOD PROTECTION BERM - CROSS SECTION

SCALE: N.T.S.

Figure 4-1

The selected elevation for the top of the levee combined with the elevation of the existing ground surface has significant bearing on the bottom width given the side slopes noted above. Construction of a berm or levee to a relatively lower elevation has the benefit of minimizing the footprint of the flood protection system, hence reducing the area of disturbance required for its construction. If floodwalls are pursued rather than berms or levees, the footprint can be reduced. However, wall heights may be limited depending on the nature of subsurface materials. Floodwalls typically are not viable in areas of very deep flooding.

A review of existing geologic mapping indicates that depth to bedrock in the study area is 40 to 60 feet, and material is a combination of glacial outwash (stratified sand) and glacial till (unsorted silt, sand, gravel, and cobbles) depending on the location. Areas that are more proximate to water are characterized by organic silt and peat with depths of at least 5 feet. Jennings Beach is comprised of sand. The vegetated ridge at Jennings Beach (constructed in the 1980s based on aerial photography) is not believed to have a concrete core and instead is likely made of various sandy fill materials. According to geotechnical engineers at GEI, most of the potential levee route appears to contain reasonably stable soils for levee construction.

With regard to other hard structures, the only in-water structure that may have some utility for the study area would be an offshore breakwater. Offshore breakwaters can be found off Bridgeport, West Haven, and New Haven. A breakwater in Ash Creek should be further evaluated only if its presence reduced wave energy sufficiently to lower than flood elevations along Riverside Drive and in the marina. However, the orientation of the estuary itself, coupled with the spit at St. Mary's Point in Black Rock, already possesses the function that a breakwater would provide. Additionally, sufficient space is not available to construct a breakwater in Ash Creek.

A breakwater offshore from Jennings Beach would likely reduce energy of waves reaching this beach. In such a case, a breakwater should be further evaluated only if it has the potential to improve (weaken) the wave setup and runup conditions of the beach to a degree that corresponding flood elevations are reduced and that overwash would be halted. In other words, if Jennings Beach were narrow or significantly eroded without a high berm, a breakwater could help protect the beach and landward neighborhoods.

The town provided a preliminary design of the Jennings Beach "engineered beach," which may be pursued to help secure future FEMA reimbursements for restoration costs after a significant coastal storm. A review of the existing and proposed conditions demonstrates that the beach is already close to an optimal profile and width. Furthermore, the ridge on the beach is already providing flood protection. Therefore, an offshore breakwater is not a high-priority option.

Finally, a hurricane barrier across the mouth of Ash Creek has been mentioned by some residents as a flood protection method that could be evaluated. If a barrier were constructed here, it could be easily tied into high ground at Jennings Beach and at St. Mary's Point in Black Rock. However, hurricane barriers are typically reserved for urbanized areas where significant residential and nonresidential areas would be protected that cannot otherwise be mitigated. The neighborhoods along Ash Creek are mainly residential and can be protected in other ways (including those discussed in this report). A hurricane barrier should be reserved as an option of last resort. Refer to Section 9.2 for additional discussion about the potential use of a hurricane barrier.

4.1.2 Soft Shoreline Protection

Soft shoreline protection aims to defend against inundation and wave power through management of beach sediment and dunes.

Beach Replenishment

Beach replenishment involves importing sand to an eroding or eroded beach from sediment-rich areas such as a harbor undergoing dredging. The slope and width of a beach affect wave setup and runup and can have a direct impact on flood elevations. Overall, beaches can reduce flood risks and erosion hazards while creating public recreation opportunities and aesthetic value and in the right conditions supporting unique habitats. Almost every shoreline municipality in Connecticut has at least one beach that is periodically nourished with sand. Examples in Fairfield include Jennings Beach and Penfield Beach.

✓ *Nourishment of Jennings Beach was considered as part of this study. It would not be an appropriate method of protection within Ash Creek given the absence of beaches in the estuary.*

Dune Management

Dune Management stabilizes these natural flood barriers to protect against surges while maintaining important natural resources. FEMA describes dunes as "important first lines of defense against coastal storms" that can "reduce losses to inland coastal development." The Lake Huron Centre for Coastal Conservation lists the benefits of dunes as shore protection, water purification, biological diversity, erosion control, and acting as a source of sediment for natural beach replenishment.

- ✓ *Dune enhancement at Jennings Beach was considered as part of this study. Dune creation would not be an appropriate method of protection within Ash Creek given the absence of adequate space in the estuary.*

Applicability to Study Area

The existing berm at Jennings Beach is a man-made berm that appears to be constructed of compacted soil based upon surficial observation and aerial photography. Such a berm will not function the same as a naturally occurring sand dune in flood mitigation, wave dampening, or vegetative habitat although it may provide some of the same functionality. A natural sand dune has begun to form at the base of the man-made berm, on which beach grasses have been growing.

Jennings Beach is a sandy recreational beach that currently provides wave energy dissipation through its beach profile (a long and relatively shallow slope) as well as the man-made berm and natural sand dune forming landward of the beach. Littoral drift on Jennings Beach moves sand in a northeasterly direction, where an existing jetty protects the inlet of Ash Creek. Beach nourishment and enhancement could extend the profile of the beach and lower its effective slope, both of which reduce energy of waves as they break earlier and disperse over greater areas, which would lower the height of required flood protections. Although detailed wind, wave, sand particle, and accretion/erosion models would have to be conducted to quantify the effects of beach enhancement, studies of shoreline in similar areas of the Connecticut shorelines in Long Island Sound often find that sand dunes and beach enhancement together can reduce the height of wave runup and therefore will lower the elevation for required flood protection.

In conclusion, the modification of the existing ridge by the construction and establishment of a sand dune in front of it, in combination with beach enhancement, may provide additional wave energy dissipation, which could reduce the overall elevation to which flood protection may be required. However, it is important to understand that these actions would not eliminate the need to maintain the flood protection function of the ridge. In short, the ridge is providing flood protection, and anything in front of it that reduces wave energy is helpful, but more natural dunes and a different beach profile would not allow the town to reduce the height of the ridge.

4.1.3 Living Shorelines

The current working definition of living shorelines according to the Connecticut Department of Energy & Environmental Protection (CTDEEP) is *"A shoreline erosion control management practice which also restores, enhances, maintains or creates natural coastal or riparian habitat, functions and processes. Coastal and riparian habitats include but are not limited to intertidal flats, tidal marsh, beach/dune systems, and bluffs. Living shorelines may include structural features that are combined with natural components to attenuate wave energy and currents."*

Living shorelines protect from erosion while enhancing habitat and water quality and preserving the natural processes and connections between riparian, intertidal, and subaqueous areas. Projects may utilize a variety of structural and organic materials, including but not limited to tidal wetland plants, submerged aquatic vegetation, coir fiber logs, sand fill, and stone. Broadly speaking, living shorelines can include beach and dune projects. These were addressed above. More narrowly, living shorelines are associated with tidal wetland and bioengineered bank projects that could vary as follows:

- Nonstructural techniques use natural elements such as vegetation, fill, and coir logs to trap sediment and reduce wave energy.
- Hybrid techniques incorporate nonstructural approaches for erosion control in combination with more traditional approaches, such as a rock structure, to support vegetation growth. Hybrid techniques are typically applied in areas of higher wave energy.

One example of a hybrid living shoreline that has been constructed in Connecticut in the last few years is a reef ball project near Lords Point in Stratford. The reef ball rows were installed in the intertidal zone and are believed to be trapping sediment on the landward side of the intertidal zone, thus supporting new marsh grasses.

Applicability to Study Area

Recent studies have quantified the acreage and lateral distance needs for a storm surge traveling over tidal wetlands to be dissipated a measurable degree. The narrow width of Ash Creek and lack of tidal wetlands at Jennings Beach are indications that these distances are not currently available or possible. Therefore, living shorelines are not feasible methods of providing flood protection from storm surges that enter the coastal floodplain from Ash Creek or Jennings Beach. However, the town is encouraged to protect and restore tidal wetlands as opportunities become available as their presence protects water quality and prevents erosion of lands behind them.

4.2 Stormwater Infrastructure

The challenge of preventing flooding in low-lying coastal areas includes preventing storm surge overwash as well as enabling the drainage of runoff flowing downhill from upland areas. This challenge is exacerbated by high sea levels that prevent simple gravity flow methods of drainage and discharge. Reducing this type of flood risk requires either: (a) pumping the stormwater out with enough force to overcome elevated seawater, or (b) preventing the seawater from entering the system. Stormwater pump stations are feasible but costly to construct and operate and represent an ongoing maintenance burden. The town is pursuing a pumping station for the South Benson Road area since this low-lying area will be at risk of flooding for many years. Preventing seawater from entering the gravity system reduces flood frequency with limited capital and operating expenses.

Duck Bill Flap Gate

One step in preventing seawater infiltration into storm drainage systems is the installation of gaskets at pipe joints to make the pipes watertight. Gasketed piping is common in water supply and sewer systems and readily available on the market. Perhaps more important is placing a flap gate or duck bill structure on the pipe outlet. A traditional flap gate is shown to the left. These are typically made of steel or aluminum and

Stormwater Flap Gate

MILONE & MACBROOM®

open under the force of water building up in the pipe behind the gate. A duck bill is shown above. Either device can work in Fairfield and may be viable options to reduce the duration of flooding landward of Ash Creek and Jennings Beach.

4.3 Summary

For each option, benefits and barriers to implementation are summarized.

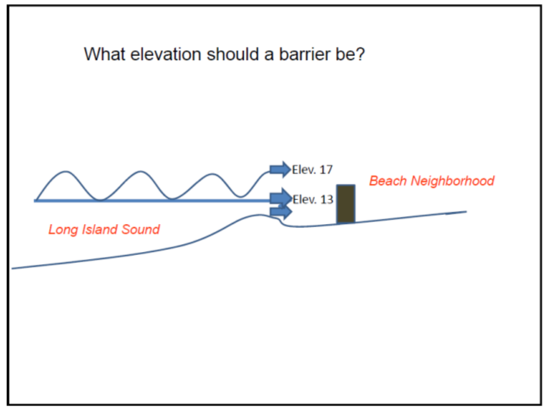
TABLE 4-2
Benefits and Barriers to Implementation

Measure	Summary	Benefits	Barriers to Implementation
Hard Shore Protection	Structure parallel to shore, set back (flood wall, levee)	• Long lasting • Effective	• False sense of security • Expensive maintenance
Hard Shore Protection	Structure parallel to shore, at edge of water (seawall, bulkhead, revetment)	• Moderate to long lasting • Effective	• False sense of security • Expensive maintenance • Frequent repairs • Ecosystem damage
Sediment Management Structures	Structures reduce wave energy and manage sediment.	• Long lasting • Support natural processes	• Does not prevent stillwater inundation flooding • Secondary impacts
Soft Shore Protection	Replenish sediment and dunes	• Support natural processes • Support ecosystems • Aesthetic	• Regular maintenance • May not be long lasting
Bioengineered Banks	Natural elements reduce wave energy and trap sediment.	• Support natural processes • Support ecosystems • Aesthetic	• Somewhat limited areas of applicability
Marsh Management	Creation/restoration of tidal marsh	• Reduce wave energy • Critical habitat	• Limited areas of applicability • Does not address stillwater inundation
Stormwater Management	Drain low areas while preventing backflow	• Support other protection methods	• May be expensive • Requires maintenance • Does not address direct hazards

5. Establishment of Flood Protection System Design Criteria

Section 2 of this report explained that existing dikes, berms, ridges, roadway alignments, tide gates, and other spots of high ground are already providing some flood protection to the area inland from Ash Creek and Jennings Beach. However, questions remain: What are the feasible elevations of flood protection systems? What elevations would be effective for long-term flood protection?

The Fairfield Flood Mitigation Plan posed the key question "What elevation should a flood barrier be?" This question was posed not just for the Ash Creek side but for all the flood protection systems that were conceptually laid out in the plan. The image to the right was featured in the plan.



One of the key aspects of this study was the need to advance this question and begin moving toward resolution of the question. The design criteria for each of the flood protection system alternatives described as part of this study are based on recent flooding events caused by Tropical Storm Irene and Hurricane Sandy, long-term tide gauge information, technical data from the FEMA Flood Insurance Study (FIS) and the North Atlantic Coast Comprehensive Study (NACCS) model outputs, sea-level-rise projections, the Federal Flood Risk Management Standard, and general design criteria utilized by federal agencies. Design scenarios for future combinations of sea-level rise and storm surges, with conditions and water surface elevations described for at least three planning horizons (2020s, 2050s, and 2080s), are outlined in this section. Appendix G supports this section of the report with technical data and projections.

5.1 Review of Recent Events

Although it is understood that the floods from Tropical Storm Irene and Hurricane Sandy breached the high ground and flooded the South Benson Road area, a review of FEMA-designated repetitive loss properties can be helpful in understanding when and where flood damage occurred. It is important to understand that repetitive loss properties are those that submit claims under the National Flood Insurance Program, and the list of such properties does not include properties where flood damages were paid out of pocket or otherwise not recorded. Because the Town of Fairfield participates in the FEMA Community Rating System (CRS), annual outreach to repetitive loss properties and the tracking of property mitigation occurs outside the scope of this study.

Seven repetitive loss properties are located north and east of Sherman Elementary School. All seven made claims after the flood from Hurricane Sandy, and three of them made claims after the flood from Tropical Storm Irene. Based on review of the best available Light Detection and Ranging (LiDAR) Digital Elevation Model (DEM) for Fairfield, it is likely that these properties were flooded from Ash Creek and/or the low area between Jennings Beach and Penfield Beach *before* flooding could have arrived from Pine Creek, which is located more distant to the southwest.

5.1.1 Tropical Storm Irene

The track of Tropical Storm Irene across Connecticut in August 2011 was slightly northeast, with storm track passing to the west of Greenwich. Initial winds would have pushed water levels in Long Island Sound to the northwest, with winds blowing east trailing behind the eye of the storm. The rise in water level in Ash Creek likely occurred before the rise in water levels in Pine Creek.

Peak storm tides during Irene were 8.52 feet (NAVD88) in Bridgeport Harbor and 8.66 feet at the Norwalk Maritime Aquarium. Peak storm tides were slightly higher along the Saugatuck River, potentially due to the effects of rainfall.

The majority of repetitive loss properties with damage from Irene are located southwest of Beach Road, away from the study area. The locations of these properties are consistent with the above assessment of surge. It is likely that water levels rose quickly along Ash Creek due to northwest winds from Long Island Sound, briefly causing flooding. However, the high ground at the bend of Riverside Drive and the Ash Creek Open Space plus the tide gates at Turney Creek and Riverside Creek would have slowed the surge leading southwestward from Ash Creek, allowing it to move into the area from the marina instead.

