

Flood Risk Management Nonstructural Flood Proofing



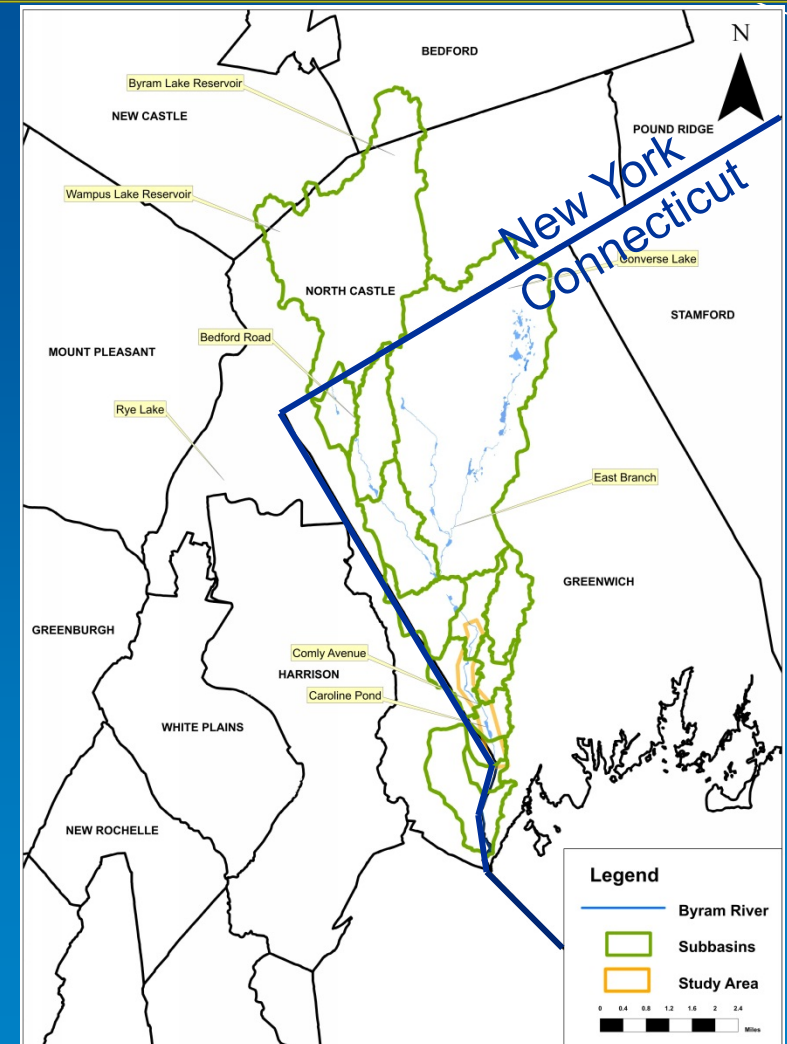
CAFM Annual
Conference

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October 29, 2014

**CDM
Smith**

Outline

- Project History & Background
- Existing Conditions:
 - Hydrologic & Hydraulic Analysis
 - Structure Inventory
- Alternatives
- Nonstructural Plan
- Recommendations



