Looking Beyond the Levee

Nonstructural Flood Mitigation Alternatives

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CDM Smith

Outline

- Project History
- Project Summary
- Nonstructural Evaluation
- Recommendations
- Questions

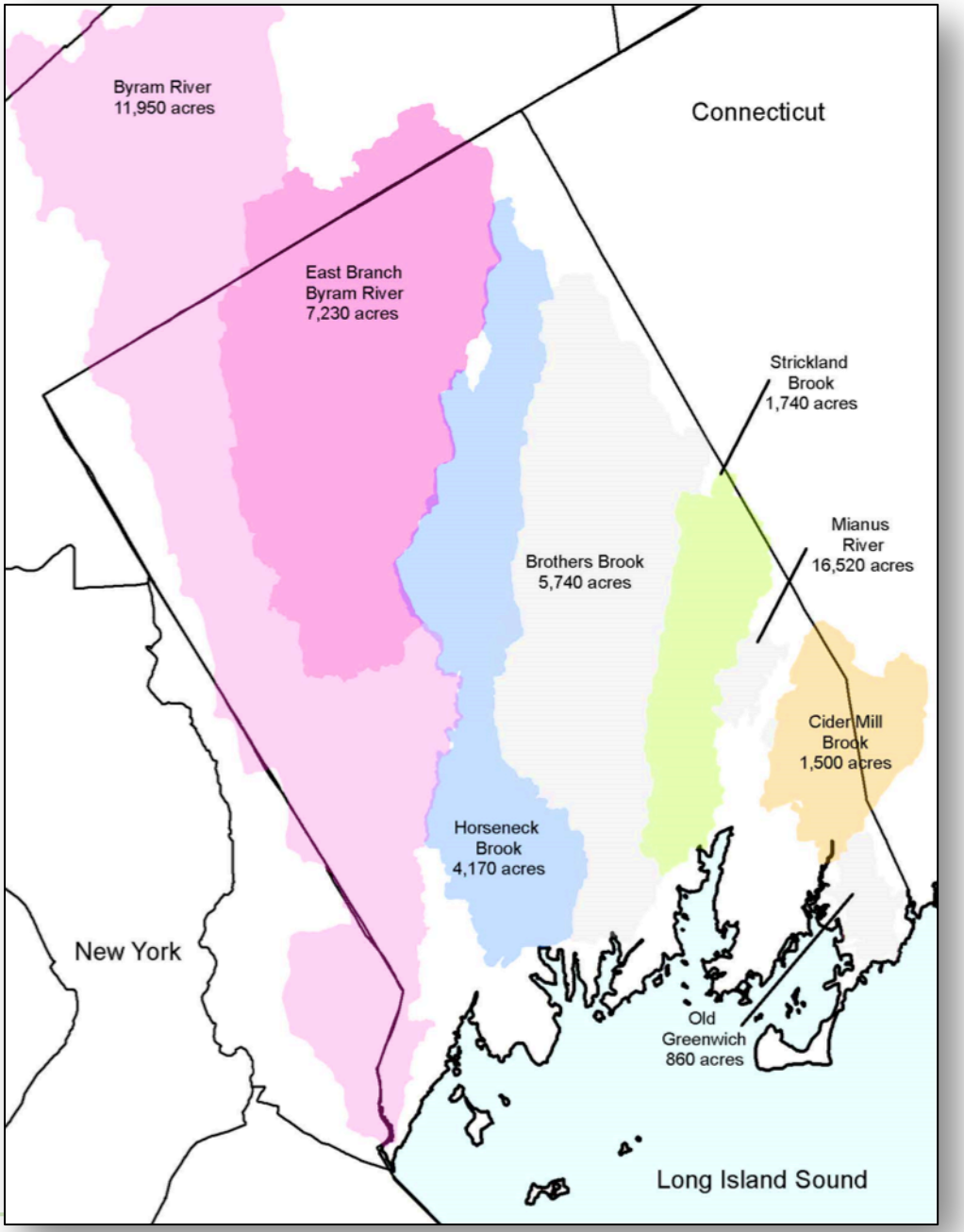
Project History

- Several damaging storm events over the last century
  - 1955, 1972, 2007, 2010
- Watershed Studies Completed between 2007 - 2010
- Capital Improvement Program (CIP) Prioritization and Ranking
  - 65 Structural Recommendations

Project History

Greenwich Watersheds:

- Byram River
- Horseneck Brook
- Brothers Brook
- Strickland Brook
- Mianus River
- Cider Mill Brook
- Old Greenwich
- Coastal Areas