Top 5 Highest Water Levels at Bridgeport Gauge Since 1964	Elevation (NAVD88)
10/30/12 (Sandy)	9.19
8/28/11 (Irene)	8.23
12/11/92 (Nor'easter)	8.17
10/31/91 ("Perfect Storm")	7.49
10/25/80	7.09

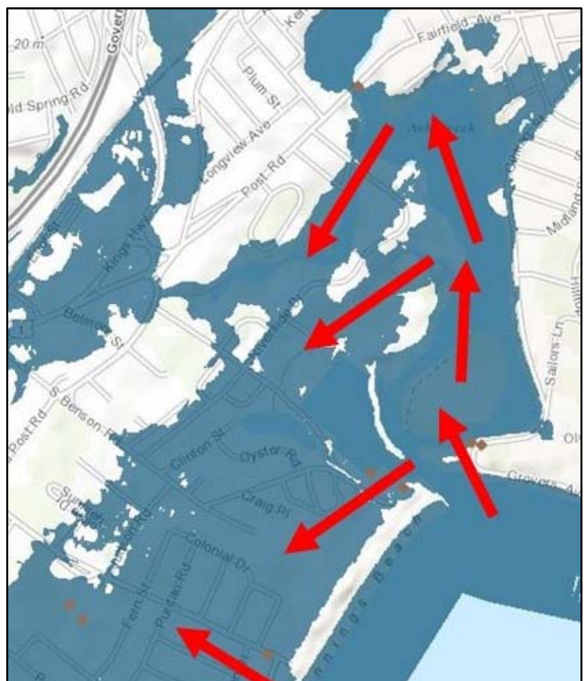
Flooding from the low area between Jennings Beach and Penfield Beach is likely the culprit for the Tropical Storm Irene damage to the repetitive loss properties southwest of Beach Road. It is possible that floodwaters met somewhere in the middle as direct connectivity occurs between floods from Ash Creek, the low area between Jennings Beach and Penfield Beach, and Pine Creek at properties located within the elevation range of 6 to 8 feet (NAVD88).

5.1.2 Hurricane Sandy

The track of Hurricane Sandy across Connecticut was generally north of west, with the storm track passing through southern New Jersey. Initial winds would have pushed water levels in Long Island Sound to the northwest, with winds blowing east trailing behind the eye of the storm. The westerly push continued throughout the majority of the storm's influence in Connecticut until near the end when winds turned more to the north. The rise in water level in Ash Creek likely occurred before the rise in water levels in Pine Creek. One characteristic of Sandy that was stronger than Irene was the rapid passage of surge across the low-lying parts of Fairfield Beach. Therefore, it is likely that significant flooding occurred through the low area between Jennings Beach and Penfield Beach just as it did through the low area south of Penfield Beach toward Shoal Point.

Peak storm surge elevations have not been published for Hurricane Sandy in Fairfield although peak heights above grade are available. Peak heights above grade were adjusted based on LiDAR contours to provide an estimated peak surge elevation in NAVD88. Estimated elevations of peak surge range from 3 to 11.3 feet across the project area, with the most representative figures in the range of 7.4 to 10.4 feet. A comparison of the surge extent to the LiDAR indicates possible surge elevations up to 12 feet near Shoreham Drive, elevations greater than 10 feet on Bay Edge Court and in portions of the Ash Creek Open Space area, and lesser elevations of 6 to 8 feet behind the berm at Jennings Beach. These are all comparable to the known flood elevation of 9.19 at the Bridgeport gauge. Appendix H contains a map prepared by the Connecticut Institute for Resilience and Climate Adaptation (CIRCA) that depicts the flooding caused by Hurricane Sandy as well as numerous properties where damage was reported.

All of the repetitive loss properties mapped in the vicinity of the project area were damaged by flooding from Hurricane Sandy as opposed to only a few that were damaged by the flood from Irene.[3] The locations of these properties are consistent with the above assessment of surge. It is likely that water levels rose quickly along Ash Creek due to northwest winds from Long Island Sound causing flooding. The high ground at the bend of Riverside Drive and the Ash Creek Open Space plus the tide gates at Turney Creek and Riverside Creek would have slowed some of the surge leading southwestward from Ash Creek, but the causeways and dikes were likely overtopped, allowing floodwaters to proceed inland. The arrows in the graphic below depict the pathways likely taken by floodwaters.



Sandy flood extents (mapped by USGS)

Flooding through the low area between Jennings Beach and Penfield Beach (the arrow at the bottom of the image) plus flooding through the low area south of Penfield Beach toward Shoal Point likely combined with flooding from Ash Creek in the area southwest of Beach Road. At some point, floodwaters from Pine Creek could also have merged with these flood pathways.

5.2 FEMA and U. S. Army Corps of Engineers Studies

Appendix G describes the flood elevations from the FEMA FIS and the NACCS model outputs. These are the two primary sets of predictive data that are available

[3] The logging of repetitive losses is dependent on flood insurance claims. It is possible that some property owners were flooded by both storms but did not claim damages until Sandy given that the storms were in back-to-back years.

for evaluating stationary flood risk. This is essentially the risk posed by storms that can occur at the present time without consideration of changing conditions and a rising base level due to sea-level rise. These two sets of data generally place 1% annual chance flood elevations in the range of 11 feet (stillwater levels) and higher if wave action is considered. By these figures, the floods from Irene and Sandy were not 1% annual chance events. A rigorous analysis of the Bridgeport tide gauge (Appendix G) does, however, plot Hurricane Sandy as more severe than the 1% annual exceedance probability level for the location of this gauge. This demonstrates that the analysis of a single gauge can reveal a different recurrence interval than comparison to FEMA and NACCS flood elevations.

5.3 Future Conditions

Fairfield is subject to sea-level-rise impacts and as such should design any proposed project to not only meet today's environmental conditions but be prepared to meet future conditions; otherwise, the significant costs for these projects may not have long-lasting impacts. State and federal funding sources both have design requirements to meet higher than minimum flooding heights and/or added sea-level-rise impacts. It should be noted that Fairfield could decide to pursue projects with lower design elevations, but these would require financing at the local level.

Appendix G includes a detailed discussion of sea-level-rise projections. As with most modeling, shorter range horizons have less variability and are easier to predict. With reference to the discussion in Appendix G and the graphic shown below, there is approximately a 1-foot variation between the lowest and the highest low rate and high rate estimates in the mid-century projections. However, further into the future where conditions are less certain, longer-range scenarios are harder to predict as seen by the different projections for the year 2100 planning horizon.

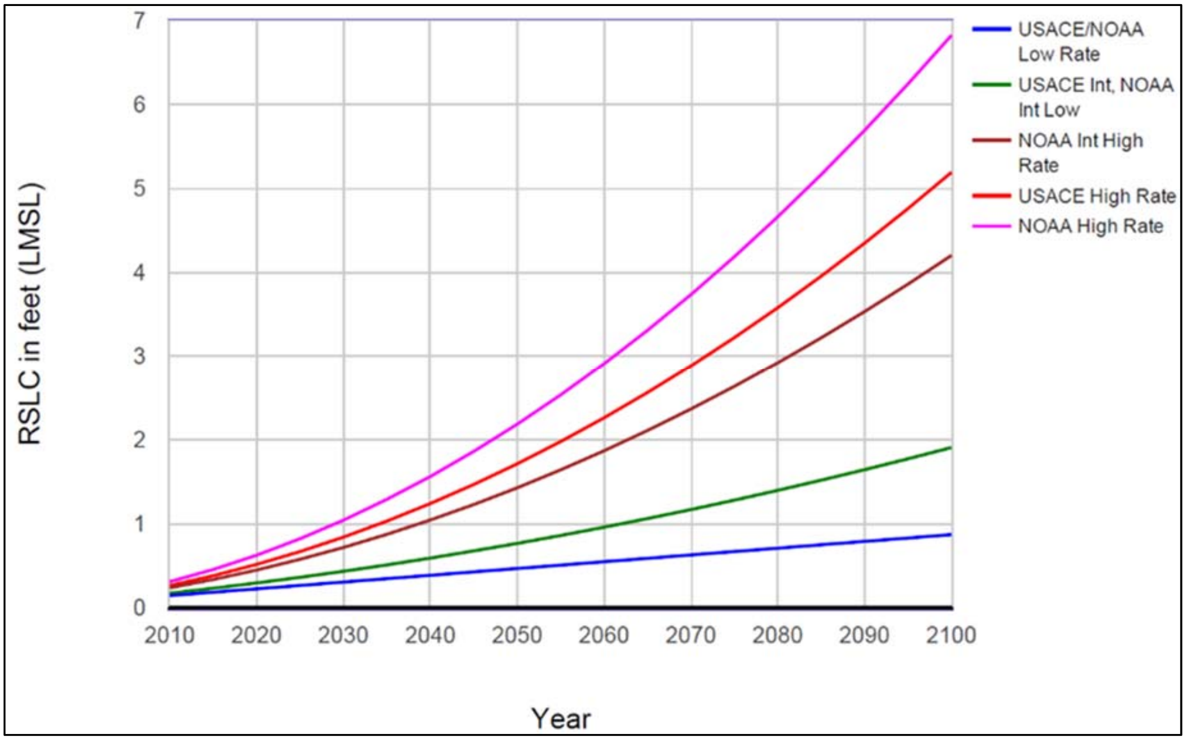


Figure 5-1
Relative Sea-Level-Change Projections – Bridgeport, Connecticut Tide Gauge

5.4 State Requirements for Addressing Sea-Level Rise

Connecticut General Statutes Section 16a-27 requires that the State Conservation and Development Policies Plan "shall (1) take into consideration risks associated with increased coastal erosion, depending on site topography, as anticipated in sea level change scenarios published by the National Oceanic and Atmospheric Administration in Technical Report OAR CPO-1, (2) identify the impacts of such increased erosion on infrastructure and natural resources, and (3) make recommendations for the siting of future infrastructure and property development to minimize the use of areas prone to such erosion," and local Plans of Conservation and Development [Section 8-23(d)11] shall consider "(11) sea level change scenarios published by the National Oceanic and Atmospheric Administration in Technical Report OAR CPO-1."

The State Conservation and Development Policies Plan ensures that any state funding for projects meets the state's growth management principles and is consistent with those policies. As reference to sea-level rise is now required as part of state land use policy analysis, it is likely that state funding sources moving forward will look to project designs to meet sea-level-rise criteria for the best utilization of state resources.

5.5 Federal Flood Risk Management Standard

On January 30, 2015, President Obama issued Executive Order (EO) 13690. It modified an earlier Executive Order in place since 1977 (EO11988, Floodplain Management) to establish a new Federal

Flood Risk Management Standard (FFRMS) for federal taxpayer-funded projects and actions. The new standard requires a climate-informed forward look to ensure that federal investments in or near floodplains are protected in the future. Aimed at increasing resilience against flooding and helping to preserve the natural values of floodplains, the FFRMS directs approaches that will take into account both current and future flood risk to ensure that projects last as long as intended. Appendix I contains an undated summary report prepared by federal agencies to assist with understanding the standard.

The FFRMS offers options for determining the vertical and horizontal extent of a floodplain in planning. The preferred option is an approach that incorporates the use of climate-informed science ("climate informed science approach" or CISA) when providing estimates of future flooding. The other approaches are using freeboard ("freeboard value approach" or FVA) or using the 0.2% annual chance flood elevation, often called the 500-year floodplain (0.2 Percent Floodplain Approach [PFA]). The Association of State Floodplain Managers (ASFPM) Foundation provides the following handy graphic to remind agencies and communities of the three methods:

Federal agencies have developed somewhat different draft procedures for implementation of the FFRMS. These procedures are not enumerated in Appendix I. Instead, individual agency guidance (much of it in draft form as of 2016-2017) must be consulted. Consider the following:

- The USACE allows use of CISA, FVA, and 0.2PFA to characterize risk and delineate the floodplain. However, additional statements in the guidance state that "all Corps actions subject to the FFRMS will utilize the CISA approach"[4] and "for critical actions that are not subject to the FFRMS, the vertical elevation and horizontal floodplain extent for critical actions will be based on the 0.2 percent annual chance flood."[5] Interestingly, the USACE guidance defines the 1% annual chance flood as "equivalent to the 1 percent flood in the North Atlantic Coast Comprehensive Study (NACCS)."[6]

- Regarding the use of the FFRMS as a design standard, the USACE guidance states that "… this vertical elevation will not be used as a design standard or to provide a minimum vertical elevation for use in the planning or design of Corps projects that involve horizontal infrastructure including

[4] Implementation of EO 11988, Floodplain Management, and EO 13690, Establishing a Federal Flood Risk Management Standard and a Process for Further Soliciting and Considering Stakeholder Input, line 320-321
[5] Implementation of EO 11988, Floodplain Management, and EO 13690, Establishing a Federal Flood Risk Management Standard and a Process for Further Soliciting and Considering Stakeholder Input, line 340-343
[6] Implementation of EO 11988, Floodplain Management, and EO 13690, Establishing a Federal Flood Risk Management Standard and a Process for Further Soliciting and Considering Stakeholder Input, line 602-603

but not limited to riverine, harbor, and coastal facilities; seawalls; jetties; revetments; engineered beaches and dunes; levees; and interior drainage facilities."[7] However, the guidance further states that "though not intended to be used as an explicit design standard, the identified vertical flood elevation and corresponding horizontal extent of the floodplain must be considered when implementing the eight-step decision making process."[8]

- FEMA proposes to "use the FFRMS-FVA as the baseline approach for both critical and non-critical FEMA federally-funded projects."[9] FEMA reasons that this will help standardize its procedures in both nondisaster and postdisaster conditions, and the use of freeboard tends to compensate for unknown factors. Furthermore, the CISA is not as well established for noncoastal flood risks. FEMA is "not proposing to use the FFRMS-0.2PFA because of the limited national availability of information on the 0.2 percent annual chance flood elevation."[10]

- FEMA states that the FVA is the 100-year BFE plus 3 feet for critical actions and the 100-year BFE plus 2 feet for noncritical actions.

- In its conclusion, FEMA explains that "FEMA proposes to combine approaches and use the FFRMS-FVA to establish the floodplain for non-critical actions and allow the use of the FFRMS-FVA floodplain or the FFRMS-CISA for critical actions, but only if the elevation established under FFRMS-CISA is higher than the elevation established under FFRMS-FVA. This proposal balances flexibility with standardization…."[11]

5.6 Summary

At a minimum, flood protection system design should consider current policies as well as the FFRMS. The most conservatively high of the current approaches is the USACE's recommendation from the "North Atlantic Coast Comprehensive Study (NACCS): Resilient Adaptation to Increasing Risk" main report (0.2% annual chance flood elevation plus three feet). At the other end of the spectrum, the current FEMA approach would be the 1% annual chance elevation plus 1 foot. Elevations resulting from the FFRMS would fall somewhere in the middle whether using the CISA or the FVA. The FEMA FVA for critical actions is the BFE plus 3 feet, which would be higher than FEMA's non-FFRMS standard but lower than the USACE's NACCS report recommendation, which is based on the 0.2% annual chance elevation.

The flood protection system segments evaluated in this report will span areas of AE 11, VE 13, and VE 15 while coming close to a VE 13 zone at the marina's boat basin. The FEMA and NACCS figures for the four segments are listed below. The final three rows list the potential design criteria under three scenarios. Note that the range is 12 feet NAVD88 to 18 feet NAVD88.