Project History

1955
Storm

1972
Hurricane
Agnes

2007
Nor'easter

2011
Tropical Storm
Irene

1959
ACOE Design

1977
ACOE Study

2008
ACOE Reconnaissance Study
Town Wide Drainage Studies

2012
ACOE/TOG
Feasibility

Results

Results

Results

Results

Flood Measures
(Levee) Constructed

Not Built
Public Opposition

Funding Obtained
for Feasibility Study

Study Started
October 2012

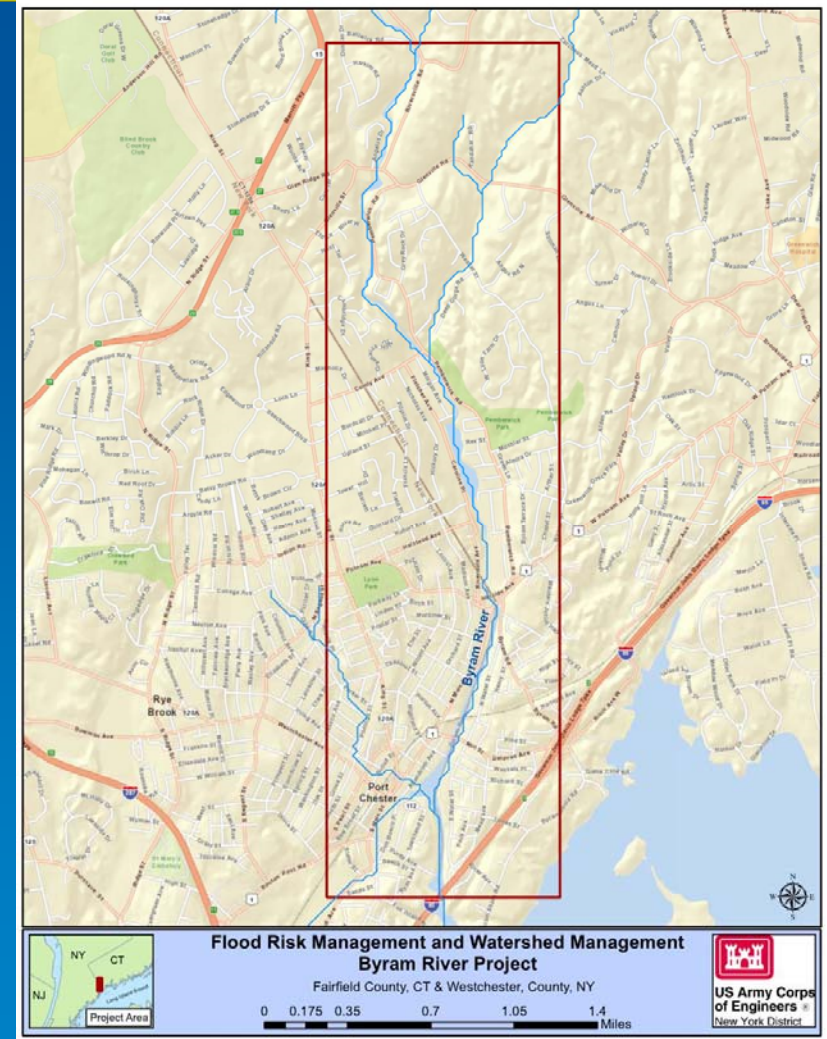
Project Background

Byram River Flood Risk Management Study

- Town of Greenwich
- Army Corps of Engineers

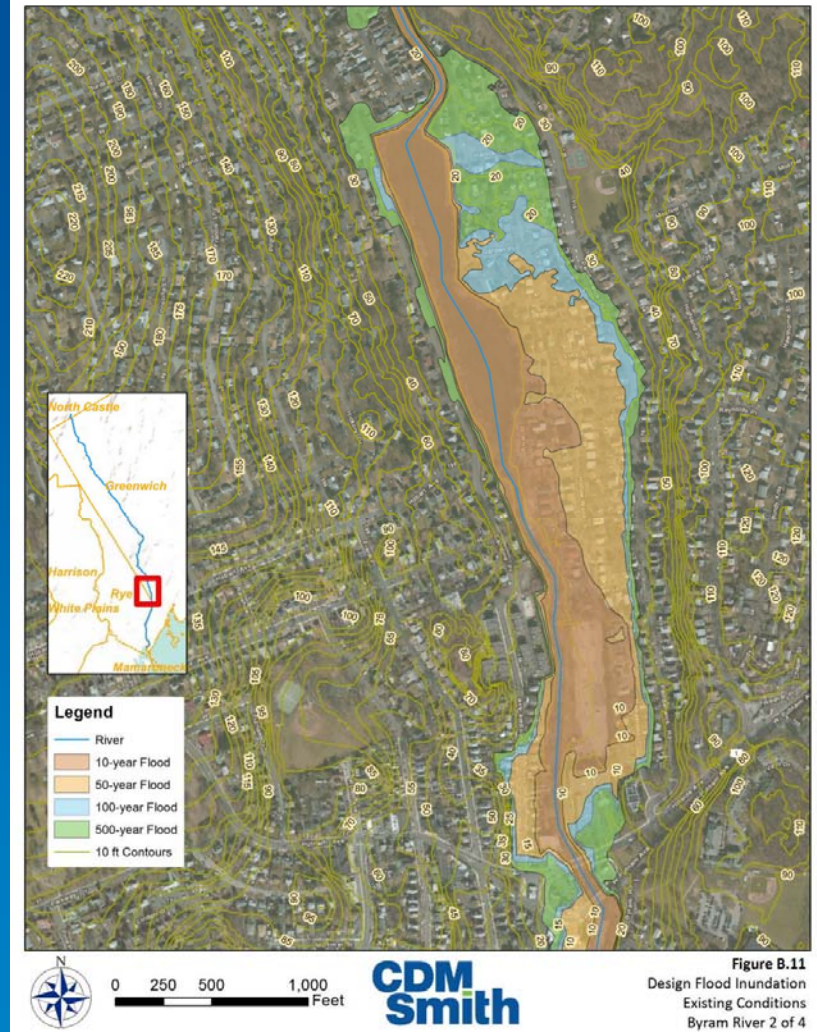
Feasibility Study

- Hydrologic & Hydraulic Analysis
- Structure Inventory
- Geotechnical Evaluation
- Environmental Inventory Report
- Nonstructural Analysis
- Alternatives Analysis
- Impact Assessment



Hydrologic & Hydraulic Analysis

- **Existing Conditions**
- **Modeling**
 - Hydrologic Model: **HEC-HMS**
 - Hydraulic Model: **HEC-RAS**
 - 10-, 50-, 100-, and 500-year Storms
- **Development of Alternatives**
 - Initial screening of mitigation measures
 - Modifications to existing model to provide comparative analysis of mitigation measures



Structure Inventory

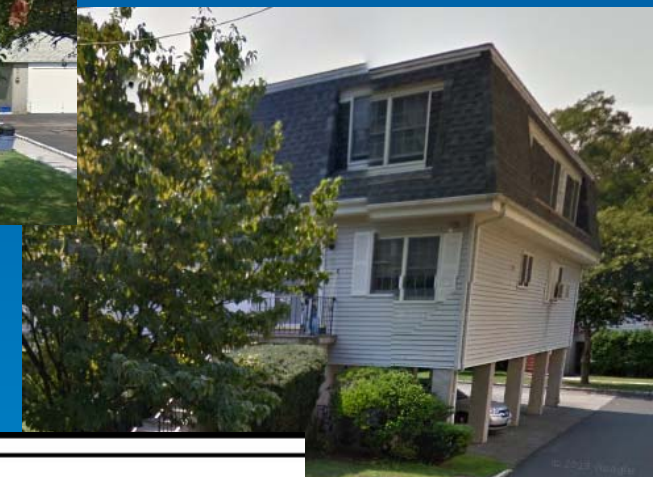
- Structure Type
- Condition
- Land Use
- Construction Type
- Garage
- Foundation
- Ground Elevation
- Low Opening
- Main Floor Elevation
- Assessed Value



