ROCKAWAY RIVER AND DEN BROOK
DENVILLE TOWNSHIP
MORRIS COUNTY, NEW JERSEY
CAP SECTION 205
FLOOD RISK MANAGEMENT STUDY

APPENDIX D
ECONOMICS

September 2023

U.S. Army Corps of Engineers
North Atlantic Division – New York and Baltimore Districts
In partnership with the New Jersey Department of Environmental Protection

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1 Introduction

The Township of Denville New Jersey Flood Risk Management (FRM) economic analysis was conducted to assess whether changes in without conditions compared to the recommended plan are economically justified. The analysis measured the flood damage reduction benefits and costs of several alternatives, including various floodwall configurations, the combination of floodwalls and selective road raising, bypass culvert, and nonstructural treatments adjacent to the Upper Rockaway River and its tributary, Den Brook.

2 Summary of Study Area

Rockaway River is in the Township of Denville, Morris County, New Jersey. The village is mostly developed, with a mix of residential and commercial structures. There are numerous small lakes within the basin and several important tributaries, including Den Brook that originates in Randolph Township, and enters the Upper Rockaway River in Denville. Note that the Lower Rockaway River is not part of the study area. Figure 1 shows the study area with Rockaway River and Den Brook.

Figure 1: Study Area

The Township of Denville had a population of 15,824 as of the 2000 Census Bureau data. In 2021 the population was 17,100, reflecting an increase of 1,276 people with a rate of 8.1 percent from 2000 to 2021.

Many people left the Denville, NJ area following the aftermath of Hurricane Irene that hit the region and caused severe damage in 2011. Since that time the Township has been rebuilt and the population reached 16,642 in 2015. The population has continued to increase and reached 17,100 in 2021, with 50.4 percent males and 49.6 percent females.

The median household income and housing values were $125,655 and $419,500, respectively, as of 2019.

Several flood events have impacted the Township of Denville, Morris County. In September 1971, most of the houses were surrounded by three feet of water. The storm damages were estimated to be $621,000. During a storm event in January 1979, many families evacuated from their homes. In April 1984, Riverside Drive East was inundated, and as a result, 110 people temporarily evacuated the township. In September 1999, Tropical Storm Floyd hit the township with approximate total damages of $250 million statewide. The latest and the most severe storm damage that has impacted Denville occurred during Hurricane Irene on August 27-28, 2011, when 13.29 inches of rain fell in Morris County. Hundreds of people left the township. Figure 2 shows some images associated with storm events.

Figure 2: Inundations in the Township of Denville, NJ

3 Methodology

3.1 HEC-FDA

This analysis follows USACE guidance for conducting flood damage analyses as contained in Engineering Regulation (ER) 1105-2-100, Appendix E, Section III, "Flood Damage Reduction", 22 April 2000. The U.S. Army Corps of Engineers (USACE) Hydraulic Engineering Center Flood Damage Analysis (HEC-FDA) version 1.4.2 tool was used to compute damages for properties in the Township of Denville during FY 2021 economic analysis. HEC-FDA provides the capability to perform an integrated hydrologic engineering and economic analysis during the formulation and evaluation of FRM plans. Generic depth-damage functions developed by the USACE Institute for Water Resources (IWR) were used within the tool to show the percentage of structure value damaged by varying water levels. Characteristics such as low opening, main floor elevation and building material were recorded to determine the percent damage to the structures resulting from inundation levels.