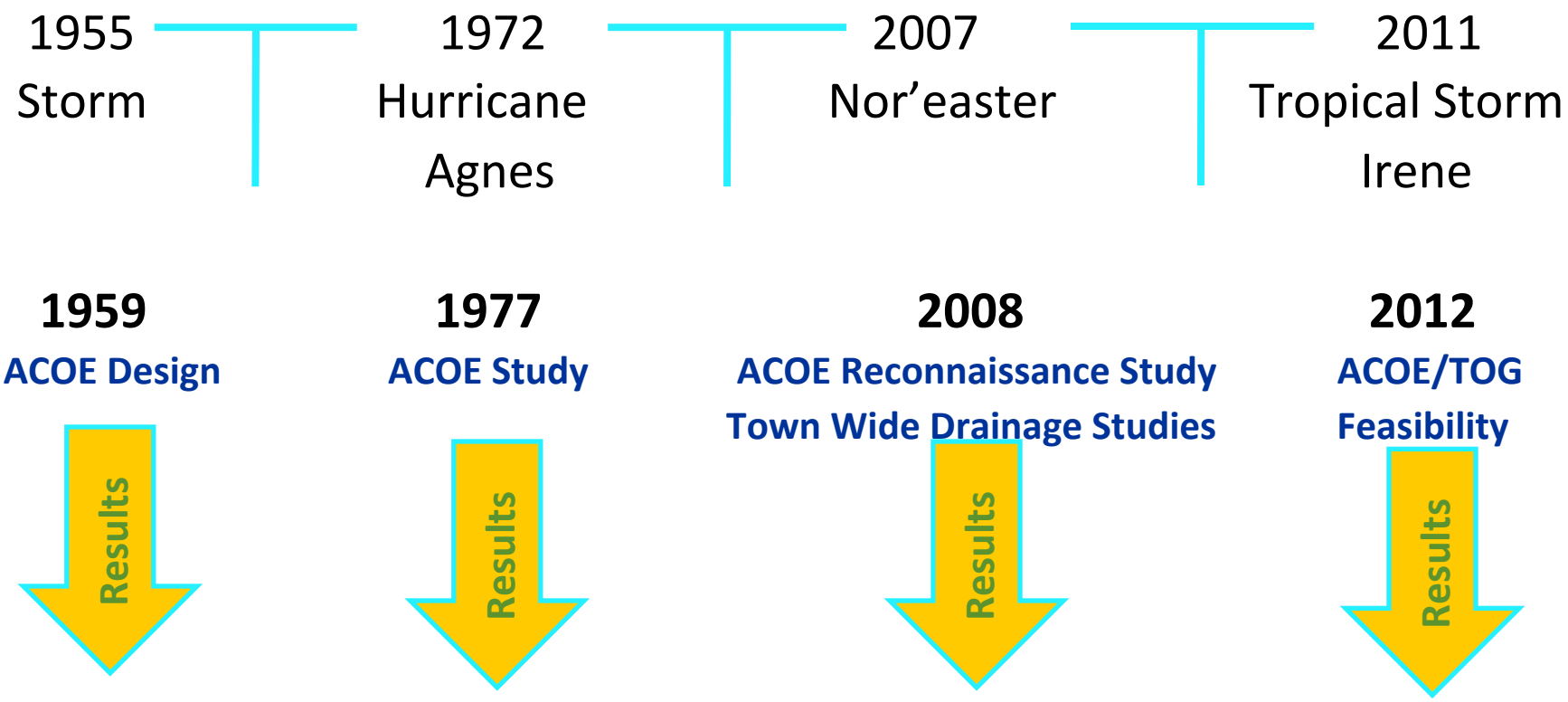
Project History

CIP Prioritization and Ranking

1) Additional Railroad Culverts
2) Cos Cob Harbor Diversion Piping
3) Stone Arch Bridges Removal
4) Sound Beach Avenue/Arcadia Road Storm Drain Replacement
5) East Putnam Bridge & Roadway Reconstruction
6) Pemberwick Road Erosion Protection
7) Church Street Storm Drain Replacement
8) Glenville Road Bridge Replacement
9) Brookside Drive Diversion Culvert
10) Mianus Park Pond Dam Improvements

Byram River
Horseneck Brook
Brothers Brook
Strickland Brook
Cider Mill Brook
Old Greenwich

Project History – Byram River Study



Project Summary

Evaluated the feasibility of nonstructural measures for flood prone areas within each watershed

- Data collection
- Reviewed all structures within flood boundaries for nonstructural recommendations
- Developed conceptual level project costs for nonstructural recommendations
- Compared costs to structural improvements recommended as part of previous studies

Nonstructural vs Structural Flood Protection

Nonstructural

Alter the impact or consequences of flooding

Adaption to the natural floodplain without changing flood characteristics

Dry Floodproofing

Wet Floodproofing Ringwalls

Elevation

Acquisition

Structural

Alter the characteristics of the flood

Reduce the probability of flooding in the location of interest by changing flood characteristics and limits