Split Level



Raised Ranch

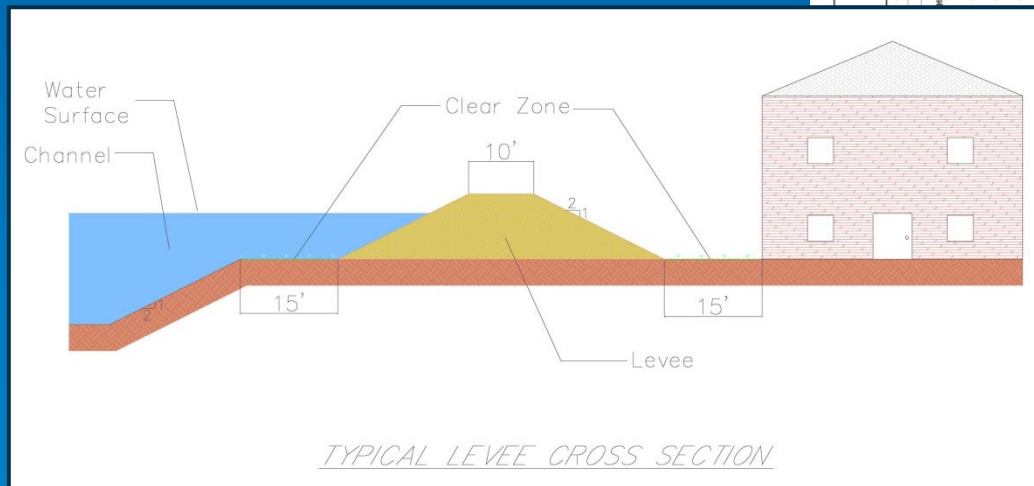
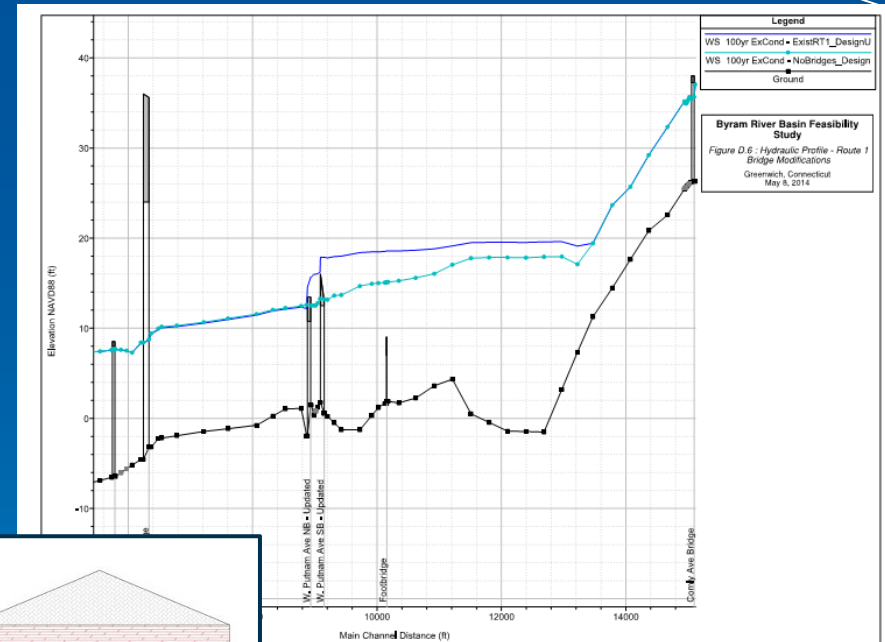


Elevated

HOUSE #	STREET NAME	BYRAM RIVER STATION	GE	ME	LE	FD										
			GROUND ELEVATION AT BUILDING	# OF STEPS	MAIN FLOOR ELEVATION	LOW OPENING ELEVATION	DEPTH OF 10-YEAR FLOODING VS. FIRST FLOOR	DEPTH OF 10-YEAR FLOODING VS. LOW OPENING	DEPTH OF 100-YEAR FLOODING VS. FIRST FLOOR	DEPTH OF 100-YEAR FLOODING VS. LOW OPENING	DEPTH OF 500-YEAR FLOODING VS. FIRST FLOOR	DEPTH OF 500-YEAR FLOODING VS. LOW OPENING	STRUCTURE TYPE	LAND USE TYPE	# OF FLOORS	TOTAL SQ. FT.
8	Riverdale Avenue	9507	20.0	8	24.7	20.0	-14	-9	-7	-2	-4	1	SB	R	2.5	3,190
11	Hillside Avenue	9512	18.0	0	18.0	18.0	-5	-5	2	2	5	5	S	C	1.5	1,959
211	Madison Avenue	9548	34.0	2	35.2	29.0	-25	-18	-17	-11	-23	-16	-	R	1	1,792
5	Riverdale Avenue	9548	18.0	7	22.1	22.1	-11	-11	-4	-4	-1	-1	-	R	2.5	1,520
13	Riverdale Avenue	9591	8.0	0	8.0	8.0	3	3	10	10	13	13	S	C	2	34,580
213	Madison Avenue	9612	34.0	0	34.0	30.0	-23	-19	-16	-12	-13	-9	-	R	2	2,776
18	Riverdale Avenue	9612	15.0	12	22.0	15.0	-11	-4	-4	3	-1	8	RR	R	2	4,058