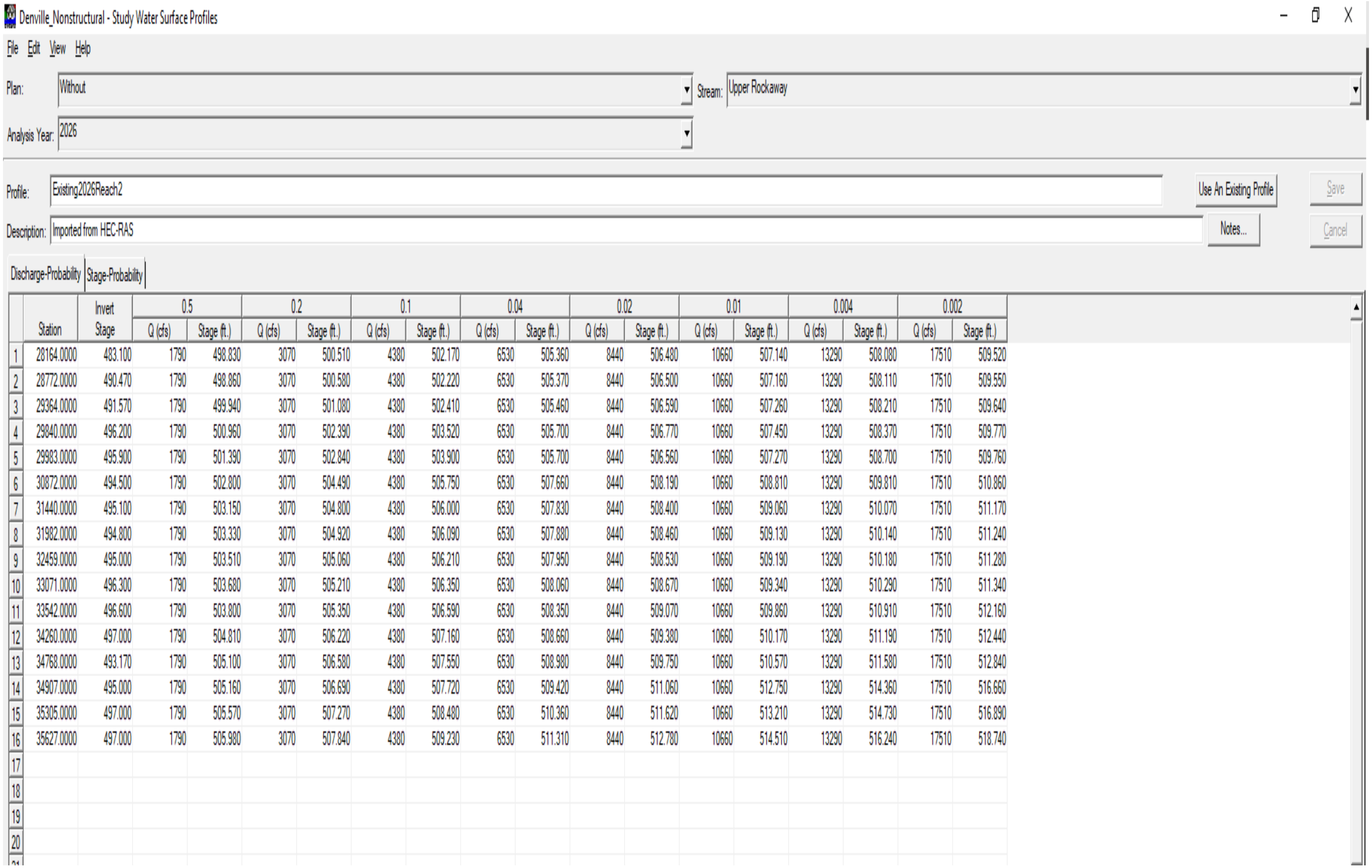
The project benefit is defined as the difference between the without and with-project equivalent annual damage from structure and content values of buildings. Benefits and costs are calculated for a 50-year period of analysis using the Fiscal Year 2021 (FY21) price level and discount rate of 2.5 percent with the Capital Recovery Factor of 0.035 to annualize benefits and costs.

For each plan, the annual benefit amount is divided by the annual cost to determine a benefit-to-cost ratio (BCR). This ratio must be equal to or greater than 1.0 for federal participation in water resource improvement projects. The plan with the greatest difference between annual benefit and annual cost will be identified. This plan usually defines the extent of federal interest in a project and is considered the National Economic Development (NED) Plan.