Dams

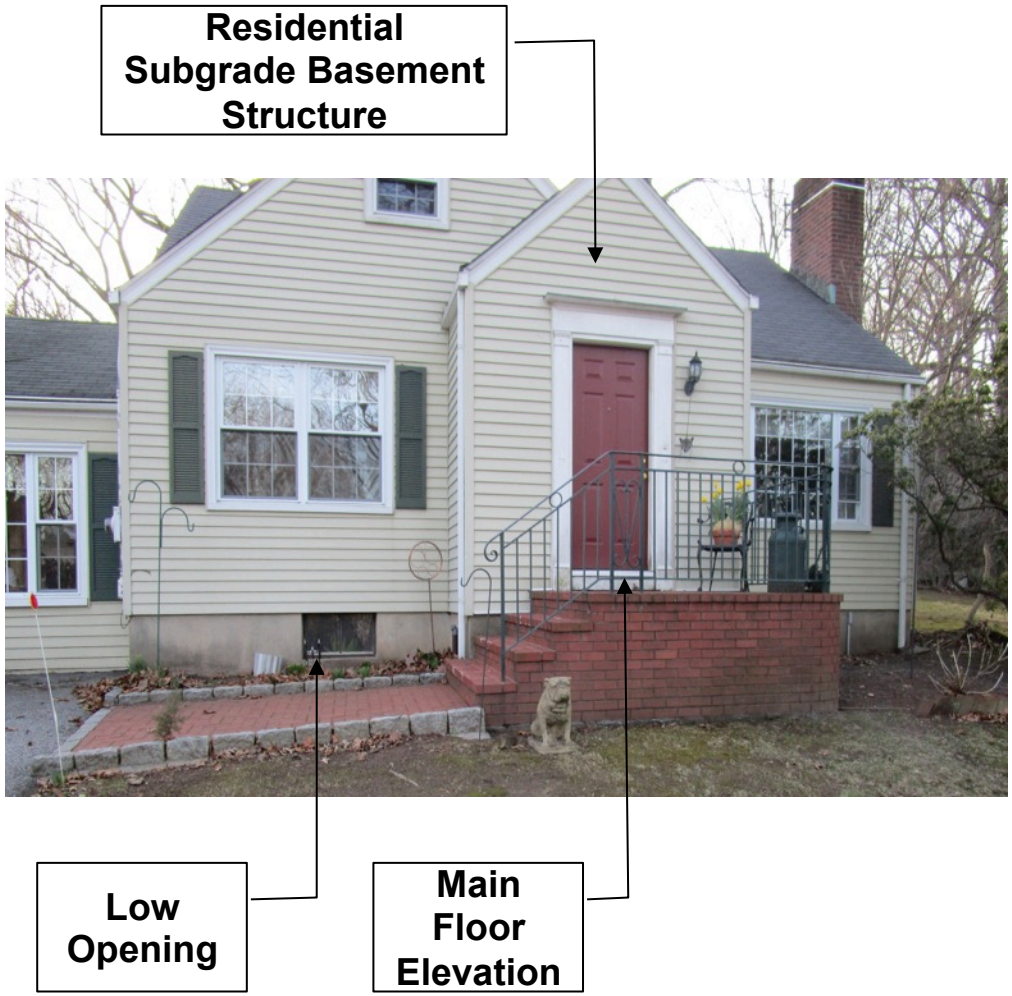
Levees

Floodwalls

Nonstructural Evaluation

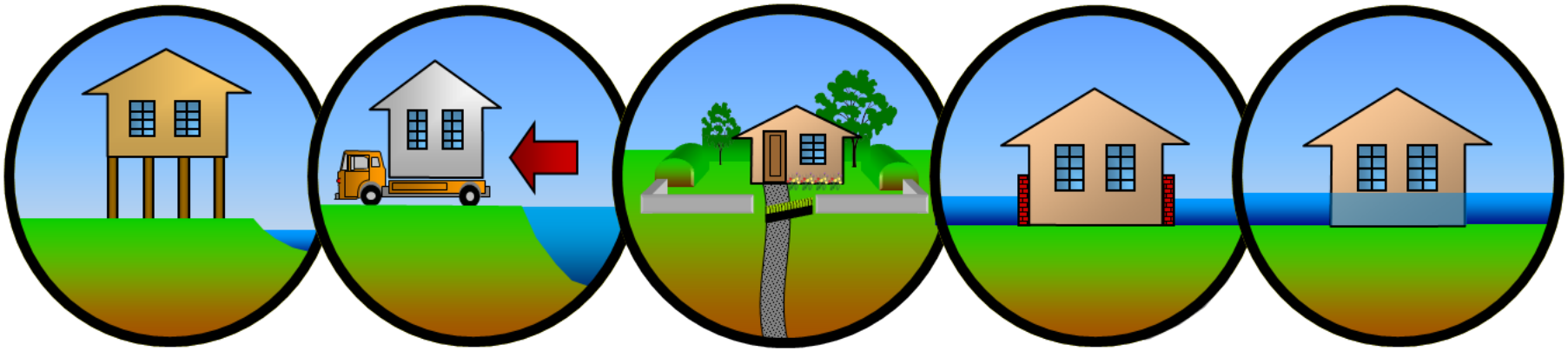
Structure Inventory

- Structure Type
- Land Use
- Construction
- Condition
- Assessed Value
- Garage
- Foundation
- Ground Elevation
- Main Floor Elevation
- Low Opening



Nonstructural Plan

- Evaluated all 493 structures for the 10, 25, 50, 100 and 500 year storm events
- Recommendations for flood proofing



Elevation

Relocation

Localized

Dry

Wet

Levees and ringwalls

Floodproofing

Floodproofing

Nonstructural Evaluation

- 10, 25, 50, 100 and 500 year storm events
- Algorithm

STREET ADDRESS		PARCEL PERIMETER (RINGWALL LENGTH, FT)	HEIGHT OF 10-YEAR RINGWALL	HEIGHT OF 100-YEAR RINGWALL	HEIGHT OF 500-YEAR RINGWALL
11	Hillside Avenue	Apart of 13 Riverdale Ringwall	-	-	-
13	Riverdale Avenue	700	7	13	16
15	Riverdale Avenue	450	5	11	14
17	Riverdale Avenue				
19	Riverdale Avenue				
21	Riverdale Avenue				
23	Riverdale Avenue				
25	Riverdale Avenue				
777	West Putnam Avenue Lot 48A	1, 300	5	12	14

Structure Type Slab-on-Grade Foundation

Description Structures that are constructed on a slab foundation at grade.

Assumptions Structures will not be dry flood proofed for main floor flood depths greater than 2-feet.

Algorithm

Residential

I. If FE < GE then No Flood Proofing Required
II. If FE+1 < ME then No Flood Proofing Required
III. If FE+1 > ME then
  a. If FE+1 > ME+3 then
    i. If Poor Condition then Buyout
    ii. Otherwise Elevation
  b. If FE+1 < ME+3 then
    i. If FE+1 < GE+6 then Dry Flood Proofing or Ringwall
    ii. If FE+1 > GE+6 then Dry Flood Proofing

Nonresidential

I. If FE<GE then No Flood Proofing Required
II. If Wood or Metal Construction Type then
  a. If FE+1 < ME then No Flood Proofing Required
  b. If FE+1 > ME then
    i. If FE+1 > ME+3 then
      1. If Poor Condition then Buyout
      2. Otherwise Elevation
    ii. If FE+1 < ME+3 then Dry Flood Proofing or Ringwall
III. If Masonry Construction Type then
  a. If FE +1 < ME then No Flood Proofing Required
  b. If FE +1 > ME then
    i. If FE+1 > GE+3 then Ringwall
    ii. If FE+1 < GE+3 then Dry Flood Proofing or Ringwall

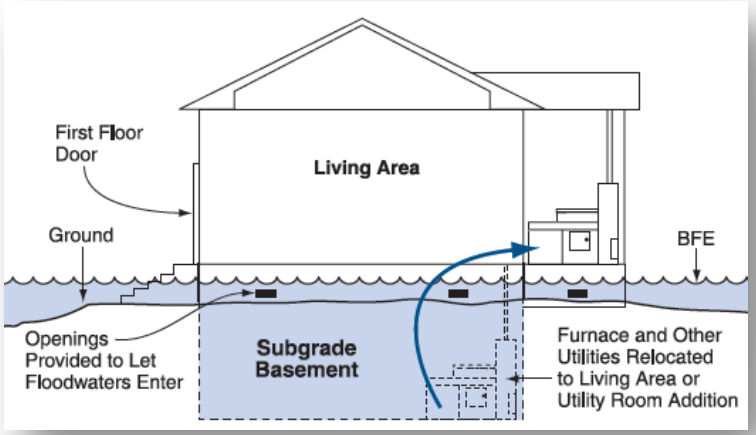
Wet Flood Proofing

What is wet flood proofing:

- Modifying uninhabited portions of the home (i.e. crawlspace or basement) so that floodwaters will enter but not cause significant damage to either the home or its contents
- Reduces risk of structural collapse as hydrostatic pressures are allowed to equalize

Things to consider:

- Requires space above the base flood elevation (BFE) to store items temporarily or permanently
- Any service equipment, such as furnaces and water heaters, below the BFE should be protected by either moving the equipment to another floor, elevating it, or protecting it in place
- Building can not be occupied during a flood, and will require water to be removed after the event