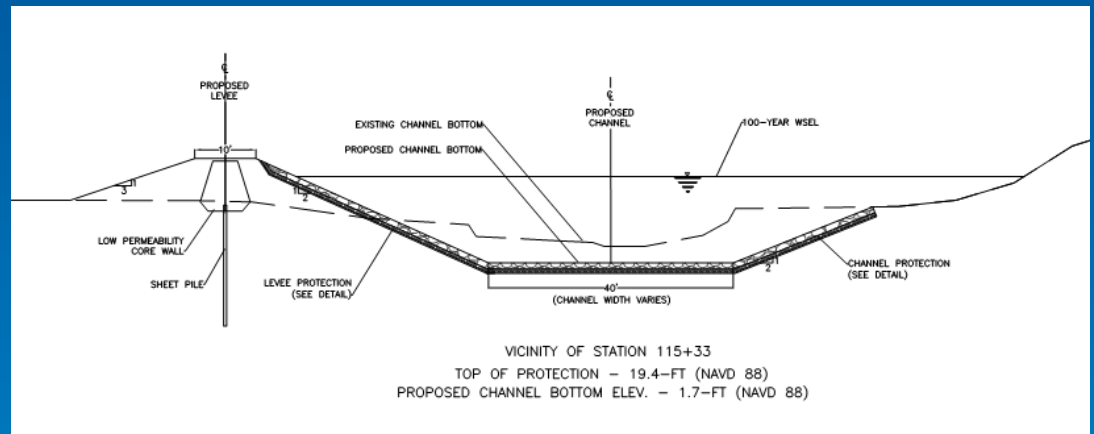
Development of Alternatives

- **Four Alternatives**
 - No Action
 - **Nonstructural**
 - Structural
 - Combination of Measures



Development of Alternatives – Structural Alternative

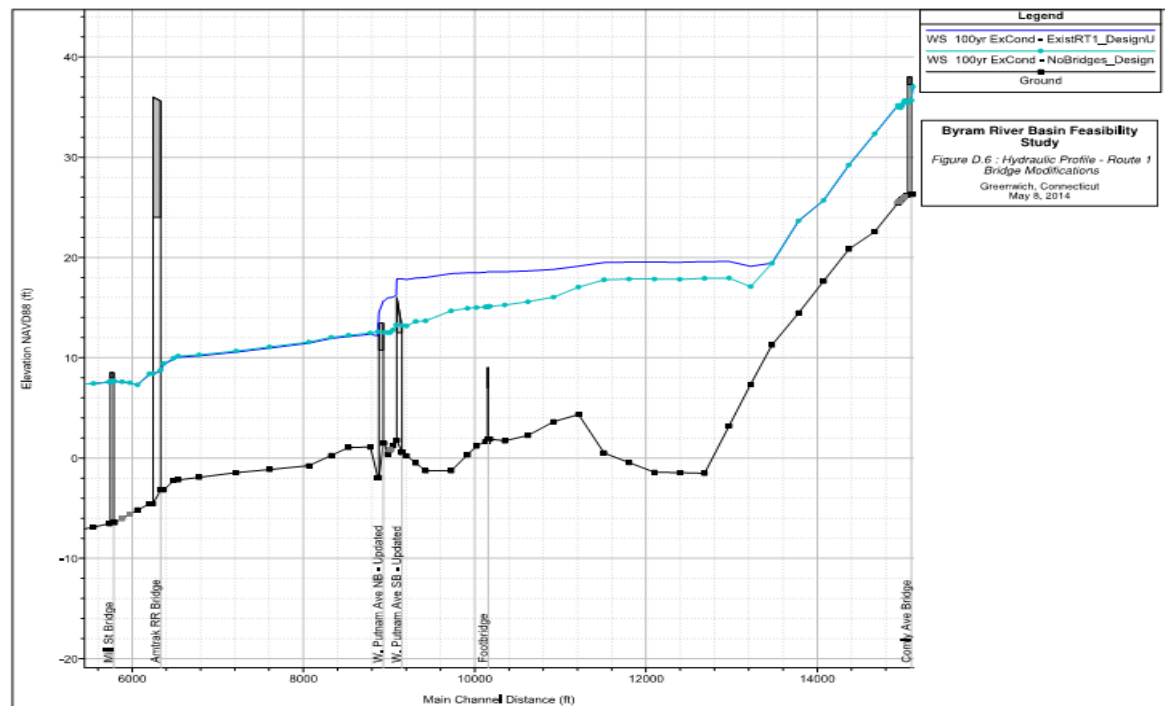
- Reduces the frequency of flooding
- Alternatives Considered:
 - Diversion/Channel Modifications
 - Storage
 - Levees
 - Floodwalls
 - Pumps
 - Bridge Modifications
- Structural Alternatives:
 - Floodwall, Levee & Channel Modifications (1977 Recommendations)
 - Combination – Bridge Replacement, Modifications to 1977 Recommendations & Nonstructural



Development of Alternatives

- **Impact Assessment**

- Hydrology & Hydraulics
- Traffic & Transportation
- Geotechnical
- Structural
- Environmental
- Utilities



Nonstructural Plan

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



Elevation

Relocation

Localized
Levees and
ringwalls

Dry
Floodproofing

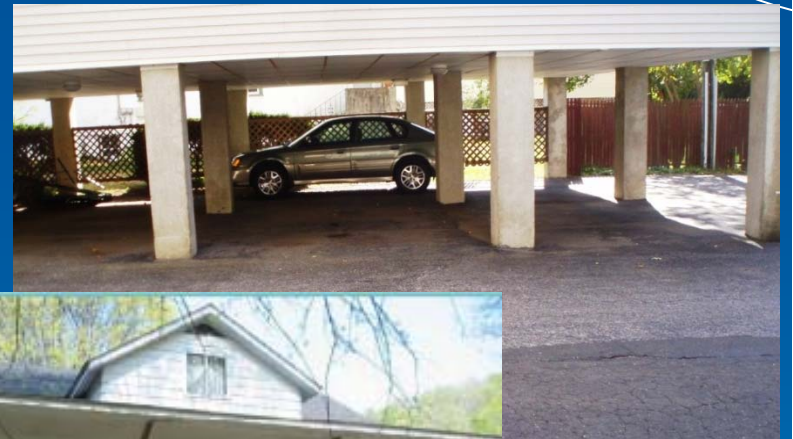
Wet
Floodproofing

Elevation

- Raising a home to prevent floodwaters from reaching living areas
- 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