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[7] Implementation of EO 11988, Floodplain Management, and EO 13690, Establishing a Federal Flood Risk Management Standard and a Process for Further Soliciting and Considering Stakeholder Input, line 256-263
[8] Implementation of EO 11988, Floodplain Management, and EO 13690, Establishing a Federal Flood Risk Management Standard and a Process for Further Soliciting and Considering Stakeholder Input, line 345-348
[9] Federal Register Vol. 81, No. 162, 8/22/16 Proposed Rules p. 57411
[10] Federal Register Vol. 81, No. 162, 8/22/16 Proposed Rules p. 57412
[11] Federal Register Vol. 81, No. 162, 8/22/16 Proposed Rules p. 57412

TABLE 5-1
FEMA and NACCS Figures for Flood Protection Segments

	Segment 1 Riverside Drive at Turney Creek	Segment 1 Riverside Drive	Segment 2 Ash Creek Open Space Dike	Segment 3 Ash Creek Open Space and Marina	Segment 4 Jennings Beach
100-year Stillwater	10.0	10.0	10.0	10.1	10.1
100-year AE Zone	12.9	11.0	12.9	11.1	11.1
100-year VE Zone	15.0	--	15.0	13.0 (nearby)	13.0
100-year Max Wave Crest	--	--	--	--	17.0
500-year Stillwater	11.4	11.4	11.4	11.4	11.5
NACCS 1% surge	9.9	9.9	9.9	9.9	9.8
NACCS 1% surge + tide	11.8	11.8	11.8	11.8	11.5
NACCS 0.2% surge + tide	15.1	15.1	15.1	15.1	14.7
***SLR @ 2100**	2 – 4 ft	2 – 4 ft	2 – 4 ft	2 – 4 ft	2 – 4 ft
NACCS 0.2 + three feet	18.1	18.1	18.1	18.1	17.7
FEMA 1% + one foot	16.0	12.0	16.0	12.1	14.0
FFRMS 1% + three feet	18.0	14.0	18.0	14.1	16.0

With reference to Tables 5, 6, and 7 in Appendix G, the range of 12 to 18 feet covers most of the future water levels under sea-level-rise conditions. The only conditions not protected in the future scenarios will be those with significant waves that may overtop flood protection systems. The future stillwater elevations and moderate wave action (including wave action inherent in the VE BFE) are believed to be protected by flood protection systems of elevation 12 to 18 feet NAVD88.

Although the design elevation will vary spatially depending on whether the flood protection system is crossing a VE or AE risk zone, the reality is that flooding does not precisely mirror the conditions depicted on the FIRM. In order to provide the highest level of protection that can result in a FEMA map revision and remove properties from the landward AE zone, flood protection would need to be constructed at the higher elevations of 15 to 18 feet.

However, if a lower level of protection is considered appropriate and a FEMA map revision is not to be pursued, flood protection could be constructed at the lower elevations of 12 to 15 feet. This lower level of protection would protect residents from the next storm similar to Tropical Storm Irene or Hurricane Sandy and some less frequent more severe storms while providing a moderate buffer for sea-level rise. These two options are summarized in the following graphic.

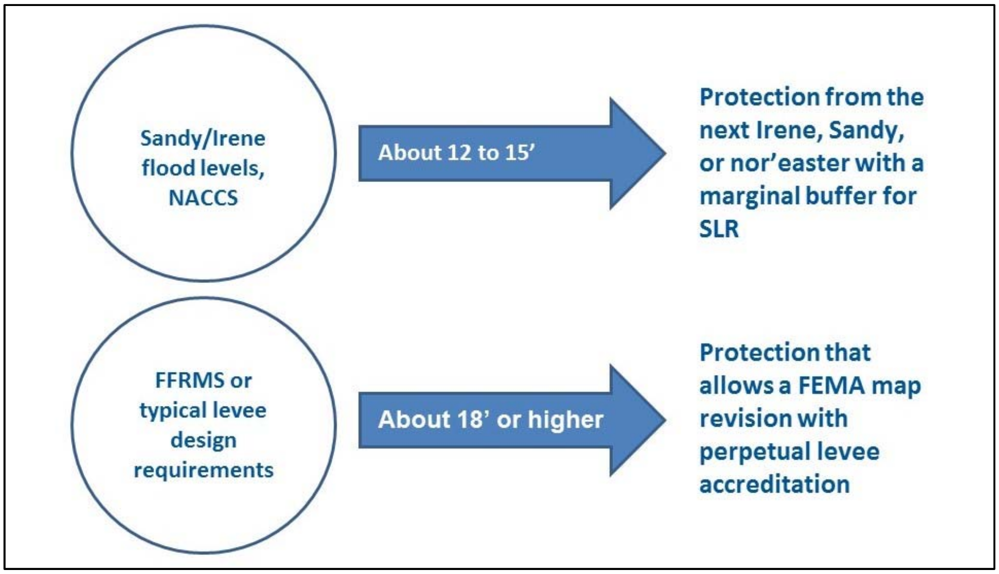


Figure 5-2
Summary of Flood Protection Options

As noted in Appendix G, recent examples of the use of various methods of calculating crest elevations can be found in the United States. For example, in the preliminary design of the Staten Island flood protection system[12] (Appendix J), the USACE utilized a number of different stillwater elevations to set elevations of the tops of earthen levees, floodwalls, and a buried seawall. The levee crest elevations are 16, 17, 18, and 19 feet NGVD, demonstrating considerable variation depending on position relative to the FEMA flood zone. The floodwall design elevations are 16, 18, 20.5, and 22.5 feet NGVD corresponding to stillwater elevations of 13, 14, 16, and 17 feet NGVD, respectively. This demonstrates that considerable freeboard (3 to 5 feet) is being applied for the Staten Island flood protection system, likely consisting of a consideration for sea-level rise plus a safety factor.

[12] Coastal Storm Risk Management Feasibility Study for South Shore of Staten Island Phase I

6. Evaluation of Other Mitigation and Resilience Options

This section focuses on other mitigation and resilience options that may be pursued in addition to, or instead of, flood protection. Issues related to access and egress in implementing flood protection/flood mitigation systems are discussed. Individual property mitigation and the benefits that could be realized if individual properties were mitigated in small or larger groups or neighborhoods are characterized. Acquisition of properties is also characterized. Issues related to roadways, utility infrastructure, and emergency services created by a comprehensive flood protection/flood mitigation system are evaluated as well.

6.1 Roads and Transportation

Methods of building resilience with roadway adaptation include road elevation, abandonment, reevaluation of emergency routes, and developing alternative egress.

- Roadway Elevation – This ensures access viability despite rising flood levels. While a practical approach, private properties often remain at lower, flood-prone elevations. A higher road surface can then impede drainage of floodwaters out of floodplain areas.
- Roadway Abandonment – It may be acceptable to abandon some roads as the cost of elevation or maintenance becomes excessive over the long term.
- Alternative Egress – This would likely be developed in connection with road abandonment or reevaluation of emergency access. New roads would have to be built along undeveloped rights-of-way. In some cases, front and rear yards of private properties can be changed if new access is developed.
- Reevaluation of Emergency Access – Some emergency routes may be abandoned (without abandoning the associated road) and alternate, nonvulnerable routes determined.

Some communities have combined flood protection with elevated roadways. This study evaluates this type of arrangement for Riverside Drive and Turney Road. Either roadway, if elevated, could provide flood protection from Ash Creek. More resilient emergency access would be provided on either roadway if it was elevated above design flood levels.

6.2 Water and Wastewater Utilities

Some coastal communities will face serious problems related to water supply and sanitary wastewater collection or disposal as sea level rises and groundwater rises accordingly. Adaptation methods may include retrofits to pumping stations, hardening of wastewater treatment plants, and extension of sewer and water systems.

Fairfield is served by Aquarion Water Company, and its water is sourced from surface water supply reservoirs and groundwater supplies that are not vulnerable to the effects of rising seas and saltwater intrusion. The positive pressure maintained in a water system will typically prevent salt water from entering pipes in low-elevation areas where that may be a concern although pipe corrosion can sometimes occur.[13] In general, Fairfield's water supply is not vulnerable, and significant adaptation is

[13] South Central Regional Water Authority is replacing water mains in East Haven that have corroded due to salt water.

not currently necessary. In some areas, the options evaluated in this study could help protect water mains from salt water that originates as overland flooding.

The Town of Fairfield is served by one water pollution control facility that discharges 10 million gallons per day of treated effluent to Long Island Sound. Vulnerable aspects of the sanitary sewer system include the treatment facility, the sewer pumping-stations that are often located at relatively low elevations, and sewer pipe infrastructure. Some of the adaptation measures for sanitary sewer systems include the following:

- Treatment Facility – steps to protect a treatment facility without relocating it include but are not limited to the following:
    - Construction of floodwalls or berms around structures
    - Floodproofing of structures or specific components
    - Elevation of structures or specific components
    - Protection of electrical supply and systems through elevation, floodproofing, and backup generators
    - Hardening of and preventing sedimentation or backflow at facility outfall
    - Protection of access to facilities through road elevation
    - Protection of records, files, and personnel
    - Enabling facilities to be operated remotely
- Pumping Stations – Steps include but are not limited to the following:
    - Elevation of station or components
    - Floodproofing station without elevating
    - Use of submersible pumps to allow for continued operation during flooding
    - Providing standby power in case supply is cut off by flooding or storm activity
    - Setting station up for rapid repair rather than attempting to prevent all damage
    - Installation of backflow prevention

The town is taking steps to protect its water pollution control facility by elevating the dike that surrounds the site. At some point in the future, the dike system may be connected to the Pine Creek dike system and eventually, in the very long term, any flood protection envisioned as part of this study and report. This would help fulfill the long-term vision in the FECB's flood mitigation plan.

6.3 Property Protection

The National Flood Proofing Committee (NFPC) defines floodproofing as "any combination of structural or nonstructural changes or adjustments incorporated in the design, construction, or alteration of individual structures or properties that will reduce flood damages." Proper floodproofing measures can reduce flood vulnerability and therefore reduce risk; however, the only way to entirely prevent damage is to relocate the structures (i.e., retreat). Floodproofing measures permitted for residential structures are more limited than those available to commercial buildings. The following section summarizes approaches to floodproofing that may be used individually or in combination for most commercial buildings. The only options available to residences are relocation or elevation.

6.3.1 Structure and/or Critical System Elevation

Elevating a structure requires raising the lowest floor so that it is above the target design level. Almost any structurally sound small building can be elevated. Design standards vary in FEMA V-zones versus

AE-zones. The process becomes more difficult and virtually impossible with a large building that has slab on grade, is constructed out of block or brick, has multiple stories, or is connected to adjacent buildings. Elevation can also create unattractive and hard-to-manage areas below the buildings. Elevation has gained much wider acceptance in recent years as a means of managing coastal buildings, particularly in residential areas. In commercial buildings, elevation to more than a few feet above street level makes for uninviting and hard-to-access retail space, so its viability is somewhat limited. Elevation is the only measure, other than relocation, that can be used to bring a substantially damaged or substantially improved residential structure into compliance with the community's floodplain management ordinance. It is also permitted in FEMA-mapped VE zones.

6.3.2 Wet Floodproofing

Modifying the operations and use of existing structures to allow flooding to occur while minimizing property damage is considered "wet floodproofing." Under this scenario, all contents (including utilities) are removed from below the flood elevation, and openings in the building wall are either maintained or increased in size to allow water to readily enter the lower floors. The openings allow the hydrostatic pressure inside and outside the building to equalize, reducing the potential for structural failure. All construction materials that may be inundated should be flood resistant to avoid deterioration and mold.

6.3.3 Dry Floodproofing

Dry Floodproofing entails making a structure watertight by sealing walls and, often, floors. Openings such as doors, windows, and vents need to be fitted with removable barriers that can be installed manually or deployed automatically during flood events. The structure being made watertight must be able to withstand the significant hydrostatic pressure that will be exerted on it during a flood event. Dry floodproofing is more often used on nonresidential structures and also requires implementation planning.

6.3.4 Ringwalls, Floodwalls, and Levees

Ringwalls, floodwalls, and levees are located away from the structure to be protected and are designed to prevent the encroachment of floodwaters. It is possible to install barriers on a neighborhood scale to protect multiple buildings, which is precisely where the subject study is focusing. However, these structures can also be situated on a site and close to a building. A well-designed and constructed barrier prevents floodwater from exerting hydrostatic or hydrodynamic forces on buildings. This avoids the need for retrofits or cleanup. Floodwalls and levees may have openings for access. These can be sealed using automatically closing barriers or manually installed barriers that depend on human intervention when flooding is predicted.

6.3.5 Temporary Barriers

Temporary flood barriers are erected manually only when flooding is imminent. These systems have a lower capital cost than a floodwall or the self-closing barriers described above, but they require human intervention prior to flooding, generating a risk that the installation is not completed, and the structures are not protected.

6.3.6 Structure Relocation or Abandonment

Relocating a structure is the most dependable method of reducing flood risks. The method involves moving the structure out of the floodplain away from potential flood hazards. Costs and new sites are usually major concerns associated with building relocation. Owners of highly vulnerable properties may wish to sell their property, thereby avoiding the costs of continued protection and maintenance. The opportunity for the Town of Fairfield to assist residents in this situation should be embraced when it arises, particularly if these properties allow for meeting other priorities such as future tidal marsh advancement or needed project area for flood protection or infrastructure projects. Meeting multiple benefits may also advance state and federal grant funding efforts where benefit/cost analysis is required.

6.4 Regulatory Tools

Many of the options listed in this section can be accomplished through, or complemented by, a variety of regulatory tools. Following is a fairly comprehensive summary for consideration.

6.4.1 Flood Damage Reduction Code Modification

In Connecticut, municipalities may increase the design standards associated with development in flood zones by modifying the municipal code, zoning regulations, and/or subdivision regulations. There are two primary methods of increasing building standards to enhance coastal resilience within the framework of these codes and regulations. These are the following:

- *Freeboard* – Freeboard standards require structures to be elevated higher than the level that FEMA requires through the National Flood Insurance Program (NFIP) regulations. To be consistent with the current State Building Code, most coastal communities in Connecticut are adopting freeboard of at least 1 foot.
- *Applying V Zone Standards Coastal A -Limit of Moderate Wave Action (LIMWA) Zones* – This requirement would to cause a structure in the coastal A zone to be constructed per V zone standards, incorporating breakaway walls, certain pile foundations, and prohibitions on uses below the first floor. The application of more stringent codes not only protects a given structure but also protects *nearby* structures from damage caused by collapsing or floating structures and debris.

6.4.2 Zoning Amendments and Other Regulatory Procedures

Zoning regulation amendments may be used to help require freeboard and other increases in building standards. Other changes to Zoning Regulations and the Zoning Map that may be considered for increasing coastal resilience include the following:

- *Tidal Marsh Protection and Advancement* – Areas suitable for marsh advancement may be regulated under a resource protection model of management.
- *Transfer of Development Rights* – Such that developers continue to own coastal land, but development is relocated to less sensitive areas.
- *Flexible Development Process* – Clustered development, planned residential development, and open-space subdivision procedures allow development consistent with coastal resiliency.
- *Land Conservation for Marsh Advancement* – Protect land through conservation easements, "rolling easements," and other arrangements. Property would remain privately owned.

- *Green Infrastructure for Private Property and Homeowner Development* – Implement incentives for property owners implementing green infrastructure improvements.
- *Water-Dependent Uses* – Allow water-dependent uses in residential areas to compensate property owners for loss of value due to restricted development opportunities.
- *Expedited Permits for Reconstruction after Emergency Events* – For work that meets new standards of coastal resiliency

Zoning overlays can be effective tools in advancing resiliency. Fairfield has already adopted a Flood Plain District Zone that limits future development in the coastal floodplain.

6.4.3 Rolling Easements

The term "rolling easements" encompasses a broad set of tools that can be used to ensure that wetlands and beaches are able to naturally migrate inland without being stopped by shore protections or development. Rolling easements can be thought of as a combination of the principles of "accommodation" and "retreat." Because it is unrealistic to prevent development of low-lying coastal lands that could eventually be submerged by a rising sea, an alternative is to allow development with the conscious recognition that the land will be abandoned if and when the sea rises enough to submerge it. From now until the land is threatened, valuable coastal land can be put to its highest use; once the land it threatened, it will convert to wetland or beach as if it had never been developed. According to Titus (*2011*), "usually, a rolling easement would be either (a) a law that prohibits shore protection or (b) a property right to ensure that wetlands, beaches, barrier islands, or access along the shore moves inland with the natural retreat of the shore."