3.2 Hydrology and Hydraulics Inputs

The study area is impacted by two overlapping flood threats, Rockaway River and its tributary Den Brook. Eight water surface profiles and their associated Annual Exceedance Probabilities (AEP) 50% (2-year equivalent), 20% (5-year), 10% (10-year), 4% (25-year), 2% (50-year), 1% (100-year), 0.4% (250-year), and 0.2% (500-year) were entered into the model for without-project conditions and future with-project conditions. The downstream station, the upstream station, and the index location for Rockaway River reach are respectively 28164, 33071, and 31440. For Den Brook reach they are 2240, 2803, and 2644 respectively. Attached files show Rockaway River reach and Den Brook reach water surface profile. Figures 3 and 4 show Rockaway River reach and Den Brook water surface profiles.

Figure 3: Rockaway River Reach Water Surface Profile



Denville_Nonstructural - Study Water Surface Profiles

File Edit View Help

Plan: Without

Stream: Upper Rockaway

Analysis Year: 2026

Profile: Existing2026Reach2

Use An Existing Profile

Save

Description: Imported from HEC-RAS

Notes...

Cancel

Discharge-Probability | Stage-Probability

		Invert	0.5		0.2		0.1		0.04		0.02		0.01		0.004		0.002	
	Station	Stage	Q (cfs)	Stage (ft.)	Q (cfs)	Stage (ft.)	Q (cfs)	Stage (ft.)	Q (cfs)	Stage (ft.)	Q (cfs)	Stage (ft.)	Q (cfs)	Stage (ft.)	Q (cfs)	Stage (ft.)	Q (cfs)	Stage (ft.)
1	28164.0000	483.100	1790	498.830	3070	500.510	4380	502.170	6530	505.360	8440	506.480	10660	507.140	13290	508.080	17510	509.520
2	28772.0000	490.470	1790	498.860	3070	500.580	4380	502.220	6530	505.370	8440	506.500	10660	507.160	13290	508.110	17510	509.550
3	29364.0000	491.570	1790	499.940	3070	501.080	4380	502.410	6530	505.460	8440	506.590	10660	507.260	13290	508.210	17510	509.640
4	29840.0000	496.200	1790	500.960	3070	502.390	4380	503.520	6530	505.700	8440	506.770	10660	507.450	13290	508.370	17510	509.770
5	29983.0000	495.900	1790	501.390	3070	502.840	4380	503.900	6530	505.700	8440	506.560	10660	507.270	13290	508.700	17510	509.760
6	30872.0000	494.500	1790	502.800	3070	504.490	4380	505.750	6530	507.660	8440	508.190	10660	508.810	13290	509.810	17510	510.860
7	31440.0000	495.100	1790	503.150	3070	504.800	4380	506.000	6530	507.830	8440	508.400	10660	509.060	13290	510.070	17510	511.170
8	31982.0000	494.800	1790	503.330	3070	504.920	4380	506.090	6530	507.880	8440	508.460	10660	509.130	13290	510.140	17510	511.240
9	32459.0000	495.000	1790	503.510	3070	505.060	4380	506.210	6530	507.950	8440	508.530	10660	509.190	13290	510.180	17510	511.280
10	33071.0000	496.300	1790	503.680	3070	505.210	4380	506.350	6530	508.060	8440	508.670	10660	509.340	13290	510.290	17510	511.340
11	33542.0000	496.600	1790	503.800	3070	505.350	4380	506.590	6530	508.350	8440	509.070	10660	509.860	13290	510.910	17510	512.160
12	34260.0000	497.000	1790	504.810	3070	506.220	4380	507.160	6530	508.660	8440	509.380	10660	510.170	13290	511.190	17510	512.440
13	34768.0000	493.170	1790	505.100	3070	506.580	4380	507.550	6530	508.980	8440	509.750	10660	510.570	13290	511.580	17510	512.840
14	34907.0000	495.000	1790	505.160	3070	506.690	4380	507.720	6530	509.420	8440	511.060	10660	512.750	13290	514.360	17510	516.660
15	35305.0000	497.000	1790	505.570	3070	507.270	4380	508.480	6530	510.360	8440	511.620	10660	513.210	13290	514.730	17510	516.890
16	35627.0000	497.000	1790	505.980	3070	507.840	4380	509.230	6530	511.310	8440	512.780	10660	514.510	13290	516.240	17510	518.740
17																		
18																		
19																		
20																		

Figure 4: Den Brook Reach Water Surface Profile

Denville_Nonstructural - Study Water Surface Profiles

File Edit View Help

Plan: Without

Stream: Den Brook

Analysis Year: 2026

Profile: Existing2026DenBrook

Use An Existing Profile

Save

Description: Imported from HEC-RAS

Notes...