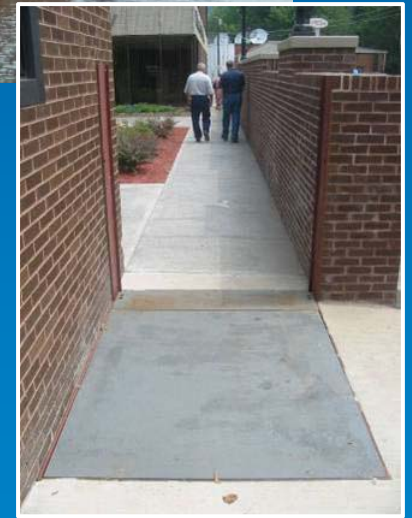
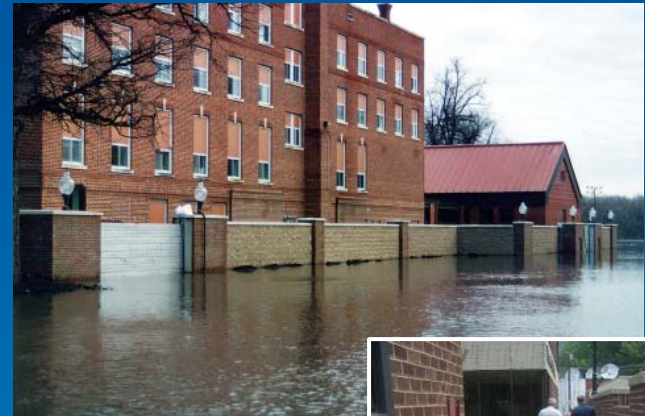
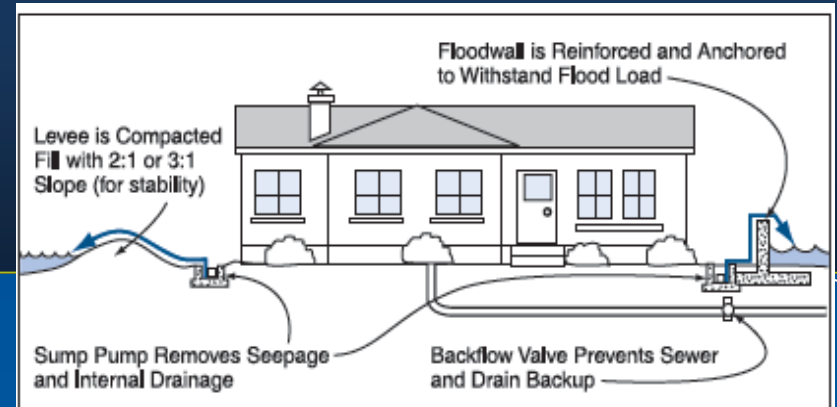


Ringwalls

- Small floodwall or levee, around your home to hold back floodwaters
- Surround a home or protect isolated openings such as doors, windows, and walkout on-grade basements

Things to consider:

- Home and surrounding area will be protected from inundation
- No significant changes to the home will be required
- Designed for an elevation equal to the base flood elevation

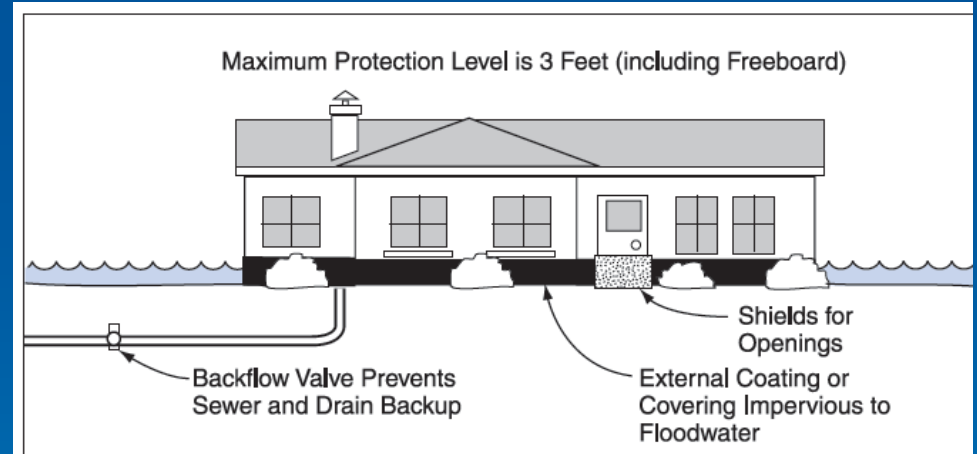


Dry Flood Proofing

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

Things to consider:

- Requires human intervention
- Seal walls with waterproof coatings, impermeable membranes, or supplemental layers of masonry or concrete
- Shield all openings, such as doors and windows, below the design flood elevation