Regulatory rolling easements may include the following:

- Local zoning that restricts shore protection
- Regulations that prohibit shore protection
- Building-permit conditions that require public access to the shorefront
- Building-permit conditions that require public access along the inland side of new shore protection structures

Property rights approaches may include the following:

- Affirmative easements that provide the public with the right to walk along the dry beach even if the beach migrates inland
- Conservation easements that prevent landowners from erecting shore protection structures or elevating the grades of their land
- Restrictive covenants in which owners are mutually bound to avoid shore protection and allow access along the shore to migrate inland
- Future interests that transfer ownership of land whenever the sea rises to a particular level
- Migrating property lines that move as the shore erodes, enabling waterfront parcels to migrate inland so that inherently waterfront activities can continue
- Legislative or judicial revisions and clarifications regarding the inland migration of public access along the shore and the rights of landowners to hold back the sea
- Transferable development rights that provide those who yield land to the rising sea the right to build on land nearby

Rolling easements are likely unnecessarily complex in the study area. The number of private properties on the Ash Creek side of Riverside Drive and Turney Drive is relatively low compared to the number of private properties to the southwest in the coastal floodplain. There, site-specific approaches are adequate for addressing the slowly developing challenges associated with sea-level rise.

6.4.4 Historic and Cultural Resources

Recognizing that historic and cultural resources were increasingly at risk from natural hazards and climate change, the State Historic Preservation Office (SHPO) embarked on a resiliency planning study for historic and cultural resources beginning in 2016. Working with the state's Councils of Government and municipalities throughout the planning process, numerous examples were identified where historic and cultural resources were specifically at risk now, could be at risk in the future, and could help generate consensus for resiliency actions. Historic resources are difficult to floodproof, elevate, or relocate without potential loss of their historicity. Therefore, flood protection systems such as berms, dikes, levees, and floodwalls may be superior to other types of flood mitigation relative to protecting historic resources.

Interestingly, few historic resources are located west of the Ash Creek/Riverside Drive corridor. The housing units near South Benson Road, Turney Road, and other nearby roads that would benefit from a flood protection system are not considered historic at this time. Therefore, protection of historic resources is not currently a benefit of pursuing a flood protection system. However, it is very important to revisit this potential in the future because the rolling 50-year eligibility for historic status can lead to additional properties being considered historic, which could bolster support for pursuing a flood protection system.

6.4.5 Community Rating System (CRS) Consistency

The Town of Fairfield was admitted to the CRS program in 2017 with a rating of 8 corresponding to a 10% reduction in flood insurance premiums. The points contributing to the rating were assigned from the CRS categories that are typically pursued in Connecticut within series 300, 400, and 500.

If flood protection systems are pursued and constructed, points may be available in the future in series 620 (levees) depending on how the flood protection system components are constructed relative to height, length, accreditation, etc. However, most CRS points tend to be awarded for protection of individual properties, outreach activities, and preservation of open space, all of which are not directly aligned with flood protection systems. Therefore, the town should not assume that construction of flood protection systems will significantly affect its CRS rating.

On the other hand, as the Town of Fairfield continues to utilize the other tools available for flood mitigation and resilience such as encouraging and tracking home elevations, these actions could strengthen the CRS rating.

6.5 Summary

For each planning option, benefits and barriers to implementation are summarized.

TABLE 6-1
Summary of Benefits and Barriers for Each Planning Option

Measure	Summary	Benefits	Barriers to Implementation
Transportation Infrastructure	Elevate roads or create alternative egresses.	• Protect emergency access and evacuation.	• Elevation may increase hazards for neighbors.
Elevation	Raise structure above flood level.	• Reduce insurance premium. • Open to residences • Permitted in V zones	• Harder to access • "Dead space" under structure • Difficult for some buildings
Wet Floodproofing	Abandon lowest floor; remove all contents.	• Relatively inexpensive	• Extensive postflood cleanup
Dry Floodproofing	Waterproof structure; install barriers at openings.	• Relatively inexpensive • Does not require additional land	• Manual barrier installation • Subject to storm predictions • Vulnerable to flow and waves
Floodwalls and Levees for Site	Concrete or earthen barriers protection	• Prevent water contact. • Avoid structural retrofits.	• May require large areas of a site • Obstructs views or access
Temporary Flood Barriers	Plastic or metal barrier	• Prevent water contact. • Relatively inexpensive	• Manual installation • Subject to storm predictions • Short term only
Relocation	Move structure to safer location.	• All vulnerability is removed. • Open to residences	• Decreased value of new site • Expensive
Building Code	Increase standards for structures.	• Protect new and improved construction	• Older structures are often exempt.
Zoning Regulations	Prevent hazardous development patterns.	• Control degree of risk in hazardous areas.	• Balance with economic pressures
Rolling Easements	Control activities on private land.	• Work with landowners for mutual benefit.	• Private landowners may not be willing partners. • Poor fit with flood protection systems parallel to shore

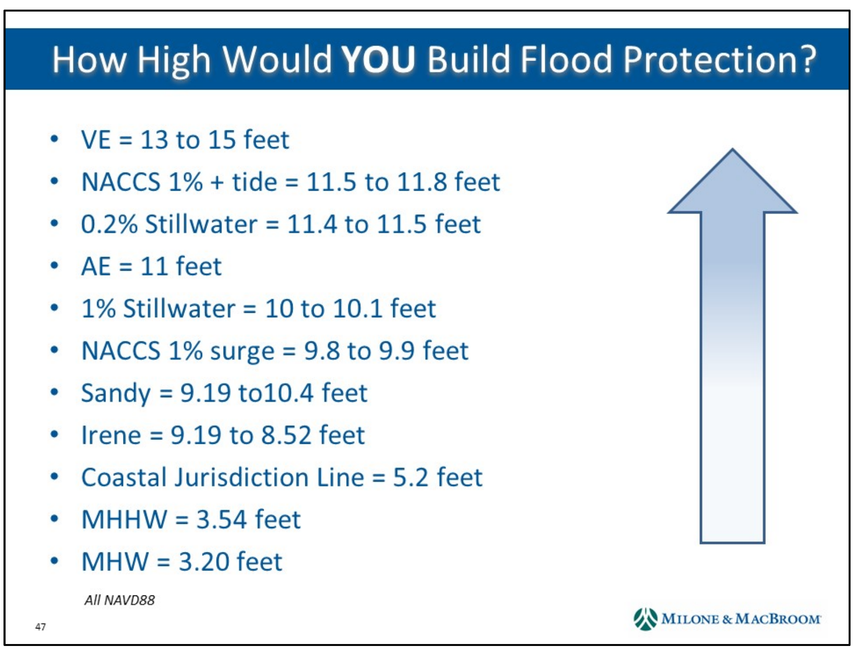
7. Public Engagement

As part of the scope of work for the planning project, the following public meetings were held to gain input from residents and other interested parties in Fairfield's floodplain.

TABLE 7-1
Public Meetings

Date	Focus	Attendees
July 12, 2016	Presentation of scope, existing flood data and wave analysis, potential sea-level rise impacts	MMI, GEI, FECB, Rick Grauer, Brian Carey, Laura Pulie, members of the public
January 19, 2017	Presentation of existing tide gate infrastructure and wide-ranging potential flood protection options	MMI, GEI, Laura Pulie, FECB, members of the public
February 13, 2017	Small group discussion of potential options for Riverside Drive tide gate, Riverside Drive roadway elevation, Riverside Drive floodwall, and Turney Road elevation	MMI, Brian Carey, Laura Pulie, FECB, Riverside Drive property owners

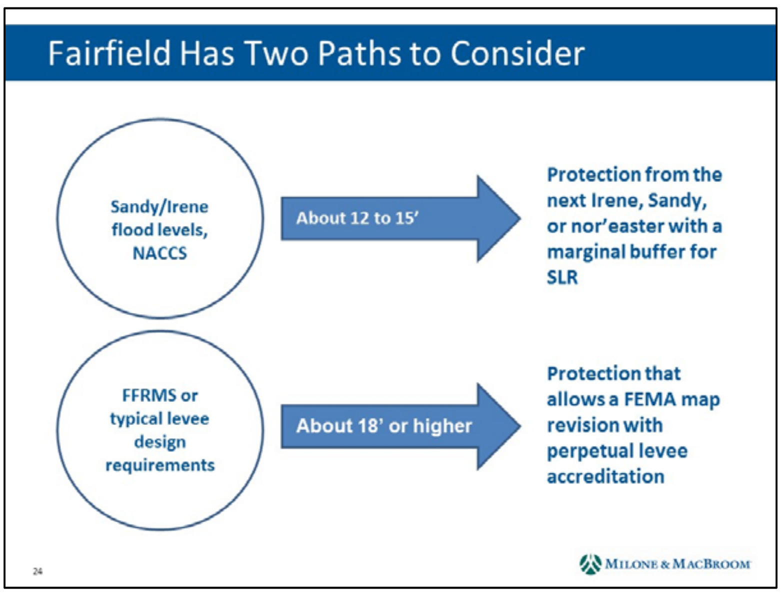
Copies of meeting materials and meeting notes for July 12, 2016, and January 19, 2017, are included in Appendices K and L, respectively. The meetings provided residents with an understanding of the flood risks that they face from various storms today (of different recurrence intervals) and the increased risks due to sea-level rise and storm surge that they can expect in future years. The meetings also posed questions about how flood protection could be oriented and the height at which it could be designed. The following key question was asked in the initial two meetings:



In addition, 3-D Google Earth views of flood protection berms/levees were viewed for the four segments of the study area. Typical images from the slides are pictured in Section 8.0.

Residents expressed concern about the impacts of most proposed alternatives relative to potential costs with the exception of the tide gate improvements to Riverside Drive. Residents were particularly concerned about view and property impacts for higher-elevation flood protection systems (15' to 18') that would be dictated by state or federal funds for designs that incorporate mitigating future sea-level rise. Some residents were in favor of lower-elevation designs that would not impede views or affect adjacent properties.

One of the main points of the second and third meetings was that the elevations of flood protection could be grouped into two categories, with each representing a pathway to flood resilience. One pathway would provide protection from the more frequent storms with a marginal buffer for sea-level rise whereas the other would provide a greater level of protection and allowance for sea-level rise, plus a potential FEMA map change when additional barriers and levees are pursued in the Pine Creek and Fairfield Beach areas.



8. Conceptual Designs

8.1 Riverside Drive, Ash Creek, and Jennings Beach Flood Protection Options

Varying estimates of freshwater flood elevations, storm surges, sea-level rise, and wave runup yield a range of elevations for which protection should be sought. Several sets of concept plans were prepared for flood protection levees and berms at the elevations developed in Section 5.0: 12, 15, and 18 feet NAVD88. These elevations bracket and fall within the range of elevations that would be logical to account for more or less freeboard and different sets of sea-level-rise projections. The lowest elevation of 12.0 feet NAVD provides substantial storm protection, including full protection from historic events such as Tropical Storm Irene (8.7 feet NAVD) and Hurricane Sandy (11.3 feet NAVD). However, the lower elevation would not satisfy FEMA requirements to provide complete protection for the 1% annual chance event, and as such, the FEMA FIRM maps could not be modified. The upper elevation that was evaluated was 18.0 feet NAVD, which provides the maximum amount of protection against even the highest FEMA estimates of wave runup and storm surge.

As a result of the public engagement portion of the study, lower-elevation barriers were also discussed (in the 10' to 11' range), and a floodwall option was conceptually placed along Riverside Drive for one plan sheet.

Plan sets were also developed for the following ancillary projects in the study area:

- Replacement of the tide gate at Turney Creek
- Replacement of the tide gate at Riverside Creek
- Flood protection options at the Jennings Beach pavilion

8.1.1 Riverside Drive

Raising elevations of Riverside Drive and the surrounding area can provide flood protection for a significant number of residential properties located to the west. In order to be effective, there must be a continuous area that does not fall below a certain elevation. This would involve raising the elevation of the Riverside Drive causeway to the north of Bay Edge Court as well as the existing flood protection dike to the south, both of which can be done with relatively little impact on surrounding homes. In the area of Bay Edge Court, however, the relatively close spacing makes it difficult to have enough space for the installation of a levee without impacting the homes it is intended to protect.

Three alternative routings for such a levee in this densely developed area were evaluated. One such alignment along the far eastern edge of the existing homes at Riverside Drive and Bay Edge Court provides the maximum amount of protection. The elevations of 12.0, 15.0, and 18.0, respectively, translate to increasing amounts of impact on the waterward sides of these properties, which may impact viewsheds and water access at these properties.

Figure 8-1
Riverside Drive and Bay Edge Court Google Earth View

A secondary alignment of the levee involves raising the roadway of Riverside Drive itself. Such a concept would require the regrading of driveways and front yards of each of the homes along Riverside Drive. While it may be difficult to achieve an elevation of 12.0 feet NAVD with the roadway without impacting the existing structures, it may be possible. However, raising the road to an elevation of 15.0 feet NAVD or 18.0 feet NAVD along the roadway would not be possible without demolishing or raising the residential structures along the roadway.

The third alignment, behind the backyards (to the west) of three homes along Riverside Drive, would be likely to have the least impact of any alignment but would also exclude the largest number of homes from its protection.

8.1.2 South Benson/Fairfield Marina

The Fairfield Marina provides seasonal docking for boat owners as well as parking lots used heavily during peak boating seasons. The presence of the marina and vegetated buffers in the area provide wave dissipation, which implies that it may be less critical to provide the absolute highest elevation of protection in this area. The elevation of the lowest points in this area varies, but through reconstruction of the roadway and adjacent parking areas, raising the grade to improve the flood protection behind them should be effective. This is not without challenges as parking and internal circulation would necessarily be modified to incorporate berms and crossings.

Figure 8-2
South Benson/Fairfield Marina Google Earth View

8.1.3 Jennings Beach

An existing man-made berm along the back of Jennings Beach provides protection against storm surge and wave runup. The berm's elevation ranges between 14.0 and 16.0 feet NAVD. Wave and wind exposure along Jennings Beach is the highest as the beach is facing Long Island Sound directly instead of being protected by the Ash Creek inlet. Dike/levee construction could seek to augment the pre-existing berm. The berm's composition is not known but is believed to be compacted soil and fill.

The Jennings Beach pavilion is constructed at the elevation of the beach with an open breezeway pass-through that causes a discontinuity in flood protection. The walls of the pavilion are grouted cinderblock, which show signs of structural cracking and spalling at various locations. The northern wall of the pavilion has fill placed directly against it in order to connect it with the flood control system to the north. The southern wall of the pavilion connects to a 50-foot-long wall constructed of 4-foot concrete blocks. It appears as if the building was retrofitted to operate as part of the flood control berm.
In order for the levee system to be effective, the breezeway must be floodproofed or the building removed/relocated. This could be accomplished through the use of a flood door or permanent reconfiguration of the building. After this deficiency is resolved, the remainder of the flood control system can be evaluated along with the structural integrity of the pavilion walls. The material construction of the existing berm can be evaluated by conducting soil borings in the existing berm. Given the proper structural modifications, the existing flood control berm could be raised to provide protection up to elevation 18.0 feet NAVD.