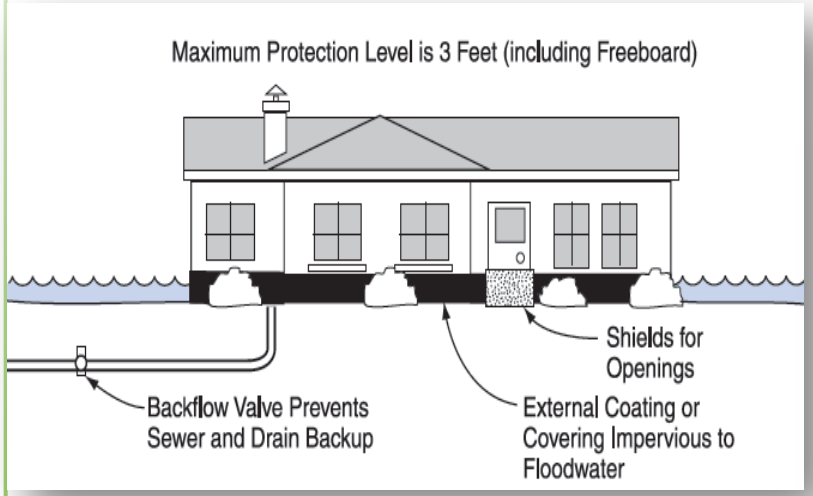
Dry Flood Proofing

What is dry flood proofing:

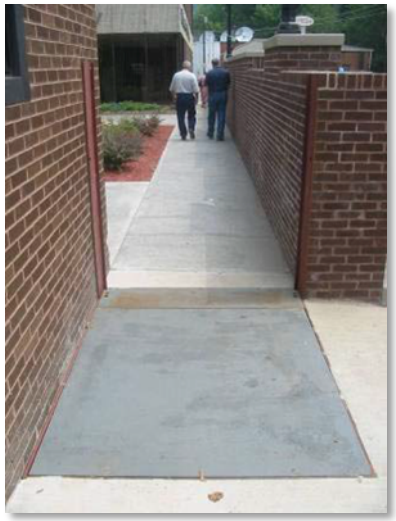
- Sealing your home to prevent floodwater from entering.
- Not recommended for flood depths greater than 3-feet.

Things to consider:

- Seal walls with waterproof coatings, impermeable membranes, or supplemental layers of masonry or concrete.
- Shield all openings, such as doors and windows, below the BFE.
- Requires human intervention.
- For homes with basements it is recommended to use wet flood proofing in conjunction with dry flood proofing.



Ringwalls

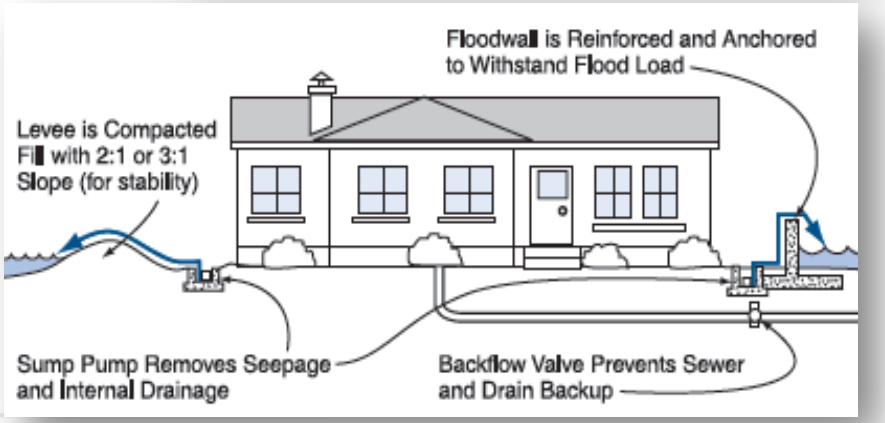


What are ringwalls:

- Building a ringwall, such as a floodwall or levee, around your home to hold back floodwaters.
- Can surround a home or protect isolated openings such as doors, windows, and walkout on-grade basements depending on flood depths, site topography, and design preferences.
- Primarily recommended for commercial properties or larger multi-family properties

Things to consider:

- The home and the area around the home will be protected from inundation, and no significant changes to the home will be required.
- No damages will be caused through inundation, hydrodynamic pressure, erosion, scour, or debris impact.
- Ringwalls should be designed for an elevation equal to the BFE.



Elevation

What is elevation:

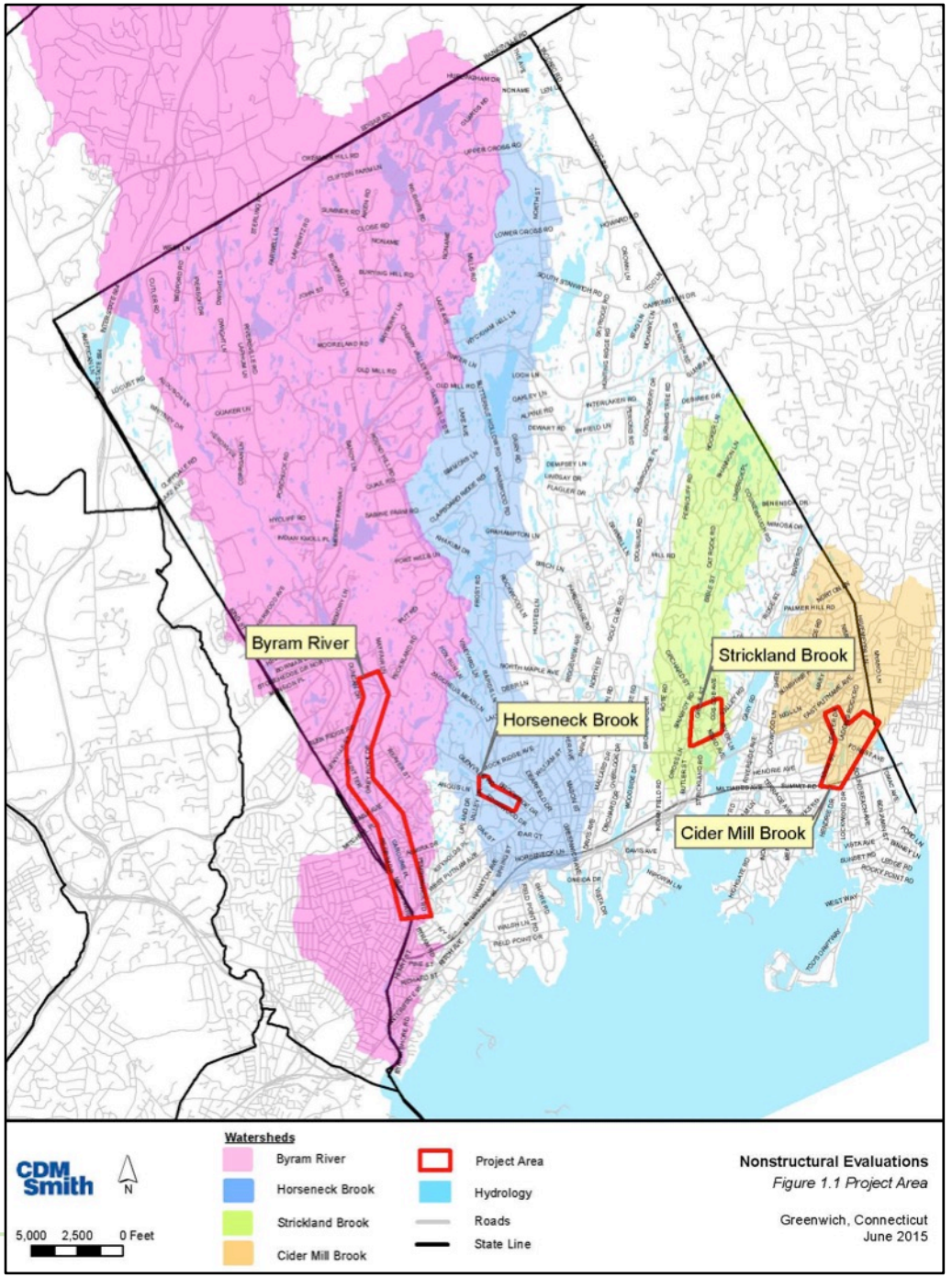
- Raising a home to prevent floodwaters from reaching living areas.
- Construct new or extended foundation or elevate on fill, piles, or columns.