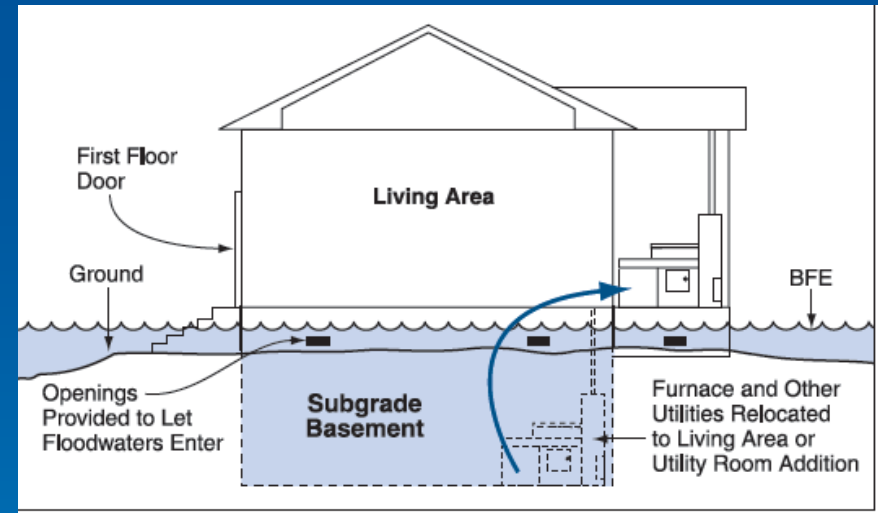


Wet Flood Proofing

- Modifying uninhabited portions of the home so floodwaters will enter but not cause significant damage
- Reduces risk of structural collapse as hydrostatic pressures equalizes

Things to consider:

- Requires space above the design flood elevation where items can be stored temporarily or permanently
- Service equipment should be protected by relocating above flood elevation or protecting it in place
- Requires removal of water after the event



Nonstructural Plan

- Recommendations for Each Storm Event
 - 10 Year
 - 100 Year
 - 500 Year
- Based on Structure Type & Use
- Determine Flood Proof Measure Based on Algorithm Results
 - Slab-on-grade
 - Subgrade Basement
 - Elevated
 - Bi-levels/Raised Ranches
 - Raised Foundations/Split Levels
 - Large Residential

Nonstructural Plan

- Algorithms
 - Structure Type
 - Use
 - Flood Elevation (FE)
 - Ground Elevation (GE)
 - Flood Depth (FD)
 - Main Floor Elevation (ME)
 - Low Opening Elevation (LE)
- Determine Details for Recommended Flood Proof Measure

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	
<i>Residential</i>	
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 <ul style="list-style-type: none"> a. If $FE+1 > ME+3$ then <ul style="list-style-type: none"> i. If Poor Condition then Buyout ii. Otherwise Elevation b. If $FE+1 < ME+3$ then <ul style="list-style-type: none"> i. If $FE+1 < GE+6$ then Dry Flood Proofing or Ringwall ii. If $FE+1 > GE+6$ then Dry Flood Proofing 	
<i>Nonresidential</i>	
I. If $FE < GE$ then No Flood Proofing Required II. If Wood or Metal Construction Type then <ul style="list-style-type: none"> a. If $FE+1 < ME$ then No Flood Proofing Required b. If $FE+1 > ME$ then <ul style="list-style-type: none"> i. If $FE+1 > ME+3$ then <ul style="list-style-type: none"> 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 <ul style="list-style-type: none"> a. If $FE+1 < ME$ then No Flood Proofing Required b. If $FE+1 > ME$ then <ul style="list-style-type: none"> i. If $FE+1 > GE+3$ then Ringwall ii. If $FE+1 < GE+3$ then Dry Flood Proofing or Ringwall 	