Figure 8-3
Jennings Beach Google Earth Google Earth View

8.1.4 Summary

This study does not prioritize one flood protection project over another with the exception of the tide gate replacement for Turney Creek at Riverside Drive, which is desired in the short term. Instead, this study provides these alternatives as a menu of options for the Town of Fairfield to consider in the years moving forward. Just as the town's flood mitigation plan envisions a phased approach to flood protection for the entire coastal floodplain (with components at Ash Creek, Fairfield Beach, Pine Creek, etc.), this study envisions possible implementation of individual components separately as funding becomes available and consensus is reached.

8.2 FEMA Map Revision for VE 15 Area

Because the BFE depicted on the FIRM is a critical deciding factor in the elevations of flood protection system components, it is important to understand how those FEMA elevations affect the conceptual designs and whether there may be potential problems with the mapping.

One section of FEMA risk mapping in the vicinity of the project area does not appear to make sense relative to the adjacent risk mapping and in the context of how it was assigned. Specifically, the VE 15 zone within Ash Creek appears to have been inappropriately assigned based on the coastal transect located on the Bridgeport side of Ash Creek (transect #44), resulting in the establishment of VE 15 BFEs instead of AE 11 BFEs. The effect on flood protection system design is that the section running through the VE 15 zone would be four or more feet higher than the immediately adjacent section running through the AE 11 zone.

Transect #44 results in a VE 15 designation for the shoreline of Black Rock. The risk designation was based on the wave analysis for this section of shoreline, which faces the open Long Island Sound. The VE 15 designation appears to have been extended to the west around St. Mary's Point and upstream into Ash Creek to the Fairfield Avenue (Route 130) bridge. The assumption that wave conditions in Ash Creek are similar to the open sound wave conditions of transect #44 are likely inappropriate. Furthermore, the VE 15 designation has been extended landward of the Riverside Drive bridge at Turney Creek and landward of the Ash Creek open space dike at Riverside Creek, creating VE 15 zones within these two estuaries while adjacent risk is designated AE 11.

In short, for these VE 15 designations to be correct, the extension of open water wave conditions from transect #44 into Ash Creek would first need to be appropriate, and then the extension of the same wave conditions into Turney Creek and Riverside Creek would also need to be appropriate. Neither of these assumptions is likely defensible.

A similar but less severe situation is present at the Turney Road boat basin, which has been given a VE 13 risk designation. The wave action necessary for this risk designation is unlikely.

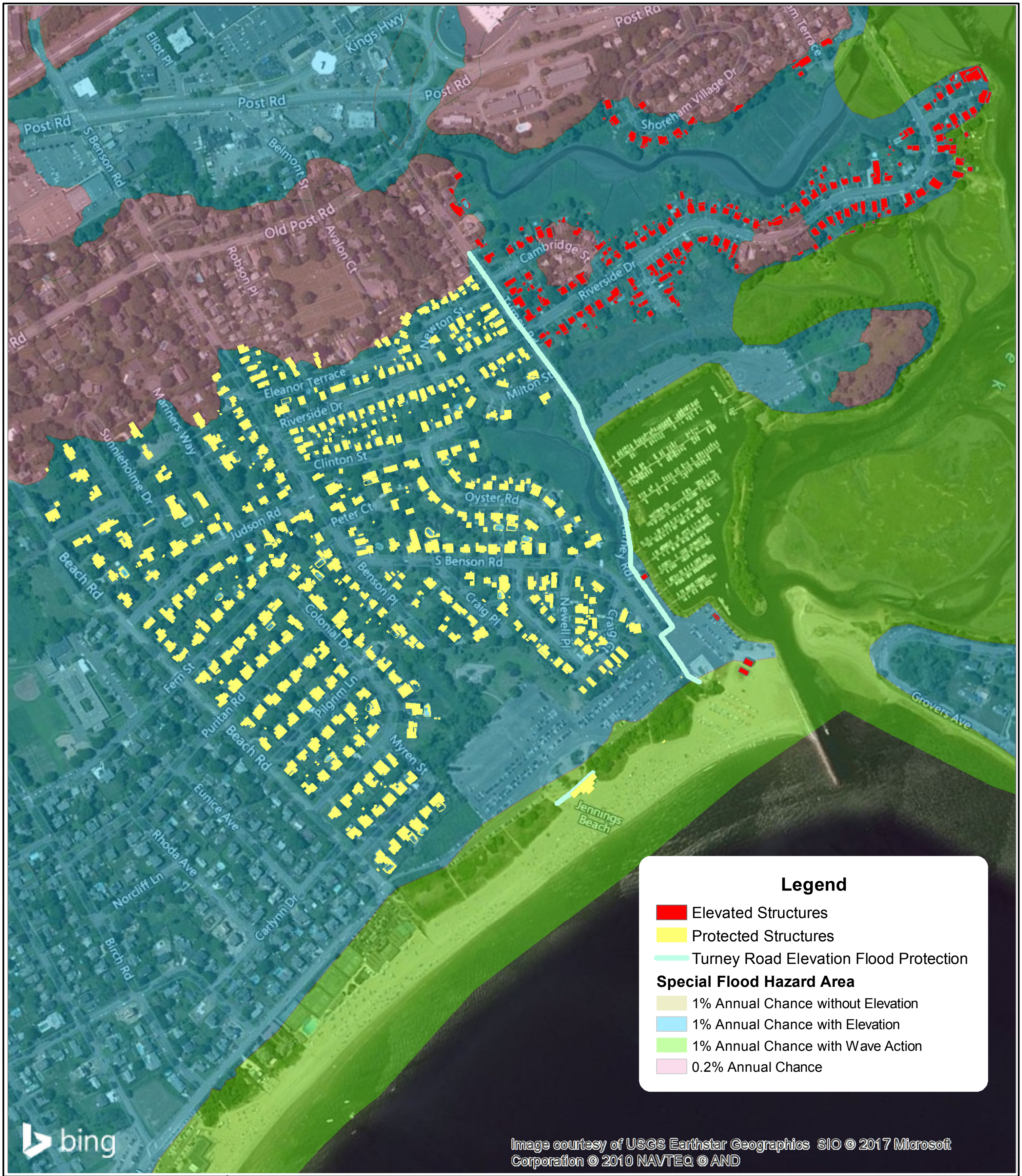
If the establishment of a VE designation in Ash Creek is deemed appropriate, it might make more sense for the VE 13 designation of Jennings Beach to be extended into Ash Creek. Nevertheless, the necessary hydrodynamics are likely not present for VE 13 risk to be extended upstream past Riverside Drive and the Ash Creek Open Space dike as the elevations of those structures would dampen wave action. Likewise, the spit separating the boat basin from Ash Creek would dampen wave action and tend to reduce the associated elevation in the basin.

Although the VE 15 designations at Turney Creek and Riverside Creek have not reportedly been a problem in the processing of development and redevelopment permit applications in the Town of Fairfield, the VE 15 designations pose a challenge in the development of design criteria for flood protection systems because the flood protection system components must be set at elevations that are higher than 15 feet. This is true whether standard freeboard or the FFRMS is applied to the design process. While the town would be remiss in establishing new (lower) base flood elevations solely for the purpose of pursuing flood protection systems designed to a lower standard, the potentially inappropriate BFEs of VE 15 and VE 13 should be corrected before the town spends resources for designing and constructing new structures.

The map appeal process is described by FEMA in the publication "Appeals, Revisions, and Amendments to National Flood Insurance Program Maps: A Guide for Community Officials," which has been amended and updated several times. The process can take several months to a year, so the town would need to consider submitting a map change well in advance of proceeding with design of flood protection system components.

8.3 Elevation of Turney Road

This conceptual design was developed after the study commenced, as an alternative to elevating Riverside Drive, the dike at the Ash Creek Open Space, and the northern part of the marina. The alternative calls for elevating Turney Road down to the marina as depicted on Figure 8-4. This alternative would then meet the remaining sections of the conceptual plans along the west side of the marina and Jennings Beach. A subset of this alternative would include elevating homes along Riverside Drive since they would be located on the Ash Creek side of the elevated Turney Road lineage.



SOURCE(S):
FEMA
ESRI

Figure 8-4: Elevated Turney Road

LOCATION:
Fairfield, CT

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Riverside Drive/Ash Creek Resiliency Study

MXD: Y:\1342-18\Maps\Figure 8-4 Elevated Turney Road.mxd

Map By: MER
MMI#: 1342-18
Original: 08/31/2017
Revision: 9/5/2017
Scale: 1 inch = 600 feet

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In Figure 8-4, blue structures represent structures protected during a storm surge by elevating Turney Road whereas red structures east of Turney Road would need to be elevated to reduce flood risk. In this flood protection plan, approximately 200 structures would need to be elevated or reconfigured. This includes approximately 111 buildings and 68 outbuildings. The Jennings Beach pavilion structure would be incorporated into the beach ridge system to close the gap there.

This design would require the reconfiguration of driveways for approximately 25 homes along Turney Road and potential changes to sanitary sewer infrastructure. Alteration of the Turney Road/South Benson Road access points to the marina and Jennings Beach would be part of this alternative as they would be with the other concepts that include the marina and Jennings Beach.

The length of this conceptual design alternative equals the length of Turney Road approximately 150 feet north of Cambridge Street to Jennings Beach and is approximately 2,700 feet long. The 100-year AE 11-foot BFE spans the length of Turney Road approximately 150 feet north of Cambridge Street to nearly the southern extent of the marina parking lot. Turney Road steadily decreases in elevation from north to south. At the intersection of Turney Road and Cambridge Street, the ground elevation is 8.0 feet; at the intersection of Turney Road and Riverside Drive, the ground elevation is 7.4 feet; and at the intersection of Turney Road and Milton Street, the ground elevation is 5.0 feet. Overall, Turney Road needs to be elevated at least 4 feet to meet the BFE level where the ground elevation is 8 feet.

BFE (NAVD88)	Flood Zone	Average Ground Elevation (ft)	Elevation Required to Raise Ground to BFE Height (ft)	Segment Length (ft)
11	AE	7.0	4.0	2,400
13	VE	10.9	2.1	250
TOTAL				2,650

8.4 Partial Completion of Conceptual Design

This section characterizes the benefits that could be realized if individual properties were protected in small or larger groups or neighborhoods instead of a comprehensive flood protection/flood mitigation system. The following discussions depict four possible flood protection strategies based on partial completion for each of the four segments considered in this study:

- Completion of only the Jennings Beach dune ridge system
- Reconfiguration of only the Fairfield Marina parking lot
- Flood protection alignment for Ash Creek Open Space only
- Completion of only the Riverside Drive/Bay Edge Court segment

In all options, these conceptual plans make the assumption that infrastructure and property are protected southwest of Jennings Beach by projects at Fairfield, Penfield Beach, and other sections of the shorefront. This study understands that these are separate projects that will be evaluated under other studies. For each comparison in this report, properties within the SFHA east of Beach Road are the focus.

8.4.1 Completion of Jennings Beach Dune Ridge System

Completion of only the Jennings Beach dune ridge system (depicted with a green line on Figure 8-5) would have little impact on altering flood conditions experienced during future storm events. During previous storms such as Hurricanes Sandy and Irene, the dune ridge provided protection to property directly behind the berm. Despite protection from the dune ridge, storm surge from Ash Creek flooded homes from the east while storm surge from the sound crossed the beach south of Jennings Beach. Therefore, fortifying the Jennings Beach dune ridge system would not provide additional value if the flood protection system did not extend to at least the Ash Creek Open Space, thereby sealing this low-lying area to mitigate the impacts of surging waters from Ash Creek.

Of the 1,975 feet required to strengthen the Jennings Beach dune ridge system, 1,962 feet fall within the VE 13 feet zone. After reviewing the LiDAR DEM, it is confirmed that the majority of elevations are above the BFE. Therefore, the Jennings Beach dune ridge system may only require minor construction to fortify the dune ridge design. Additionally, a small fraction of the conceptual design falls within the 100-year AE flood zone for a BFE of 11 feet. The LiDAR DEM reveals that elevations need to be raised on average over 5 feet along the area to meet the BFE.

BFE (NAVD88)	Flood Zone	Average Ground Elevation (ft)	Elevation Required to Raise Ground to BFE Height (ft)	Segment Length (ft)
11	AE	6.0	5.0	13
13	VE	14.5	negligible	1,962
TOTAL				1,975

8.4.2 Completion of Fairfield Marina Flood Protection Alignment

Completion of only the Fairfield Marina parking lot components (orange line depicted on Figure 8-6) would likely offer additional flood protection as compared to the limited protections provided by existing high ground in the open space, along Riverside Drive, and at Jennings Beach.

Coupled with the existing Jennings Beach dune ridge system, realignment of the marina parking lot may cut off storm surge from parts of Ash Creek. This would potentially protect a significant amount of homes south of Judson Road and Clinton Street.

Of the 1,456 feet required for the Fairfield Marina parking lot realignment, 1,362 feet (93%) of the conceptual design falls within the AE flood zone for a BFE of 11 feet. This area spans the northern Fairfield Marina parking lot down through the South Benson Road/Turney Road Jennings Beach access point. The LiDAR DEM shows that the elevation needs to be raised on average approximately 2.37 feet to meet the BFE. The remaining 94-foot segment falls within the VE flood zone for a BFE of 13 feet and covers one of the pedestrian access points to Jennings Beach. On average, this segment requires an elevation of approximately 2.6 feet to meet the BFE.