Things to consider:

- House must be structurally sound.
- Homes with basement will require it to be filled as part of elevation.
- Space below a house on an open elevation can be utilized for parking.
- ACOE typically recommends the property to be raised above the BFE.

Nonstructural Studies

- Byram River
- Horseneck Brook
- Strickland Brook
- Cider Mill Brook



Byram River

Alternatives

- No action
- Structural – Levee and floodwalls
- Nonstructural
- Bridge replacement
- Combinations

Benefit Cost Ratio (BCR)

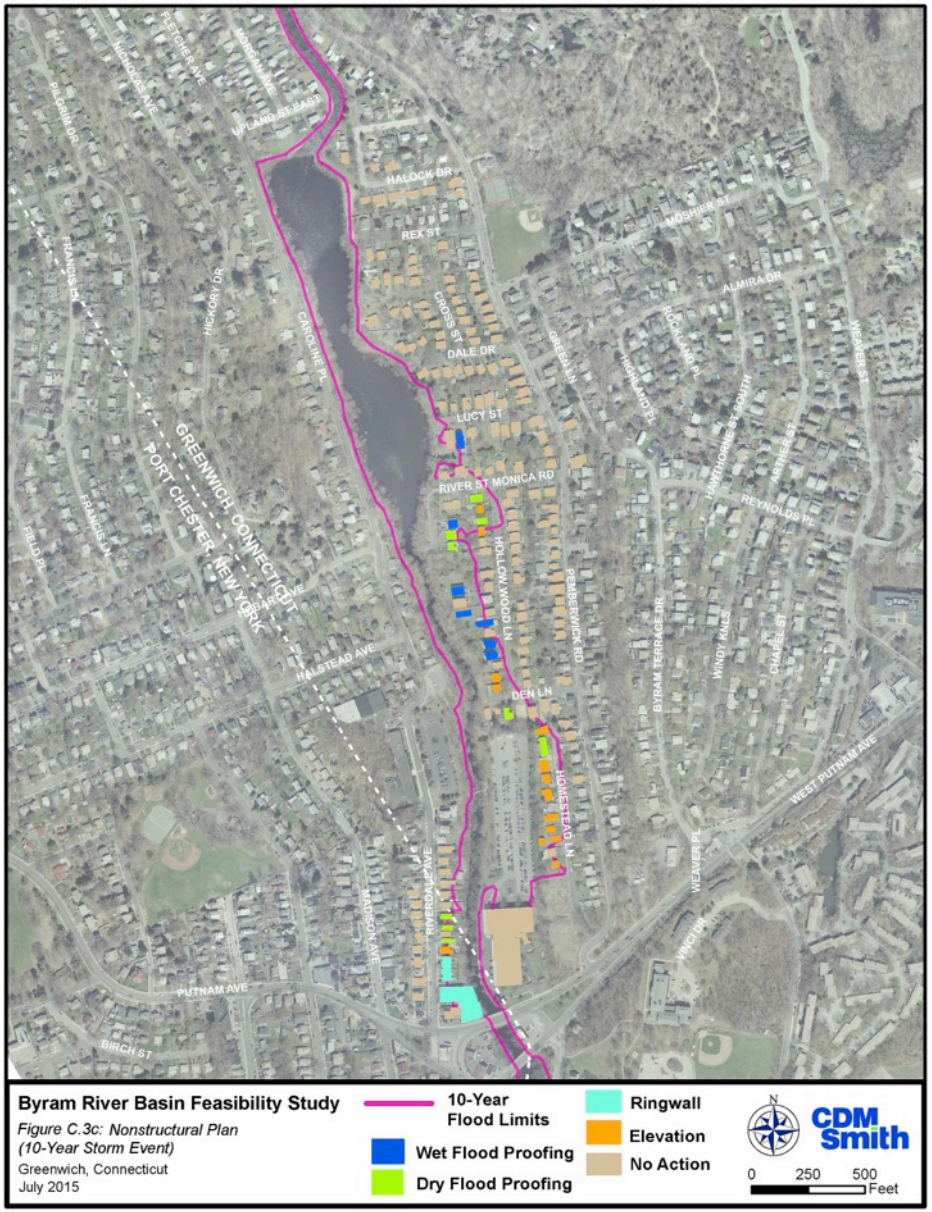
- ACOE performed a BCR analysis for each alternative