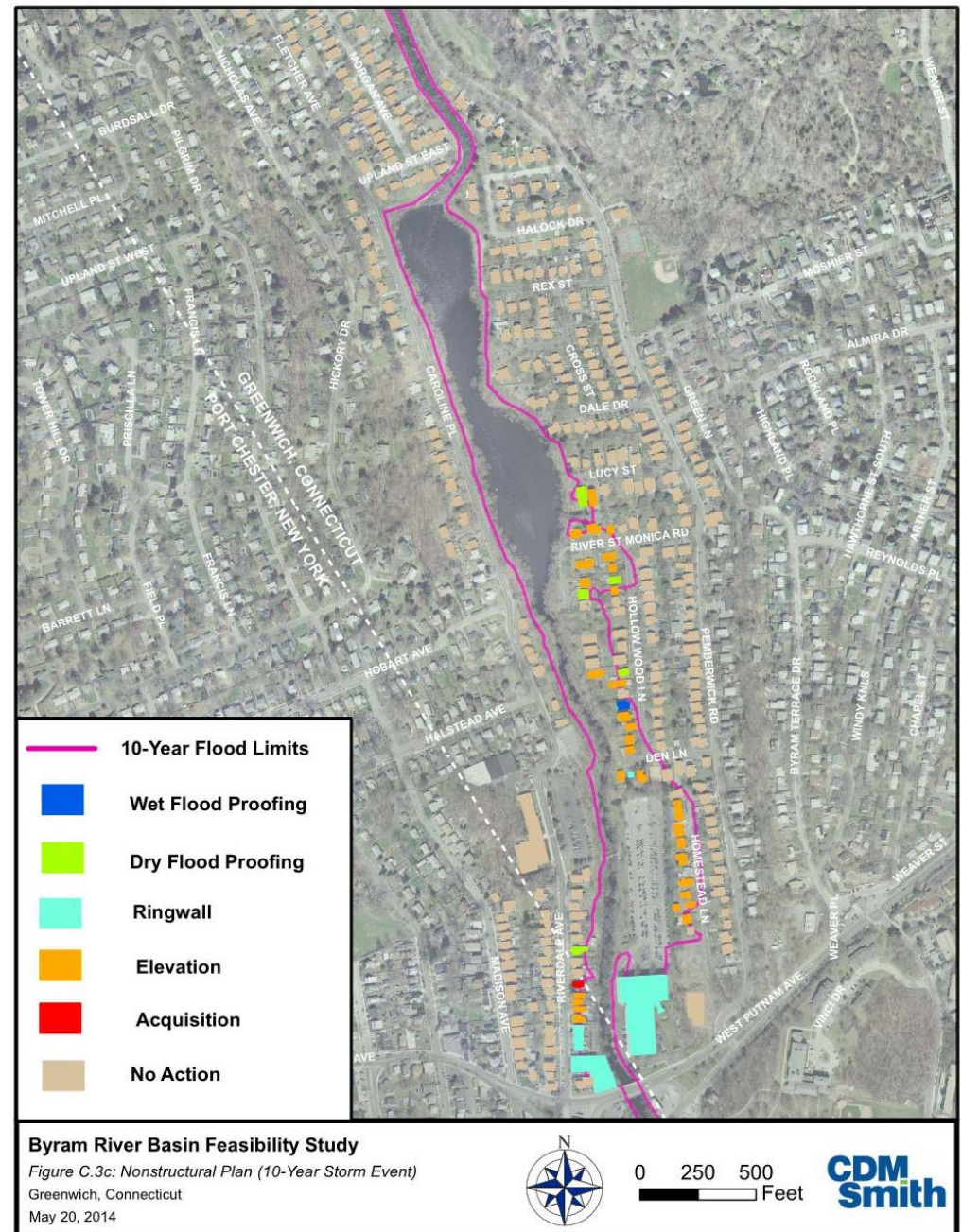
Nonstructural Plan

10 Year Water Surface Elevations

47 Flood Proofing Measures

- Dry Flood Proofing
- Wet Flood Proofing
- Floodwall
- Elevation
- Acquisition

Design to 100 Year Elevation



Nonstructural Plan – 10 Year

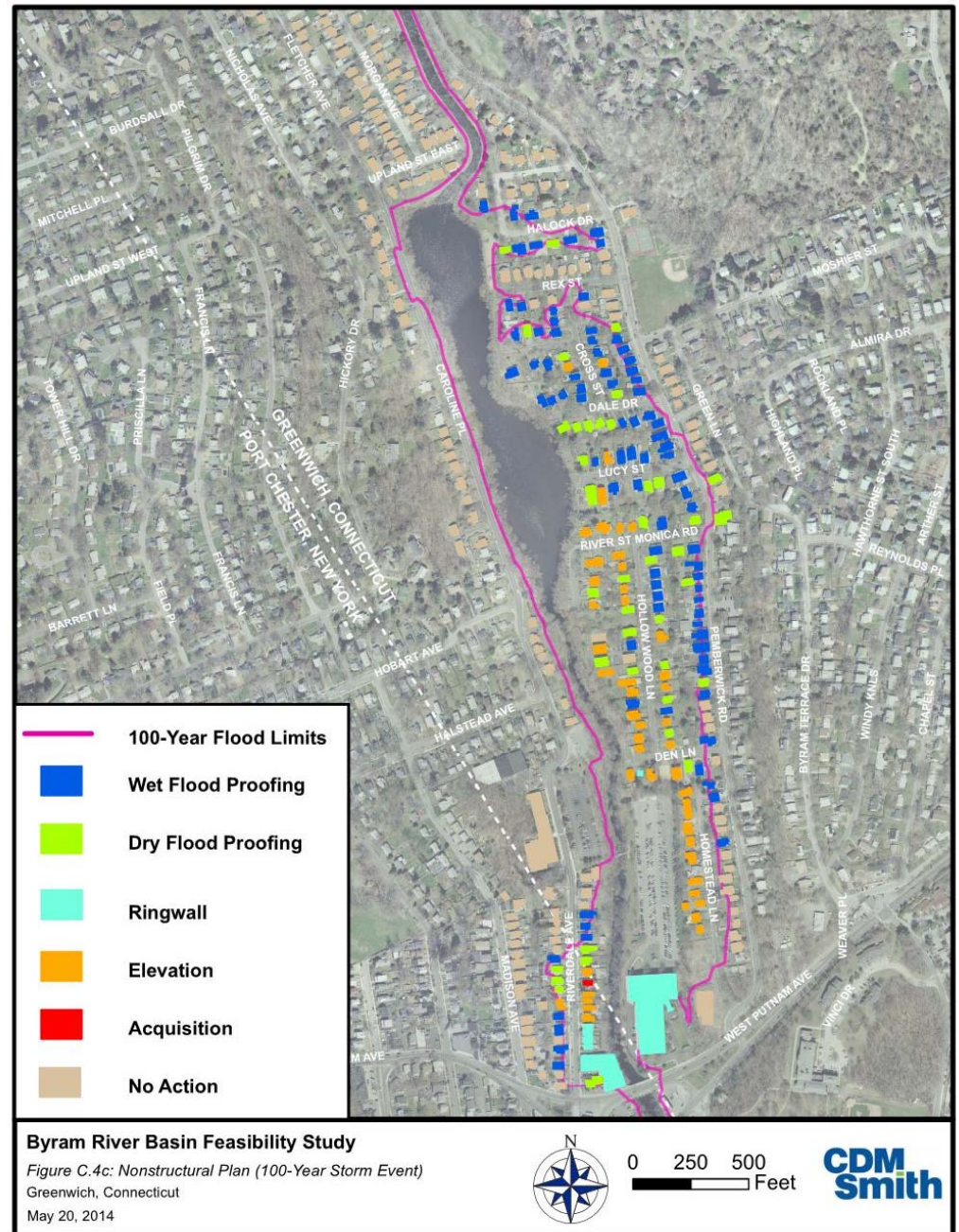
Structure Type	Flood Proofing Measure				
	Dry	Wet	Ringwall	Elevation	Acquisition
Slab-on-Grade			4	1	
Subgrade Basement	4		1	18	1
Elevated					
Bi-Levels				1	
Raised Ranch		1		7	
Raised Foundation				1	
Split Level	1			1	
Large Residential			6		
Total	5	1	11	29	1