BFE (NAVD88)	Flood Zone	Average Ground Elevation (ft)	Elevation Required to Raise Ground to BFE Height (ft)	Segment Length (ft)
11	AE	8.6	2.4	1,362
13	VE	10.5	2.6	94
TOTAL				1,456

SOURCE(S):
FEMA
ESRI

Figure 8-5: Jenings Beach Dune Ridge System

LOCATION:
Fairfield, CT

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Riverside Drive/Ash Creek Resiliency Study

MXD: Y:\1342-18\Maps\Figure 8-5 Jennings Beach Dune Ridge System.mxd

Map By: MER
MMI#: 1342-18
Original: 08/31/2017
Revision: 08/31/2017
Scale: 1 inch = 600 feet

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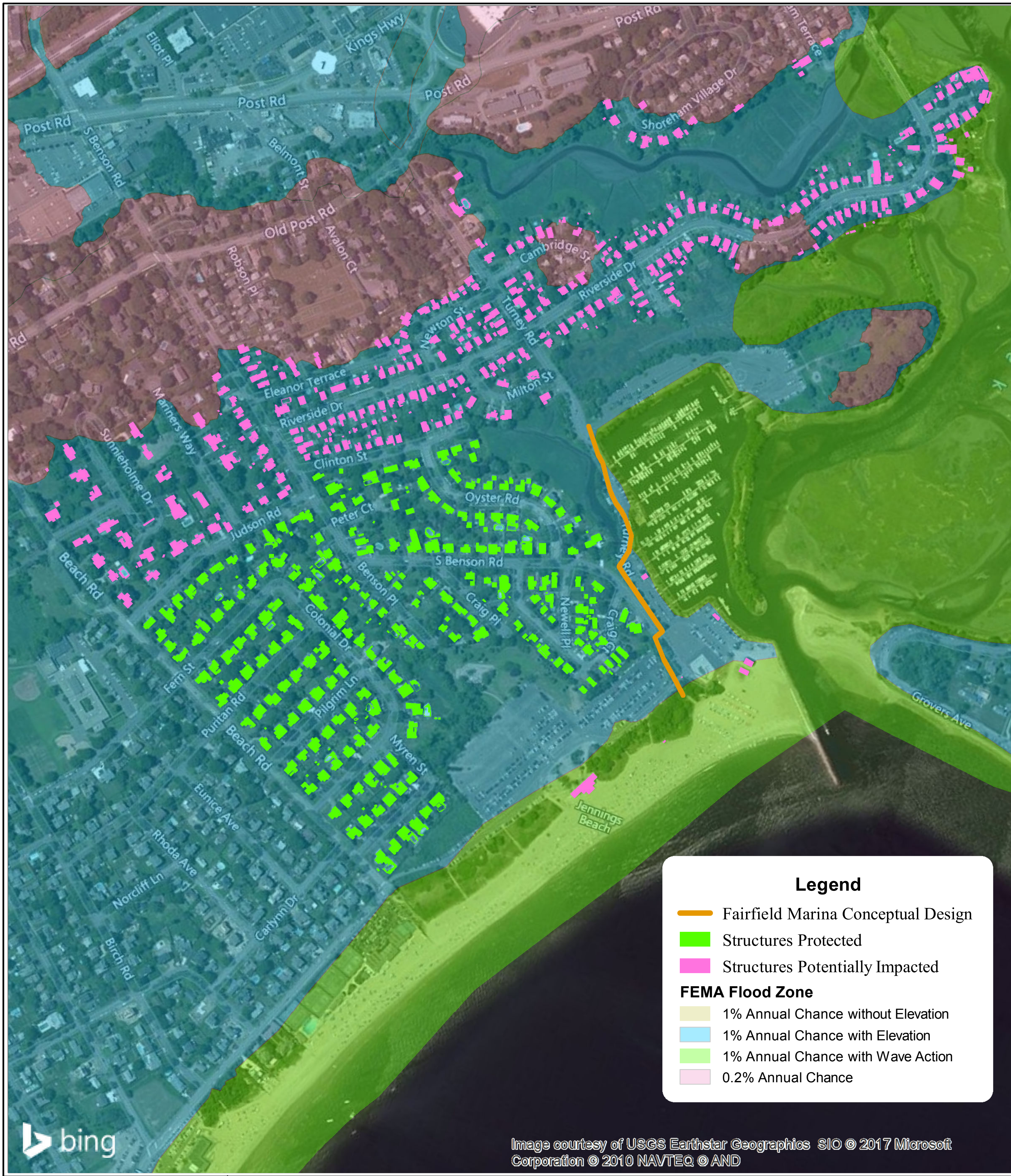

SOURCE(S):
FEMA
ESRI

Figure 8-6: Fairfield Marina Parking Lot

LOCATION:
Fairfield, CT

N

Riverside Drive/Ash Creek Resiliency Study

MXD: Y:\1342-18\Maps\Figure 8-6 Fairfield Marina Parking Lot.mxd

Map By: MER
MMI#: 1342-18
Original: 08/31/2017
Revision: 08/31/2017
Scale: 1 inch = 600 feet

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8.4.3 Completion of Ash Creek Open Space Flood Protection System

Nearly all (1,497.94 feet) of the Ash Creek Open Space flood protection segment falls within the AE flood zone at a BFE of 11 feet. This area needs to be raised, on average, approximately 2.5 feet to meet the BFE. Although a flood protection system through the open grassy area at Ash Creek Open Space may be the most feasible area to implement part of the proposed flood protection system, this section implemented on its own may be the least effective method to mitigate flooding for the surrounding property owners. Storm surge from Ash Creek would reach around this segment, as depicted by all structures in the orange color on Figure 8-7.

BFE (NAVD88)	Flood Zone	Average Ground Elevation (ft)	Elevation Required to Raise Ground to BFE Height (ft)	Segment Length (ft)
11	AE	8.5	2.5	1,498
15	VE	9.8	5.2	13
TOTAL				1,511

8.4.4 Completion of Riverside Drive/Bay Edge Court Flood Protection System

Nearly half of the Riverside Drive/Bay Edge Court conceptual design falls within the AE flood zone with an 11-foot BFE, and the remaining segment falls within the VE flood zone with a 15-foot BFE. The segment that falls in the AE flood zone covers a small area along the bridge over Turney Creek and the curved section of Riverside Drive. Elevations along these areas need to be raised approximately 2 feet to meet the BFE. The segment that falls in the VE flood zone covers a section of Riverside Drive and the dike system that crosses Ash Creek to the south of the residential development. The elevation needs to be raised, on average, approximately 8.5 feet to meet the BFE.

BFE (NAVD88)	Flood Zone	Average Ground Elevation (ft)	Elevation Required to Raise Ground to BFE Height (ft)	Segment Length (ft)
11	AE	9.1	1.9	788
15	VE	6.5	8.5	843
TOTAL				1,631

Completion of only the Riverside Drive/Bay Edge Court flood protection system (either a floodwall along the side of the road or an elevated road, both represented with a red line below in Figure 8-8) may provide additional protection to homes along Riverside Drive depicted in green. However, storm surge could still access the central part of the study area from the marina.

SOURCE(S):
FEMA
ESRI

Figure 8-7: Ash Creek Open Space

LOCATION:
Fairfield, CT

N

Riverside Drive/Ash Creek Resiliency Study

MXD: Y:\1342-18\Maps\Figure 8-7 Ash Creek Open Space.mxd

Map By: MER
MMI#: 1342-18
Original: 08/31/2017
Revision: 08/31/2017
Scale: 1 inch = 600 feet

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SOURCE(S): FEMA ESRI	**Figure 8-8: Riverside Drive and Bay Edge Court Flood Protection**	**LOCATION:** **Fairfield, CT**
	Riverside Drive/Ash Creek Resiliency Study MXD: Y:\1342-18\Maps\Figure 8-8 Riverside Drive and Bay Edge Court Flood Protection.mxd	Map By: MER MMI#: 1342-18 Original: 08/31/2017 Revision: 08/31/2017 Scale: 1 inch = 600 feet

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9. Other Options

9.1 Floodable Neighborhood

Under a "floodable neighborhood" option, flood protection system components would not be pursued in the long term. Approximately 425 houses (depicted in pink on Figure 9-1) between the Beach Road boundary to the west, Jennings Beach to the south, and extending along Riverside Drive would need to be elevated to protect against the 100-year storm scenario. Approximately 200 outbuildings are also located in this area.

This option accommodates flooding. The most significant challenge with this alternative is the private cost associated with elevating a significant number of structures. Although many homes have already been elevated and additional elevations are anticipated, many homeowners do not have the resources for elevating homes.

Perhaps just as significant, utility infrastructure and roadways will need to be addressed over time to become more resilient against repeated flood events. Under current conditions for a 100-year storm, access to most of the residential neighborhood will not be possible. Major roads cut off during a storm event include Beach Road, South Benson Road, Turney Road, Riverside Drive, and Old Post Road. Flooding at the intersection of Old Post Road and Turney Road during a 100-year storm event could increase the likelihood of isolation for a large portion of the neighborhoods adjacent to Jennings Beach. Figure 9-2 depicts the roads at risk to flooding and impeded access.

Of the options presented in Section 6.1, few are practical in this area. The roads serve too many homes to be considered for abandonment. However, the town may be able to prioritize which roads are elevated while determining that some may not need to be elevated. For example, the north-south roads such as Turney Road should be more resilient while the connector streets could be left less resilient to frequent flooding. This approach would facilitate late evacuations as well as emergency access to homes during floods.

It is important to understand that the "floodable neighborhood" option is the current scenario. The town does not need to select this alternative; it is the default. However, a conscious choice to proceed in this direction may encourage the neighborhoods and town to work together to build flood resiliency by planning for groups of home elevations, stormwater system upgrades, and modest roadway elevations to maintain emergency access.

9.2 Hurricane Barrier

Section 4.1 introduced the concept of hurricane barriers for flood protection. A hurricane barrier is a specific type of floodgate, designed to prevent a storm surge. In the case of Ash Creek, a hurricane barrier along Jennings Beach could potentially mitigate the impacts of storm tidal flooding upstream. Hurricane barriers have been used in Connecticut, including most notably the Stamford Hurricane Protection Barrier[14] in Stamford Harbor (Appendix F).

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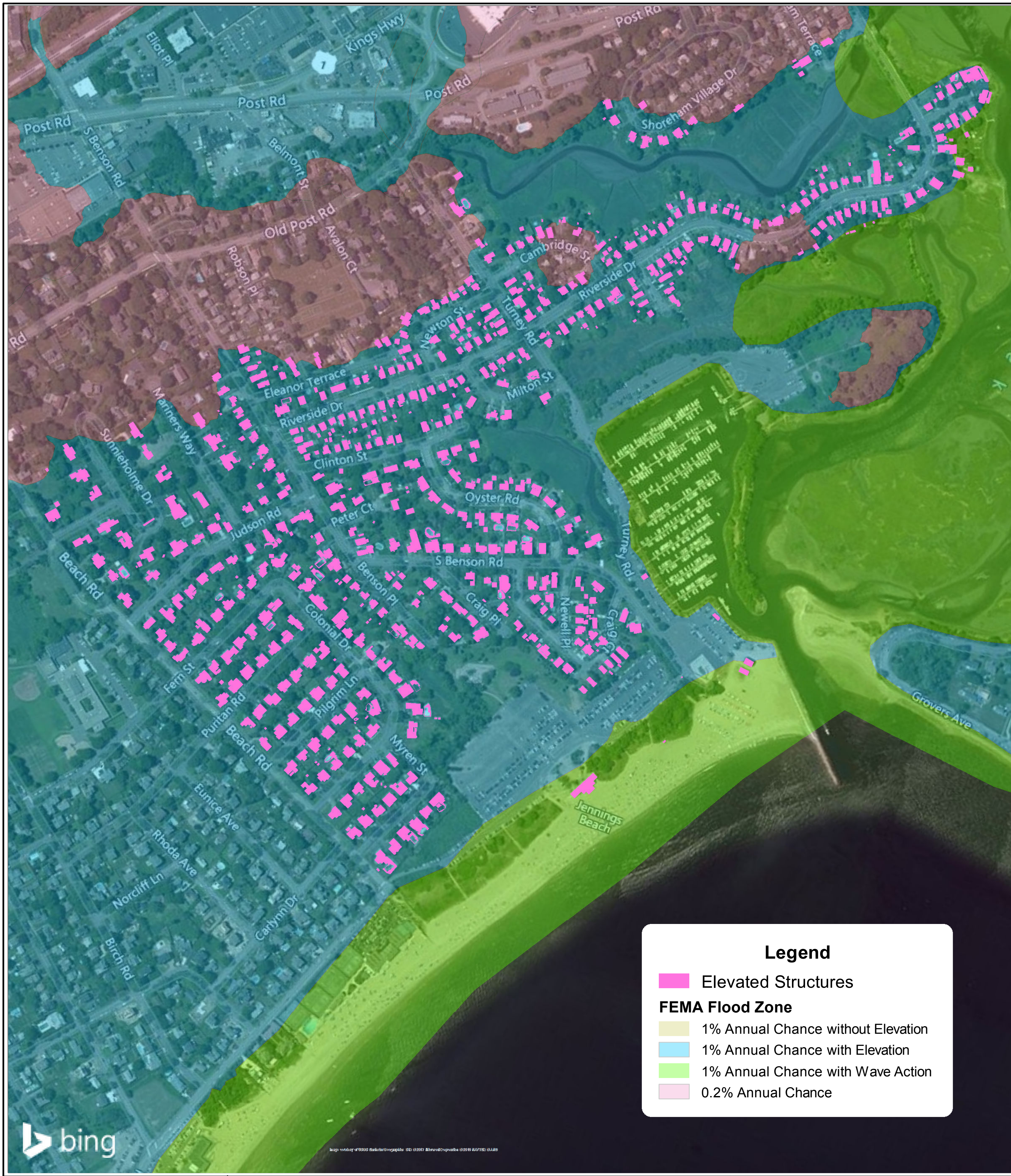
[14] http://www.nae.usace.army.mil/Missions/Civil-Works/Flood-Risk-Management/Connecticut/Stamford-Hurricane-Barrier/



SOURCE(S):
FEMA
ESRI

Figure 9-1: Flood-able Neighborhood Option

LOCATION:
Fairfield, CT

N

Riverside Drive/Ash Creek Resiliency Study

MXD: Y:\1342-18\Maps\Figure 9-1 Floodable Neighborhood Option.mxd

Map By: MER
MMI#: 1342-18
Original: 08/31/2017
Revision: 08/31/2017
Scale: 1 inch = 600 feet

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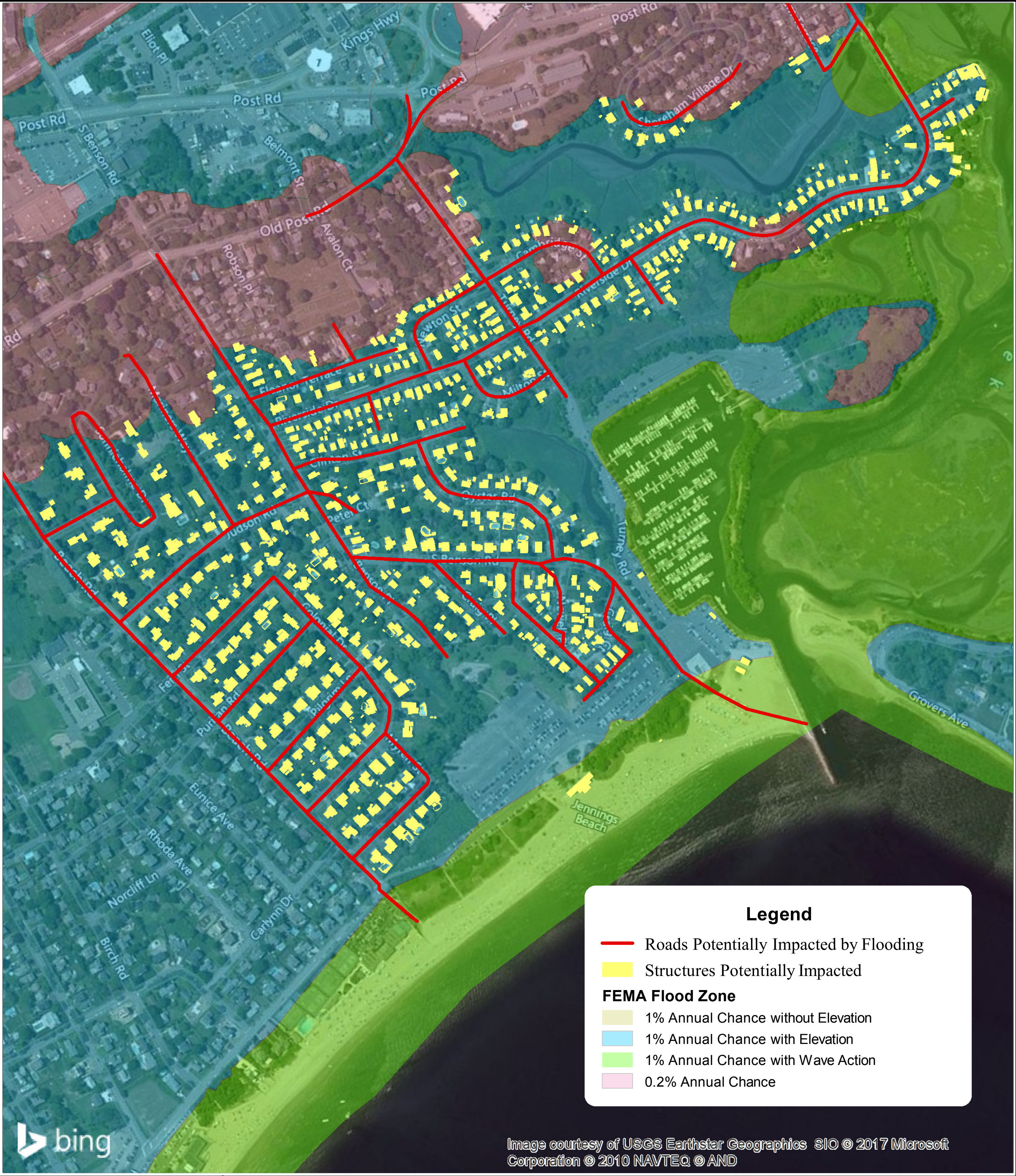