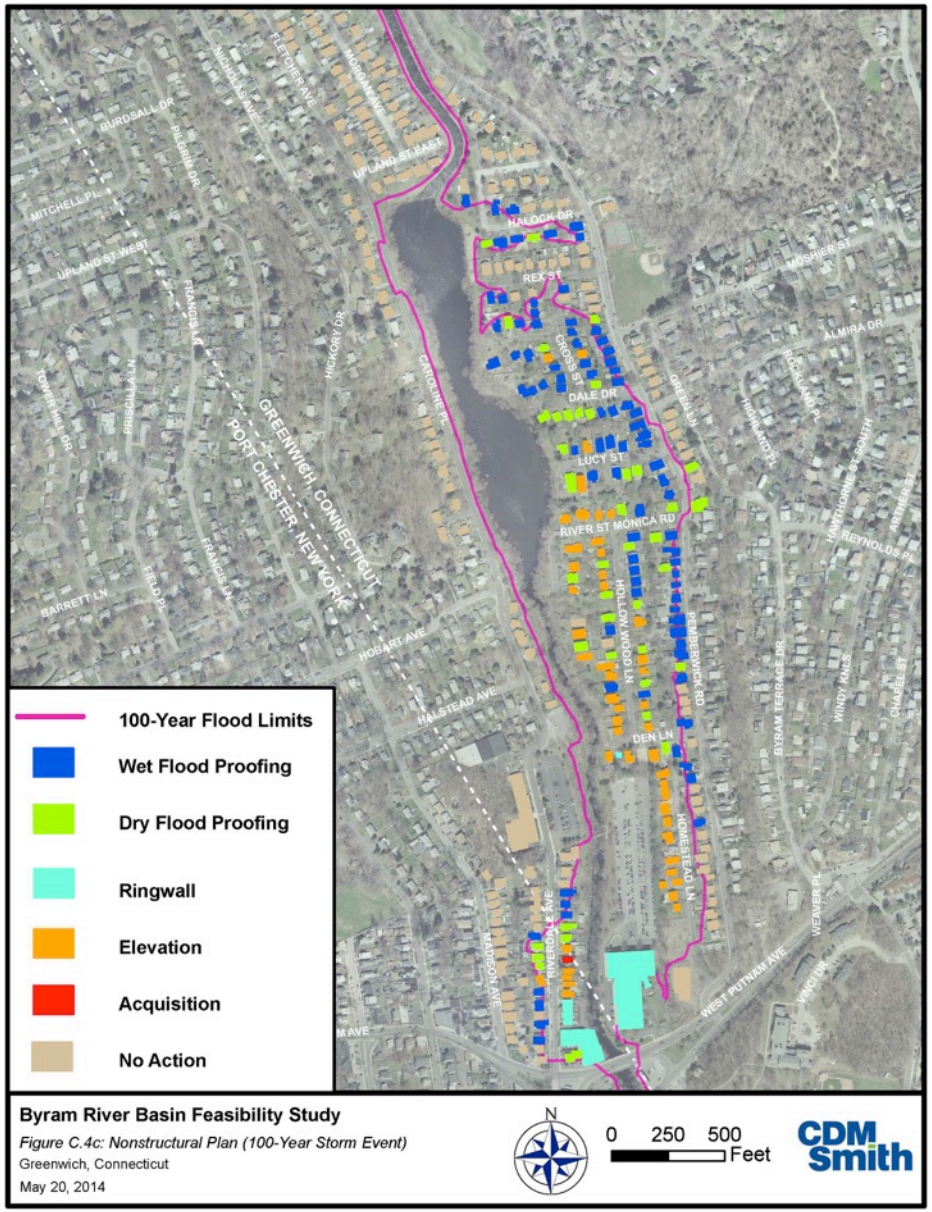
Two projects yielded a BCR greater than 1.0

- 10-Year Nonstructural Plan
- Route 1 Bridge Replacement

Alternatives are being presented to Residents

Byram River – Nonstructural Recommendations





Byram River – Nonstructural Recommendations

10 Year Storm Event

Structure Type	Flood Proofing Measure				
	Dry	Wet	Ringwall	Elevation	Acquisition
Slab-on-Grade	-	-	4	1	-
Subgrade Basement	4	-	1	18	1
Elevated	-	-	-	-	-
Bi-Levels	-	-	-	1	-
Raised Ranch	-	1	-	7	-
Raised Foundation	-	-	-	1	-
Split Level	1	-	-	1	-
Large Residential	-	-	6	-	-
Total (47)	**5**	**1**	**11**	**29**	**1**