Cancel

Discharge-Probability | Stage-Probability

	Station	Invert Stage	0.5		0.2		0.1		0.04		0.02		0.01		0.004		0.002	
			Q (cfs)	Stage (ft.)	Q (cfs)	Stage (ft.)	Q (cfs)	Stage (ft.)	Q (cfs)	Stage (ft.)	Q (cfs)	Stage (ft.)	Q (cfs)	Stage (ft.)	Q (cfs)	Stage (ft.)	Q (cfs)	Stage (ft.)
1	178.0000	495.160	210	498.780	390	500.460	720	502.100	1140	505.340	1460	506.470	1600	507.130	1820	508.080	2450	509.510
2	216.0000	495.500	210	499.150	390	500.140	720	501.840	1140	505.320	1460	506.470	1600	507.130	1820	508.070	2450	509.510
3	314.0000	494.810	210	500.010	390	501.020	720	502.570	1140	505.880	1460	507.000	1600	507.510	1820	508.210	2450	509.550
4	714.0000	493.230	210	500.080	390	501.160	720	502.840	1140	505.940	1460	507.050	1600	507.560	1820	508.260	2450	509.610
5	781.0000	493.200	210	500.080	390	501.160	720	502.840	1140	505.940	1460	507.050	1600	507.560	1820	508.260	2450	509.610
6	1095.0000	493.200	210	500.080	390	501.160	720	502.840	1140	505.940	1460	507.050	1600	507.560	1820	508.260	2450	509.610
7	1427.0000	493.240	210	500.080	390	501.160	720	502.840	1140	505.950	1460	507.050	1600	507.560	1820	508.270	2450	509.610
8	1800.0000	494.300	210	500.080	390	501.160	720	502.840	1140	505.940	1460	507.050	1600	507.560	1820	508.260	2450	509.600
9	2240.0000	495.270	210	500.080	390	501.100	720	502.840	1140	505.970	1460	507.080	1600	507.590	1820	508.290	2450	509.640
10	2355.0000	496.360	210	500.030	390	501.060	720	503.790	1140	506.150	1460	507.210	1600	507.710	1820	508.400	2450	509.730
11	2644.0000	491.500	210	500.730	390	502.190	720	504.050	1140	506.240	1460	507.280	1600	507.770	1820	508.450	2450	509.780
12	2803.0000	491.400	210	500.730	390	502.190	720	504.060	1140	506.250	1460	507.300	1600	507.790	1820	508.470	2450	509.800
13																		
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16																		
17																		
18																		
19																		
20																		

As part of this study, an economic analysis was conducted using depth-damage data from models. Actual damage data from previous flooding events mentioned in the previous section were not collected or used.

3.3 Assumptions

The following assumptions are made for this analysis:

a. Inflation is not factored into the analysis. All prices are in constant FY 2021 dollars.

b. Land use zoning and construction codes will not change during the period of analysis.

c. Real property will continue to be repaired to pre-flood conditions after each flood event. Structures are not removed or acquired even they exceeded the 50 percent substantial damage since there is no USACE guidelines that require the removal or acquisition of structures once damage has exceeded its present value threshold. The homeowners have cultural norms to stay in their community. Hence, it is more likely that property owners would continuously to repair their properties due to flood damages since this often has occurred in the study area. The reconstruction of substantial damaged buildings to levels above the regulated Base Flood Elevation (BFE) in accordance with floodplain management will provide them resiliencies against future storms. All new buildings and additions to post-FIRM buildings after July 1, 1991, must be elevated at least as high as FEMA Base Flood Elevation (BFE) and are not included in the benefit base.

d. Damaged or destroyed properties will be restored to pre-storm conditions and remain in the structure inventory for the 50-year period of analysis.

e. Empirical storm frequencies are based on historical records and indicate the probability of future events.

f. Damages are related to the first-floor elevation of the residential and nonresidential structures and to their low opening.