SOURCE(S):	Figure 9-2: Roads at Risk to Flooding	LOCATION: Fairfield, CT

SOURCE(S):
FEMA
ESRI

Figure 9-2: Roads at Risk to Flooding

LOCATION:

Fairfield, CT

N

Riverside Drive/Ash Creek Resiliency Study

MXD: Y:\1342-18\Maps\Figure 9-2 Roads at Risk of Flooding.mxd

Map By: MER
MMI#: 1342-18
Original: 08/31/2017
Revision: 08/31/2017
Scale: 1 inch = 600 feet

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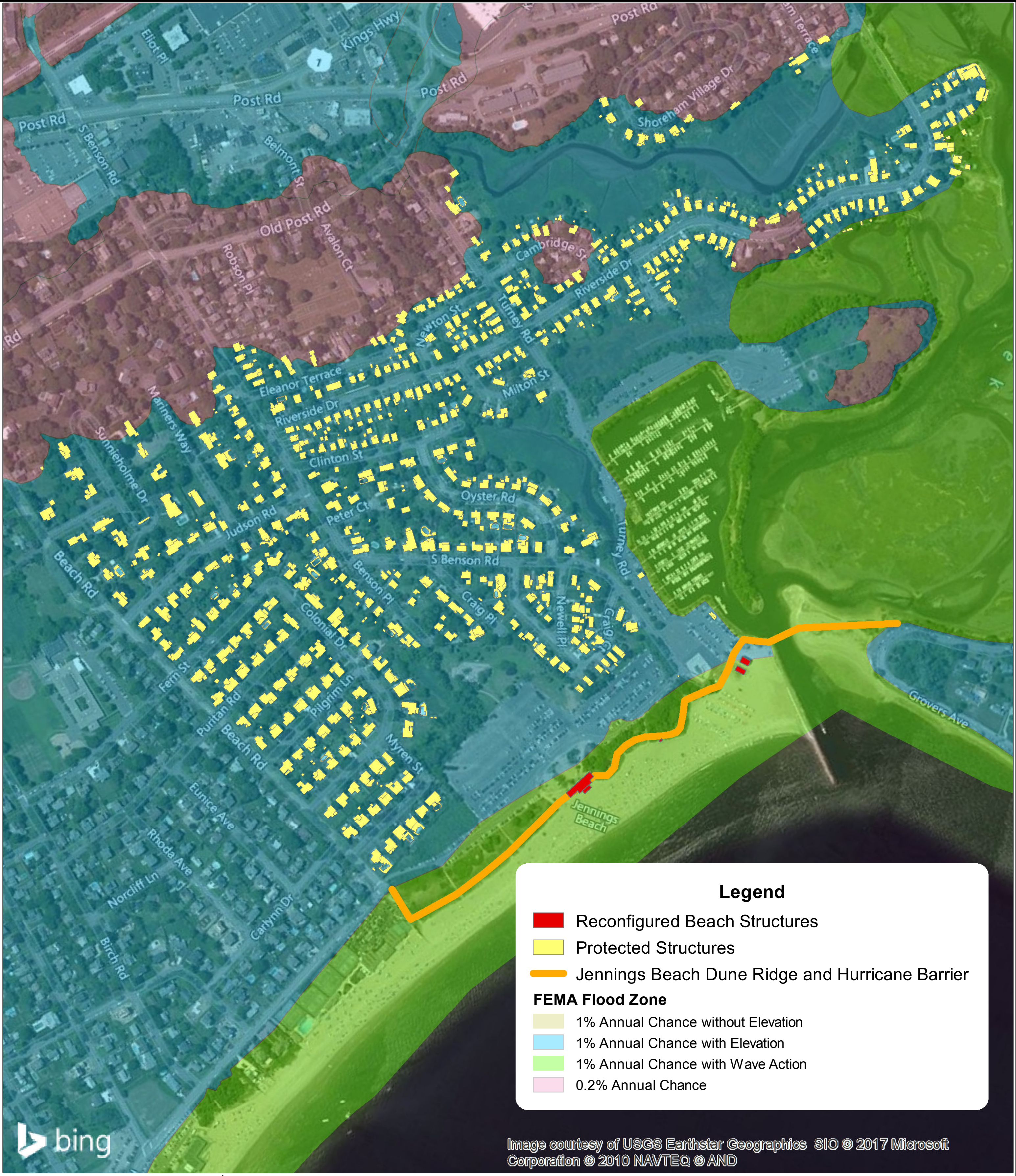
This conceptual alternative depicts a hurricane barrier beginning near the Jennings Beach jetty, which would extend to Black Rock. Both ends of the barrier system would need to tie into high ground. Improvements to the Jennings Beach dune ridge system are also anticipated in this design as this area would become one of the tie-ins to high ground.

The length of this conceptual design project spanning from the western reaches of Jennings Beach across Ash Creek to Black Rock is approximately 3,230 feet. The VE 13 zone covers the entire Jennings Beach dune ridge system. Only minor improvements may need to be made to increase the elevation of the dune to meet the BFE to protect against a 100-year storm. These improvements would include reconfiguring the Jennings Beach pavilion. The VE 15 flood zone spans the inlet from the Ash Creek jetty to Black Rock. The gate structure located here would need to be significantly elevated to meet the BFE plus some freeboard but not less than 11.5 feet in height.

BFE (NAVD88)	Flood Zone	Average Ground Elevation (ft)	Elevation Required to Raise Ground to BFE Height (ft)	Segment Length (ft)
11	AE	6.9	4.1	232.
13	VE	13.5	Negligible	2,370
15	VE	3.5	11.5	628
TOTAL				3,230

In Figure 9-3, green structures represent structures protected during a flood by installing a hurricane barrier. Red structures are the few that would need to be reconfigured.

Negative impacts of a hurricane barrier tide gate structure are possible. Even when not deployed in the "closed" position, the tide gate abutments and structure could potentially alter the sediment transport processes in Fairfield and Bridgeport.



SOURCE(S):
FEMA
ESRI

Figure 9-3: Hurricane Barrier Protection

LOCATION:
Fairfield, CT

N

Riverside Drive/Ash Creek Resiliency Study

MXD: Y:\1342-18\Maps\Figure 9-3 Hurricane Barrier Protection.mxd

Map By: MER
MMI#: 1342-18
Original: 08/31/2017
Revision: 08/31/2017
Scale: 1 inch = 600 feet

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10. Cost Estimates

The cost estimates provided in this section provide a way for understanding how much each measure costs per segment. Town staff, residents, and the FECB can then analyze whether the assumed benefit for each potential project justifies the cost. These projects can be viewed as pieces of a puzzle where some segments might be more appropriate to fund locally due to a desired lower elevation of the finished project. That portion can then be connected into state or federally funded efforts constructed at higher elevations where appropriate and higher elevation and more significant flood protection are warranted.

In the following table, segment identification prefixes match the segments identified in Sections 2 and 3 of this report. Suffixes are used to identify types of structures:

1 = Riverside Drive
2 = Ash Creek Open Space Dike
3 = Ash Creek Open Space and Marina
4 = Jennings Beach
LEV = dike, berm, or levee
FW = floodwall
TG = tide gate
PAV = beach pavilion

TABLE 10-1
Cost Estimates per Flood Protection Segment or Flood Mitigation Option

Segment or Option	Alternative Description and Elevation Height Provided	Outcomes	Estimated Cost or Cost Range*
1LEV-A-12	Elevate Riverside Drive (12')	Moderate flood protection. Approximately 3 driveways affected.	$1.5M
1LEV-A-15	Elevate Riverside Drive (15')	Moderate flood protection with sea-level rise considered. Approximately 10 driveways affected.	$2.2M
1LEV-A-18	Elevate Riverside Drive (18')	Highest flood and sea-level-rise protection. Grading required significantly affects adjacent properties and houses.	$5.5M
1FW-A-12	Flood wall along Riverside Drive (12')	Moderate to excellent flood protection depending on spatial limits of the 12', 15', or 18' sections. Higher elevations accommodate flooding under sea level rise scenarios.	$0.5M to $1M depending on where the height variations are positioned
1FW-A-15	Flood wall along Riverside Drive (15')		
1FW-A-18	Flood wall along Riverside Drive (18')		

Segment or Option	Alternative Description and Elevation Height Provided	Outcomes	Estimated Cost or Cost Range*
1TG-A	Riverside Drive tide gate system with (2) self-regulating tide gates (SRTs), and (3) flap gate replacements with food barrier with side bulkheads. Daylight portion of Ash Creek.	Some flood protection with improved flood drainage out of Turney Creek with a manual sluice gate that would allow for flooded areas to drain faster. Storm surge protection depends on heights of wall above structure.	$2.6M
1TG-B	Alternative Riverside Drive tide gate system with (2) SRTs, (2) flap gates, and (1) manual sluice gate with side bulkheads. Daylight portion of Ash Creek.	Some flood protection with improved flood drainage out of Turney Creek with a manual sluice gate that would allow for flooded areas to drain faster. Storm surge protection depends on heights of wall above structure.	$2.7M
BR	Riverside Drive bridge replacement	Accommodates increased tidal flow from new tide gates, and post-flood drainage	--- (not directly part of flood protection)
1LEV-B-12	Elevate Riverside Drive inside curve (12')	Moderate flood protection for properties on the west side of Riverside Drive. Houses on outside of curve remain unprotected.	$1.7M
1LEV-B-15	Elevate Riverside Drive inside curve (15')	Moderate flood protection for properties on the west side.	$2.0M
1LEV-B-18	Elevate Riverside Drive inside curve (18')	Moderate flood protection for properties on the west side.	$2.8M
1LEV-C-12	Elevate Riverside Drive outside curve (12')	Moderate flood protection for all houses and properties on Riverside Drive and Bay Edge Court. Visual impact – 2'-4' berm.	$1.4M
1LEV-C-15	Elevate Riverside Drive outside curve (15')	Moderate flood protection with sea-level rise for all houses and properties on Riverside Drive and Bay Edge Court. Visual impact – 5'-7' berm.	$6.7M
1LEV-C-18	Elevate Riverside Drive outside curve (18')	Highest flood protection for all houses and properties on Riverside Drive and Bay Edge Court. Visual impact – 8'-10' berm Grading affects homes on Bay Edge Drive.	$14.3M
2LEV-12	Elevate Ash Creek dike (12')	Moderate flood protection with better tidal flow and post-storm drainage.	$0.2M
2LEV-15	Elevate Ash Creek Drive dike (15')	Moderate flood protection with sea-level rise considered.	$0.3M
2LEV-18	Elevate Ash Creek Drive dike (18')	Highest flood protection with sea level rise considered but maximum impact to marshes.	$0.5M

Segment or Option	Alternative Description and Elevation Height Provided	Outcomes	Estimated Cost or Cost Range*
2FW-12	Add floodwall (12') to dike	Moderate flood protection and reduced footprint in tidal marshes.	$0.6M
2FW-15	Add floodwall (15') to dike	Moderate flood protection with sea-level rise considered and reduced footprint in tidal marshes as compared to dike raised to elevation 15'.	$0.8M
2FW-18	Add floodwall (18') to dike	Height requires steep grading. Significant tidal wetland impacts, but less impact than dike raised to elevation 18'. Visual impacts.	$1.0M
2-TG	Ash Creek tide gate – add additional 30" culvert	Additional tidal marsh flow and post-flood drainage.	$2.0M
3LEV-12	Flood protection (12') in open space and around marina	Moderate flood protection. Some modifications to marina circulation necessary.	$1.9M
3LEV-15	Flood protection (15') in open space and around marina	Moderate flood protection with sea-level rise considered. Many modifications to marina circulation necessary.	$2.7M
3LEV-18	Flood protection (18') in open space and around marina	Highest flood and sea-level-rise protection. Significant modifications to marina circulation necessary.	$3.7M
4PAV-A	Jennings Beach pavilion – breezeway floodwalls	Pavilion will be impacted by surge and surge debris. Reinforcement of pavilion needed.	$0.5M to $1M depending on nature of building reinforcement
4PAV-B	Jennings Beach pavilion – landward flood control wall	Connects to existing wall and existing vegetated berm. Surge protection for area behind. No pavilion protection. Reinforcement of pavilion needed. Need to determine access.	$0.4M
4PAV-C	Jennings Beach pavilion – seaward flood control wall around patio	Connects to existing wall and existing vegetated berm. May reduce flooding impacts to pavilion. Need to determine access. Potential scour.	$0.6M
4PAV-D	Relocate pavilion or reconstruct upland	Pavilion is protected. Access to new pavilion will need to be determined.	$2M to $3M
4LEV-12	Maintain Jennings Beach berm	Moderate flood protection (same as current protection).	<$0.1M

Segment or Option	Alternative Description and Elevation Height Provided	Outcomes	Estimated Cost or Cost Range*
4LEV-15	Maintain and minimally heighten Jennings Beach berm	Moderate flood protection with sea-level rise considered. Some earthwork required.	<$0.1M
4LEV-18	Heighten Jennings Beach berm	Highest flood and sea-level-rise protection. Moderate earthwork required.	$0.3M
5LEV-12	Elevate Turney Road (12')	Provides elevated access. Provides flood protection to areas west. Approximately 5 driveways affected.	$1.8M
5LEV-15	Elevate Turney Road (15')	Provides elevated access. Provides flood protection to areas west. Approximately 13 driveways and 2 houses affected.	$3.0M
5LEV-18	Elevate Turney Road (18')	Provides elevated access. Provides flood protection to areas west. Approximately 10 driveways and 11 houses affected.	$6.8M
HB	Hurricane barrier across Ash Creek	Surge protection to entire study area.	$20M to $30M based on planning-level costs estimated for a barrier at the Mystic River
AQ	Property acquisitions	Can be targeted to areas needed. FEMA funding sometimes available.	$0.5M to $2.5M per property (depends on individual market values)
LOMR	Letter of Map Revision (LOMR) for VE 15 area of Riverside Drive	Allows for decreased design heights for elevated flood protection structures within this area.	$50,000
FN	Floodable Neighborhood: elevate homes as well as roads to maintain access	Elevate all homes in area. Estimated 300+ homes. Need elevated roadway access for future evacuations.	$0.1M to $0.5M per property

*Estimated costs are based on quantities, earthwork, and/or per-foot costs for linear structures. Acquisition of private property is not included in any estimate except for flood mitigation option AQ.

11. Regulatory Permit Review

The proposed flood mitigation projects for Riverside Drive/Ash Creek are all located near federally regulated tidal waters or wetlands or near or below the state's Coastal Jurisdiction Line (CJL), which is elevation 5.2 NAVD88 in Fairfield. The permitting requirements for this type of work have been described below for applicable agencies with a project-specific table to follow that indicates expected permitting for each flood protection segment, option, or alternative.