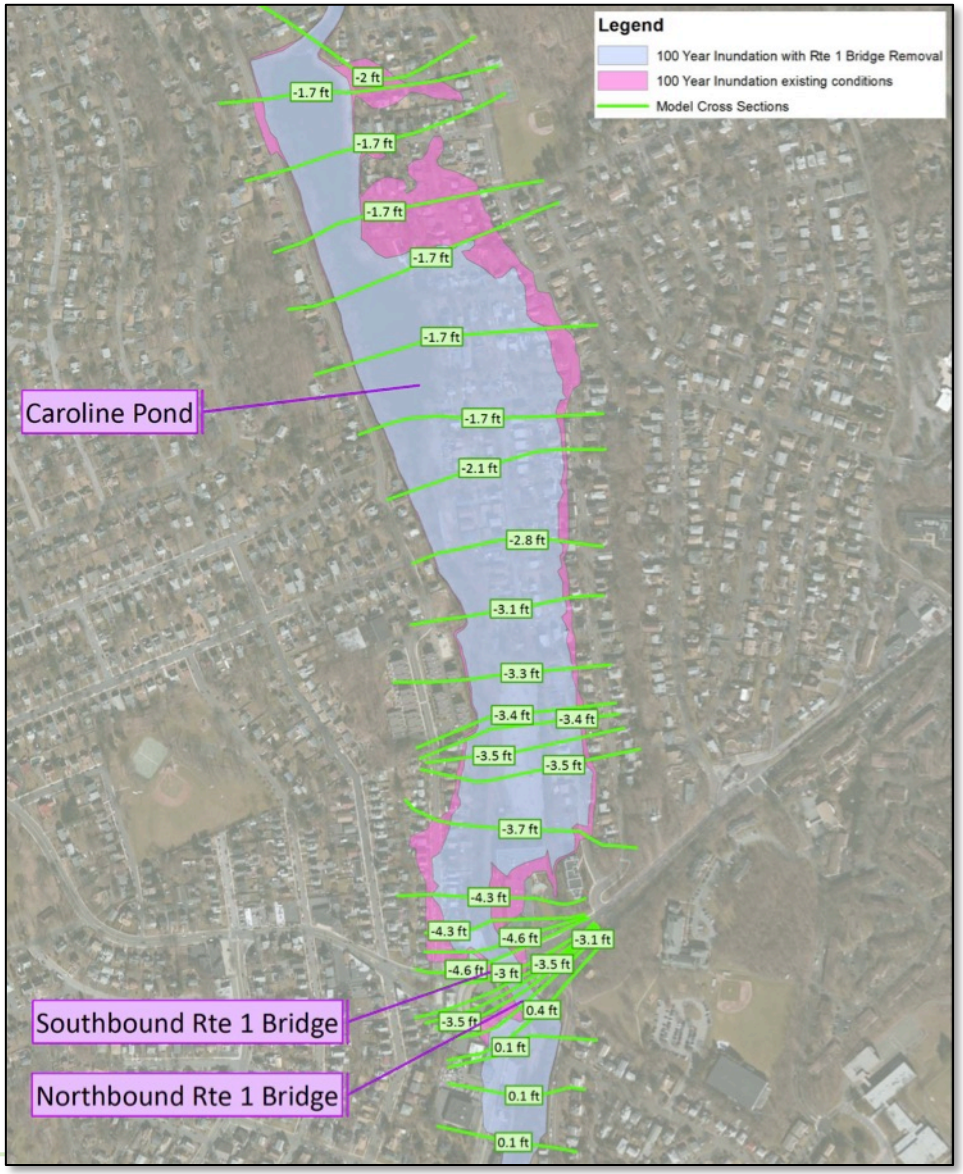
100 Year Event

Structure Type	Flood Proofing Measure				
	Dry	Wet	Ringwall	Elevation	Acquisition
Slab-on-Grade	4	-	4	2	-
Subgrade Basement	34	55	1	28	1
Elevated	1	-	-	-	-
Bi-Levels	1	1	-	1	-
Raised Ranch	6	28	-	15	-
Raised Foundation	-	2	-	3	-
Split Level	1	7	-	1	-
Large Residential	-	-	6	-	-
Total (202)	**47**	**93**	**11**	**50**	**1**

Byram River – Bridge Replacement

Flood depth reductions up to 4.6 feet (100 year)

- Brings the 100 year elevations just below the 25 year existing
- Significant cost benefits from decreases in flood damages



Cider Mill Brook

- Drainage System Evaluation (2009)
- Recommended Plan for the 25-Year Storm Event
  - Installation of twin 10-foot by 6-foot culverts under the railroad
  - Replacing the existing culvert under East Putnam Avenue

- CIP Prioritization Railroad Culverts

Table 3.3 – Summary of Recommended Plan

Improvement	*Recommended*
Binney Park Improvements (3.1.1)	√
East Putnam Avenue Improvements (3.1.2)	√
Palmer Hill Road Improvements (3.1.3)	√
Specific Structure Maintenance (3.1.4)	√
Harding Road Improvements (3.1.5)	
Upstream Structures and Channel Improvements (3.1.6)	
Storage Areas (3.1.7)	

Table 3.4 – Summary of Project Costs

Binney Park Improvements – Railroad Culvert	$ 4,300,000
East Putnam Improvements – Route 1 Culvert	$ 2,300,000
Palmer Hill Improvements – Roadway Culvert	$ 500,000
Specific Structure Improvements – Culvert Clearings	*
Opinion of Probable Construction Cost	$ 7,100,000
25% Contingency	$ 1,800,000
Engineering and Implementation Costs (25%)	$ 2,200,000
Opinion of Probable Project Costs	**$ 11,100,000**

Note: Land costs/easements not included, costs are 2011 dollars with 7% inflation rate.
* Culvert cleaning costs have not been included. It has been assumed that the Town of Greenwich DPW Staff will perform the cleaning.

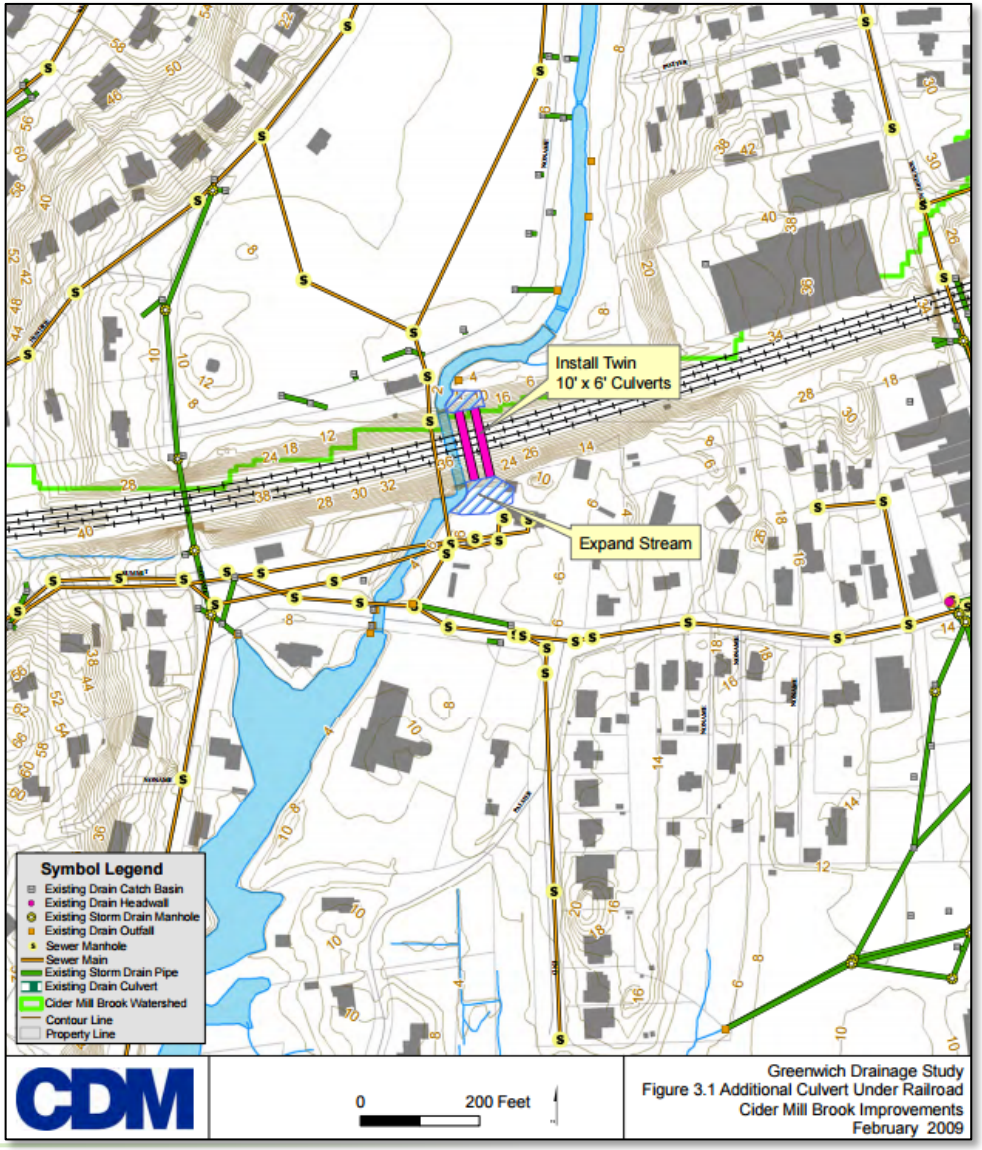
- Nonstructural Plan
- Hybrid Plan

Cider Mill Brook – Structural Recommendation

Railroad culvert replacement

- Reduced 100-year storm flood depths as much as by 4.5-ft
- Location of relief culvert under the railroad
- Flood mitigation on Arch Street during the 25-year storm to allow emergency access