3.4 Flood Damage Computation

One of the chief inputs in developing a model using the HEC-FDA program is the structure inventory. The structure inventory was created considering the 1% AEP floodplain developed by USACE Hydrology and Hydraulic (H&H) group.

The structure inventory was developed using ArcGIS Pro software version 2.3.0. A shapefile was paired with digital elevation data presented in the North American Vertical Datum (NAVD88) elevation to obtain ground elevations of structures within the flood zone. The shapefiles were then joined with one another and clipped in the study area. Then the flood zone shapefile was used to select all of the structures within the floodplain. The residential structure values were calculated using Marshall & Swift Residential Estimator 7 version 7.7.7. The commercial structure values were calculated using Marshall & Swift Commercial Estimator 7 / Agricultural Estimator version 7.2.10. Marshall & Swift provides accurate costs for structures found throughout the United States and Canada by assessing their cost primarily through the building material, the type of roof, the square footage, the effective age, the number of stories, and their location factor. Table 1 shows a random sample of 30 structures in the Township of Denville, NJ.

Table 1: Random Sample of Structures

Struct Name	Category Name	Occupancy Type	CSVR[1]	IMPRVT_VAL[2] ($)	YR	Sq Feet	DRV[3] ($)	Story Number
1	Nonresidential	N13	1.88	253400	1949	3774.59	294442	1
13	Nonresidential	N13	0.73	138400	1957	3512.06	227556	1
25	Nonresidential	N13	0.21	1020200	1974	4225.11	1070908	1
37	Nonresidential	N13	0.21	93100		1577.86	245513	1
49	Nonresidential	N13	0.21	1100800		10764	1453147	2
61	Nonresidential	N14	0.21	524000	1966	3240.85	829479	2
73	Residential	IWR5	1	260200	1934	2875.35	567928	2
85	Residential	IWR5	1	150200	1952	1341.05	300423	2
97	Nonresidential	N14	0.21	135400	1959	2406.52	261868	2
109	Residential	IWR4	1	95600	1946	1165.77	298511	1
123	Residential	IWR5	1	117900	1925	1088.08	258462	2
133	Nonresidential	N14	1.28	351400	1945	4374.59	443927	2
144	Residential	IWR6	1	149900	1937	1139.06	267481	2
157	Residential	IWR4	1	200500	1963	1455.91	271904	1
169	Residential	IWR4	1	153300	1980	1358.77	393833	1
181	Residential	IWR5	1	126400	1928	955.88	289753	2
193	Residential	IWR5	1	209900	1950	1751.42	439146	2
205	Residential	IWR4	1	147800	1968	1380.62	318830	1
217	Residential	IWR4	1	104800	1960	1059.68	252448	1
229	Residential	IWR5	1	229500	1940	2064	240134	2
241	Residential	IWR5	1	269800	2001	2076.12	838017	2
253	Residential	IWR6	1	112600	1924	1700	210303	2
265	Residential	IWR4	1	130600	1955	1431	198790	1
277	Residential	IWR6	1	250600	1951	2206.55	319305	2
289	Residential	IWR6	1	140600	1930	1234.38	208425	2
301	Residential	IWR6	1	191800	1948	1871	282274	2
313	Residential	IWR5	1	161100	1948	1133.78	223688	2
325	Residential	N14	0.21	119500	1950	1299.75	216305	2
349	Residential	IWR5	1	111700	1958	1083.68	196673	2
361	Residential	IWR6	1	179000	1930	1229.08	207828	2
		Total IMPRVT_VAL =		**7230000**		**Total DRV = 11627301**		
		DRV to IMPRVT RATIO =			**1.608**			

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[1] Content-to-Structure Value Ratio
[2] Structure Improvement Value
[3] Depreciated Replacement Value
N13 – Nonresidential Structure without Basement
N14 – Nonresidential Structure with Basement
IWR4 – One Story Residential Structure with Basement
IWR5 – Two Stories Residential Structure with Basement
IWR6 – Split-Level Residential Structure with Basement

Reasonable coefficients of the sample structure values by their square footages were derived for residential and nonresidential structures. These coefficients were used to multiply each structure's square footage to obtain the DRV of all structures in the inventory.