Nonstructural Plan

100 Year Water Surface Elevations

202 Flood Proofing Measures

- Dry Flood Proofing
- Wet Flood Proofing
- Floodwall
- Elevation
- Acquisition



Nonstructural Plan – 100 Year

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	47	93	11	50	1

Nonstructural Plan

Detailed quantities for each alternative

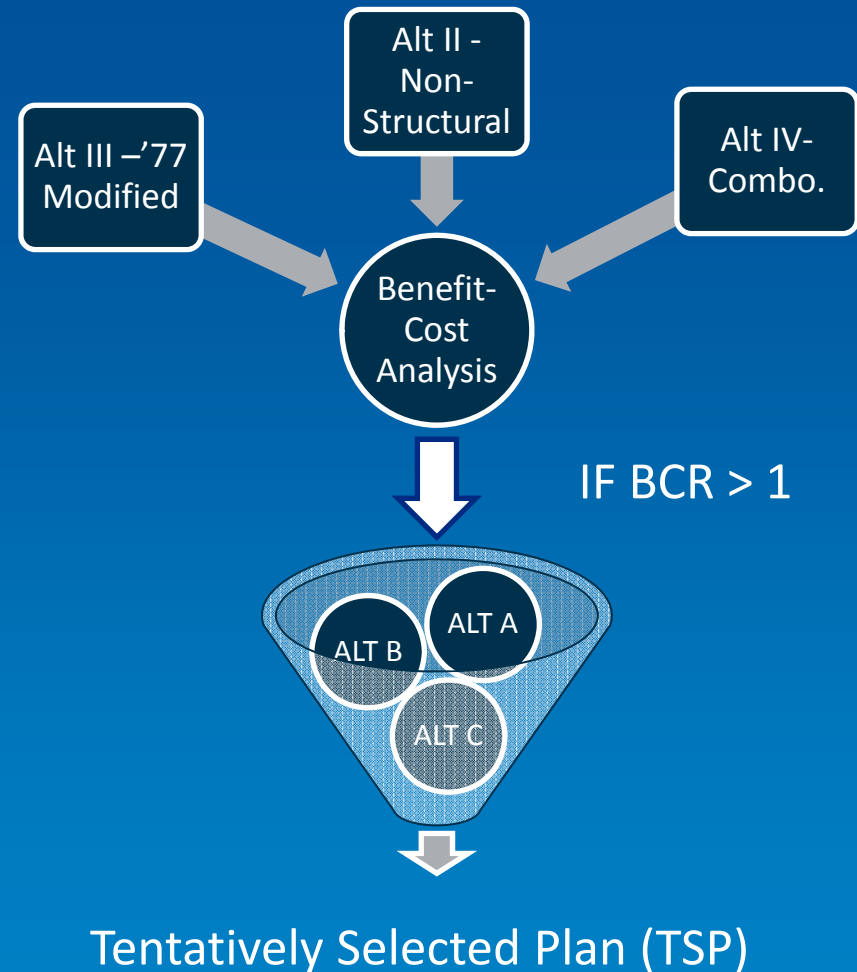
- Storm event
- Structure type
- Flood proofing measure

Byram River Feasibility Study
Nonstructural Plan - Ringwall Measurements
Greenwich, Connecticut

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	700	-	-	-
13	Riverdale Avenue		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
499	Den Lane	200	5	11	14
200	Pemberwick Road Building 2	650	-	5	6
200	Pemberwick Road Building 3	450	7	11	15
10	Glenville Street	600	19	21	23

Cost Benefit Analysis

- **Benefit Cost Ratio > 1**
- **No Action**
 - \$5M - \$8M Estimated Annual Damages
- **Nonstructural**
 - \$17M - \$50M Based on Protection Level
- **Structural (1977 Modified Plan)**
 - \$50M - \$56M
- **Combination Plan**
 - $> \$56M$



Proposed Nonstructural Plan

NON-STRUCTURAL MEASURE	NUMBER OF PROPERTIES		
	10-YR	100-YR	500-YR
Wet or Dry Floodproofing	6	140	188
Localized Ringwalls / Levees	11	11	13
Elevation (or raising) on Piers	29	50	121
Buyout / Acquisition / Relocation	1	1	2
TOTAL	47	202	324
ESTIMATED COST RANGE	\$17M to \$21M	\$24M to \$30M	\$45M to \$50M

Recommendations

- Selected Alternative Needs to Meet $BCR > 1$
- $Cost < 4 \times \text{Damages}$
- Damages \$5M - \$8M
- Recommended Project \$20M - \$32M
- Structural Plans $BCR < 1$ (i.e. too costly to support damages)
- 10 Year or 100 Year Nonstructural Plan BCR close to 1

Next Steps

- More Detailed Structure Inventory - Survey
- Refine Flood Proofing Measures for 10 year and 100 year storm events
- More Detailed Cost Estimate for each Structure/Recommended Flood Measure
- Determine BCR for each alternative
- Select the Tentatively Selected Plan
- Nonstructural Plan is the Cost Beneficial Alternative

Questions?

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