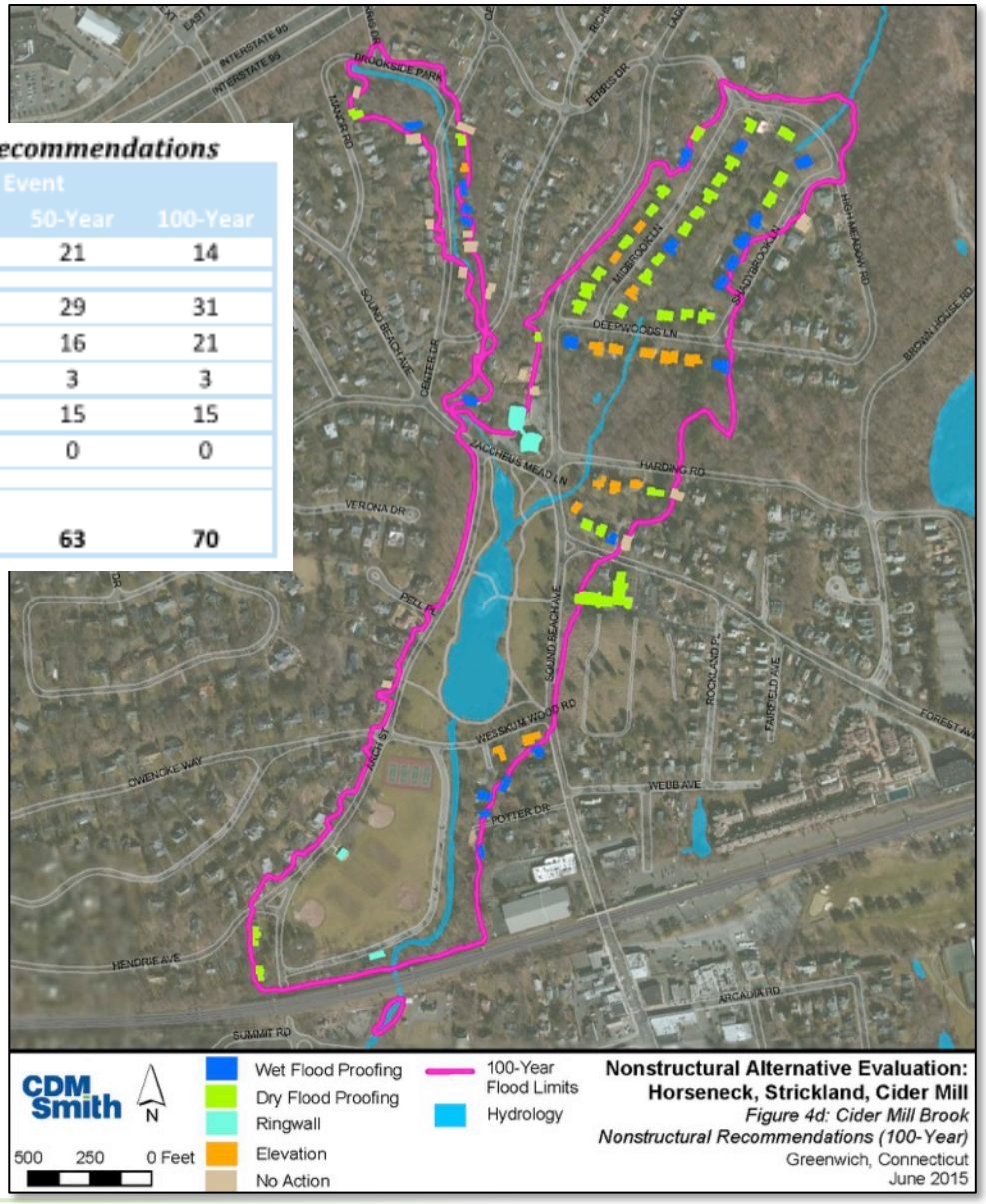
Conceptual Cost: $6,720,000



Cider Mill Brook – Nonstructural Recommendations

Table 2 Cider Mill Brook Nonstructural Flood Protection Recommendations

Flood Protection Measure	Storm Event			
	10-Year	25-Year	50-Year	100-Year
No Action Required	39	32	21	14
Dry Floodproofing	19	25	29	31
Wet Floodproofing	10	11	16	21
Ringwall	3	3	3	3
Elevation	13	13	15	15
Acquisition	0	0	0	0
Total Number of Structures Requiring Flood Protection Measures	45	52	63	70



Elevation

- 13-15 Properties
- Increases costs

100 year nonstructural recommendations - $7.2M

Cider Mill Brook – Hybrid Plan

Bridge Replacement at Sound Beach Avenue

- Roadway Raising
- $1M bridge replacement project
- Nonstructural considerations for individual properties

Conceptual Costs

Developed using the Army Corps of Engineers average unit costs for nonstructural improvements developed and included in the Byram River Feasibility Study

Storm Event	Byram River	Cider Mill Brook
10-Year	$18M	$4.9M
25-Year	$29M	$5.7M
50-Year	$36M	$6.6M
100-Year	$41M	$7.2M
Structural Recommendation	$91M	$6.7M
Bridge Replacement	$23M	$1.0M

Recommendations

Byram River

- Nonstructural alternative being considered (10 Year Storm)
- Route 1 Bridge Replacement is preferred but more complex

Cider Mill Brook

- Nonstructural recommendations are not cost effective
- Nonstructural (50-year) had similar conceptual costs to the relief culvert
- Nonstructural recommendations do not address roadway flooding, emergency access and public safety
- Hybrid plan: roadway improvements and nonstructural with considerable cost savings

Summary

Importance of including cost benefit analysis

- Damages need to be included
- Benefits (reduction of damages) need to out way the costs (BCR > 1)

Nonstructural improvements

- Do not impact the natural floodplain
- Elevation and acquisition significantly increase nonstructural costs
- Can be cost effective - Byram River
- Hybrid plans need to be considered - Cider Mill Brook
- Nonstructural not applicable – Horseneck Brook (emergency access)

Need to address emergency access and roadway flooding

- Critical public safety rating
- Emergency access routes and emergency facilities

Questions?