11.1 Federal Permitting

The U.S. Environmental Protection Agency (EPA) through Section 404 of the Clean Water Act (CWA) regulates activity within the waters of the United States, including tidal wetlands. The 404 program's primary objective is that no discharge of dredged or fill material may be permitted if: (1) a practicable alternative exists that is less damaging to the aquatic environment or (2) the nation's waters would be significantly degraded. The USACE serves as the permit reviewer in some capacity for most requests within tidal wetlands. Section 404 requires a permit be issued prior to any dredging or fill material being discharged into waters or tidal marshlands of the United States. Applicants must first show that steps have been taken to avoid impacts to wetlands, streams, and other aquatic resources; that potential impacts have been minimized; and that compensation will be provided for all remaining unavoidable impacts. Compensatory mitigation may include restoration, establishment/creation of new wetland or aquatic resources, enhancement, or preservation.

USACE issues Nationwide Permits (NWP) for certain categories of work. In lieu of these, CTDEEP adopted a conditional 401 State Water Quality Certification for 21 General Permit categories for activities (both in tidal and nontidal waters) that are specifically applicable to our region that allow for expedited review times for those activities that fall under certain identified thresholds. The thresholds are delineated by Self-Verification (SV) and Pre-Construction Notification (PCN). SV indicates a limited scope and allows for the applicant's proposal to be shared via the state DEEP's ongoing communication/ coordination with USACE. The PCN usually signifies a larger scope or project area and requires essentially a limited coapplication to the USACE at the same time the state DEEP application is processed. Scope that exceeds that allowed for either SV or PCN review will require an Individual Permit (IP) and be subject to the USACE's standard permitting requirements per EPA's CWA Section 404(b)(1) Guidelines.

The state's General Permit categories are effective from August 2016 through August 2021 and include some activities that are potentially relevant to the Riverside Drive/Ash Creek projects, namely the following:

- GP#2 - Repair or maintenance to existing, currently serviceable structures/fill
- GP#7 - Beach nourishment
- GP#9 - Shoreline and bank stabilization
- GP#18 - Linear transportation projects (wetland crossings)
- GP#19 - Stream, River, and Brook (nonwetland) crossings

See New England Division for the USACE at http://www.nae.usace.army.mil/Missions/Regulatory.aspx for these specific guidance documents. However, GP#18 projects with impacts over 1 acre are ineligible, and projects larger than that may still require IP review. Should the activity meet the requirements of the General Permit activities allowed, these are processed primarily at the state level described in the next section with the CTDEEP coordinating the permitting process with USACE.

11.2 State Permitting for Coastal Activities

In Connecticut, permitting for activities within tidal waters and wetlands is conducted by DEEP's newly reorganized Land and Water Resources Division (LWRD). Within the previously mentioned USACE General Permit activities, the state DEEP and LWRD would process many of the Riverside Drive/Ash Creek mitigation proposals under permits for Structures, Dredging, and Fill. Findings for Coastal Zone Management (CZM) consistency by the DEEP are also required, and if the project has potential to impact any endangered or threatened species, or species of special concern, or their essential habitats, review of Connecticut's Natural Diversity Database (NDDB) areas with a referral to DEEP's Wildlife staff may also be required. It should be noted that a portion of Riverside Drive, Jennings Beach, and most of Ash Creek are located within the current NDDB area of referral.
ftp://ftp.state.ct.us/pub/dep/gis/endangeredspeciesmaps/nd051.pdf

A Certificate of Permission (Connecticut General Statutes [CGS] 22a-363b) can be issued for repair of previously permitted structures, which appears to potentially be applicable to tide gate replacements at Turney Creek and Riverside Creek. The majority of the segments and projects described in this report appear to require permitting through the IP described above or the General Permit application process for Structures, Dredging and Fill for regulated activities such as filling, erection of structures or potential obstacles or obstructions to tidal flow, and construction staging within the CJL and/or tidal wetlands (CGS 22a-28 to 35a).

Projects with State funding – or federal funding routed through the State – require a Flood Management Certification (FMC) signed by a certified engineer www.ct.gov/deep/lib/deep/Permits_and.../IWRD_AttF.doc that states that the project design is compliant with flood design requirements per CGS 25-68h-1 through 25-68h-3. The FMC may be applicable to many of the segments and projects described in this report.

11.3 Local Permitting

State statute (CGS 25-84 through 25-95) enables local municipalities such as Fairfield to have a FECB that consists of at least five members who are electors of the town. FECBs have the ability to plan, lay out, acquire, construct, reconstruct, repair, maintain, supervise, and manage local flood or erosion control systems. FECBs also have the ability to purchase private properties needed for flood or erosion control systems, enacting condemnation proceedings if necessary. In addition, FECBs can vote to issue bonds and levy additional special fund assessments for costs related to projects for properties that may benefit from flood or erosion control projects.

The Riverside Drive/Ash Creek mitigation project sites are all located partly or completely within the FEMA SFHA, which requires at a minimum a Development Permit per Section 32.5 of the Fairfield Zoning Regulations. More specifically, Section 24 (Land Excavation and Fill Regulations) appears to require a Special Permit for the filling activities required as part of the construction for many of the alternatives.

As all the proposed mitigation sites are located within the state's coastal boundary, a Coastal Site Plan review per Section 2.14 is required before the town's Planning and Zoning Commission. As most of the projects are shoreline flood and erosion control structures, mandatory referral to the CTDEEP within 15 days of application receipt is required. Although most of the proposed projects appear to require a Special Permit, which is a public hearing, the CTDEEP may also request a public hearing before the local Planning and Zoning Board had one not been required.

It should be noted that Fairfield's Purchasing Department requires that bidders for projects and their contractors be responsible for securing all necessary permits, state and local, as required by the town. All application and permit fees are waived for Town of Fairfield projects.

In Table 11-1, FMC is listed for scenarios where State funding is involved.

TABLE 11-1
Permits Needed per Flood Protection Segment or Flood Mitigation Option

Segment or Option	Alternative Description and Elevation Height Provided	Federal or State Permitting Required	USACE and/or DEEP	Local Permit
1LEV-A-12	Elevate Riverside Drive (12')	GP #18, FMC	DEEP	CSPR & SP
1LEV-A-15	Elevate Riverside Drive (15')	GP #18, FMC	DEEP	CSPR & SP
1LEV-A-18	Elevate Riverside Drive (18')	GP #18, FMC	DEEP	CSPR & SP
1FW-A-12	Floodwall along Riverside Drive (12')	FMC	DEEP	CSPR
1FW-A-15	Floodwall along Riverside Drive (15')	FMC	DEEP	CSPR
1FW-A-18	Floodwall along Riverside Drive (18')	FMC	DEEP	CSPR
1TG-A	Riverside Drive tide gate system with (2) SRTs, and (3) flap gate replacements with flood barrier with side bulkheads. Daylight portion of Ash Creek.	Certificate of Permission, GP#2, previously permitted. (SV eligible) or IP if changes are significant FMC	DEEP	CSPR
1TG-B	Alternative Riverside Drive tide gate system with (2) SRTs, (2) flap gates, and (1) manual sluice gate with side bulkheads. Daylight portion of Ash Creek.	Certificate of Permission, GP#2, previously permitted. (SV eligible) or IP if changes are significant FMC	DEEP	CSPR
BR	Riverside Drive bridge replacement	GP#18 FMC	DEEP	CSPR/SP
1LEV-B-12	Elevate Riverside Drive inside curve (12')	IP due to tidal wetland impacts at Turney Creek FMC	DEEP	CSPR/SP with referral to DEEP
1LEV-B-15	Elevate Riverside Drive inside curve (15')	IP due to tidal wetland impacts at Turney Creek FMC	USACE & DEEP	CSPR/SP with referral to DEEP
1LEV-B-18	Elevate Riverside Drive inside curve (18')	IP due to tidal wetland impacts at Turney Creek	USACE & DEEP	CSPR/SP with referral

Segment or Option	Alternative Description and Elevation Height Provided	Federal or State Permitting Required	USACE and/or DEEP	Local Permit
		FMC		to DEEP
1LEV-C-12	Elevate Riverside Drive outside curve (12')	IP due to tidal wetland impacts at Ash Creek FMC	USACE & DEEP	CSPR/SP with referral to DEEP
1LEV-C-15	Elevate Riverside Drive outside curve (15')	IP due to tidal wetland impacts at Ash Creek FMC	USACE & DEEP	CSPR/SP with referral to DEEP
1LEV-C-18	Elevate Riverside Drive outside curve (18')	IP due to tidal wetland impacts at Ash Creek FMC	USACE & DEEP	CSPR/SP with referral to DEEP
2LEV-12	Elevate Ash Creek dike (12')	GP#2 FMC	DEEP	CSPR/SP with referral to DEEP
2LEV-15	Elevate Ash Creek Drive dike (15')	IP (tidal wetland encroachment) FMC	USACE & DEEP	CSPR/SP with referral to DEEP
2LEV-18	Elevate Ash Creek Drive dike (18')	IP (tidal wetland encroachment) FMC	USACE & DEEP	CSPR/SP with referral to DEEP
2FW-12	Add floodwall (12') to dike	GP (category uncertain) FMC	USACE & DEEP	CSPR/SP with referral to DEEP
2FW-15	Add floodwall (15') to dike	IP (tidal wetland encroachment) FMC	USACE & DEEP	CSPR/SP with referral to DEEP
2FW-18	Add floodwall (18') to dike	IP (tidal wetland encroachment) FMC)	USACE & DEEP	CSPR/SP with referral to DEEP
2B-TG	Ash Creek tide gate – Add additional 30" culvert	Certificate of Permission, GP#2, previously permitted. (SV eligible) FMC	DEEP	CSPR
3LEV-12	Flood protection (12') in open space and around marina	GP (tidal wetland encroachment may be minimized) FMC	USACE & DEEP	CSPR/SP with referral to DEEP
3LEV-15	Flood protection (15') in open space and around marina	IP (tidal wetland encroachment) FMC	USACE & DEEP	CSPR/SP with referral to DEEP
3LEV-18	Flood protection (18') in open space and around marina	IP (tidal wetland encroachment) FMC	USACE & DEEP	CSPR/SP with referral to DEEP
4PAV-A	Jennings Beach pavilion – breezeway floodwall	FMC	DEEP	CSPR with referral to

Segment or Option	Alternative Description and Elevation Height Provided	Federal or State Permitting Required	USACE and/or DEEP	Local Permit
				DEEP
4PAV-B	Jennings Beach pavilion – landward flood control wall	FMC	DEEP	CSPR with referral to DEEP
4PAV-C	Jennings Beach pavilion – seaward flood control wall around patio	FMC	DEEP	CSPR with referral to DEEP
4PAV-D	Relocate pavilion or reconstruct upland	Depends on new location	DEEP	CSPR
4LEV-12	Maintain Jennings Beach berm	--	--	--
4LEV-15	Maintain and minimally heighten Jennings Beach berm	--	DEEP	CSPR
4LEV-18	Heighten Jennings Beach berm	GP#9 FMC	DEEP	CSPR/SP with referral to DEEP
5LEV-12	Elevate Turney Road (12')	GP#18 FMC	DEEP	CSPR/SP with referral to DEEP
5LEV-15	Elevate Turney Road (15')	GP#18 FMC	DEEP	CSPR/SP with referral to DEEP
5LEV-18	Elevate Turney Road (18')	GP#18 FMC	DEEP	CSPR/SP with referral to DEEP
HB	Hurricane barrier across Ash Creek	IP FMC	USACE & DEEP	CSPR with referral to DEEP
AQ	Property acquisitions	N/A	N/A	N/A
FN	Floodable Neighborhood: elevate homes as well as a road to maintain access	If homes have project area between Mean High Water and CJL, then a Certificate of Permission is required.	DEEP	CSPR if within 100 feet of resources

DEEP – State Department of Energy and Environmental Protection
CT CAM – Required Referral to State
CSPR –Coastal Site Plan Review by Local Planning & Zoning Board
GP – General Permit
PCN – Preconstruction Notification
SV – Self Verification
SP – Special Permit
USACE – US Army Corps of Engineers

12. Conclusion and Recommendations

12.1 Conclusion

Through the coordination of its Engineering and Conservation staff and the FECB, the Town of Fairfield has reviewed flood mitigation alternatives to prevent the Riverside Drive/Ash Creek neighborhood from experiencing future flood damage. Current risks and future sea-level rise impacts were reviewed in relation to the type and height of projects that should be contemplated given the different requirements of potential funding sources. It is understood that the alternatives discussed as part of this report are only a small portion of a broader system that would need to be installed to eliminate flooding risk to the town's coastal floodplain.

Of all the alternatives, the Riverside Drive tide gate system replacement project is the town's highest priority project due to its age and failing condition and the need to better address drainage flow out of Turney Creek following a significant storm event. Town staff has already initiated potential local funding for this project. All other alternatives presented as part of this report require additional discussion with town residents to determine if they support any of the options and if the resulting benefits justify the significant costs. It should be noted that the permit application process for some of these options may be challenging particularly if other alternatives result in less impact to tidal wetlands and other resources.

12.2 Recommendations

The following recommendations are offered. The sequence has been arranged such that each step will facilitate execution of the next step. However, it is important that the town implement specific projects in a manner that secures funding and meets the public's expectations.

a. Continue to encourage individual home elevations throughout the coastal plain flood zones, working in connection with the town's recent entry and subsequent participation in the CRS.
b. Replace Riverside Drive tide gates at Turney Creek with allowance for future construction of a flood protection system component (for example, future construction of a vertical wall on top of the tide gate structure).
c. Replace Ash Creek Open Space tide gate at Riverside Creek with allowance for future widening or heightening of the dike (in other words, ensure that the culvert can withstand additional weight and that the ends will have clearance if new fill is placed).
d. Close the low-lying gap at the Jennings Beach pavilion building with one of the following options:
    - Relocate the building and connect the two ends of the wooded dune ridge.
    - Retrofit the building to serve as storm surge protection.
    - Build floodwalls in front of or behind the building to provide storm surge protection.
e. Request and obtain a FEMA map revision for the VE 15 sections of Turney Creek and Riverside Creek and for the VE 13 section of the South Benson Marina boat basin.
f. Following the FEMA map revision, pursue segments of a flood protection system in the following sequence:
    1. Riverside Drive at Turney Creek (Construct a wall alongside the road and along top of tide gate structure; or elevate the road.)
    2. Ash Creek open space dike (Construct a wall on dike and/or increase the width and height of the dike.)

3. West side of South Benson Marina with connection to Jennings Beach ridge (Construct a berm combined with elevated grade, internal circulation, and parking areas.)

g. Continue working with property owners to identify methods of providing flood protection to areas west of Ash Creek. This *may* include the following:
   1. Elevating the section of Riverside Drive inclusive of the bend
   2. Constructing a low wall along the section of Riverside Drive inclusive of the bend or
   3. Elevating Turney Road

If elevating the section of Riverside Drive inclusive of the bend [g(1)] or constructing a low wall along the section of Riverside Drive inclusive of the bend [g(2)] is selected in the future, then a wall along Riverside Drive at the tide gate, the elevated Ash Creek Open Space dike, and flood protection in the marina [f(1), f(2), and f(3)] will connect to it. These individual projects will work in concert for flood protection.

If elevating Turney Road [g(3)] is selected in the future, then flood protection in the marina [f(3)] will connect to it. If a wall along Riverside Drive at the tide gate and the elevated Ash Creek Open Space dike [f(1) and f(2)] have already been constructed, they will provide some limited flood protection on their own. In other words, these efforts will not have been wasted resources if the town later pursues elevation of Turney Road as flood protection.

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