Table 2 shows a sample of structures in the study area. The depreciated replacement costs of the buildings were used as the structure values in the structure inventory.

Table 1: Sample of Structures in the Study Area

Structure Name	Structure Address	DRV ($000s)	Number of Stories	Structure Value in the Inventory ($000s)
25	6 BLOOMFIELD AVE	1,071	1	1,071
49	1 BROADWAY	1,453	2	1,453
61	18 BROADWAY	829	2	829
73	4 THIRD AVE	568	2	568
85	9 THIRD AVE	300	2	300
109	5 HINCHMAN AVE	299	1	299
123	18 HINCHMAN AVE	258	2	258
144	6 HEWETSON RD	267	2	267

The value of contents for each structure was determined according to pre-defined content-structure value ratios for each damage function.

The Analysis of Nonresidential Content Value and Depth-Damage for Flood Damage Reduction Studies (IWR Report 96-R-12 May 1996) was used to determine the content values of the structures. These depth damage functions are appropriate for this study because they were developed during the expert solicitation process for similar occupancies in a location relatively close to the Township of Denville, New Jersey.

Based on the Economic Guidance Memorandum (EGM) 01-03 and (EGM) 04-01, the residential content value was assumed to be equal to 100% of the structure value, since the depth-damage functions model content damage as a percentage of the structure value. Table 3 is a condensed structure inventory that contains Structure Occupancy Types, Structure Values, and Content Values.

A Digital Elevation Model was used in conjunction with parcel data to determine the ground elevation of each structure. The first floor, which was determined by a combination of the first-floor survey provided by the sponsor on most structures, by GIS capability, and by desk top survey, was also used as a reference point for beginning damage when the structure contains a basement or other low opening point. A random sample of structures was used in the study area. Street View options from Google Earth, Google Maps and Bing were used to assess the first-floor elevation, which was the height of the ground elevation plus the foundation height. The beginning damage was a reference point at the low opening where water was likely to enter the building from the ground elevation. The final component necessary to complete the structure inventory was the location of the structures with their respective river station.

Table 3: Condensed Structure Inventory

Structure Occupancy Type	Description	# of Structures	Structure Value ($000)	Content Value ($000)	Total Value ($000)
IWR1	One Story/ No Basement	28	6,583	6,583	13,166
IWR2	Two Story/ No Basement	44	12,025	12,025	24,050
IWR3	Split-Level/ No Basement	11	2,798	2,798	5,596
IWR4	One Story/ With Basement	14	3,220	3,220	6,440
IWR5	Two Story/ With Basement	89	35,052	35,052	70,104
IWR6	Split-Level/ With Basement	88	22,732	22,732	45,464
N13	Nonresidential/ No Basement	61	64,355	41,944	106,299
N14	Nonresidential/ With Basement	36	34,327	10,502	44,829
T77	Emergency Flood Fighting	1	51	1,544	1,595
	Total	**372**	**181,143**	**94,456**	**317,543**

The river stations were placed over the existing GIS dataset and Geological Coding (geo-coding) was used to assign a location to each structure by determining the structure's latitude and longitude. Using the latitude and longitude data, each structure was assigned a river station. Once each structure had been assigned a river station, the structure inventory was imported into the HEC-FDA program. The HEC-FDA program utilizes hydrologic data to determine the frequency and elevation, or stage, of water surfaces during a flood event. The stage-frequency data is combined with the structure data to determine the extent of damages based on low opening and first floor elevations of buildings in the study area.

The computation of annual flood damages is based on the application of depth-damage functions to the structures in the study area to compute damage incurred by structures and contents during flood events of different probabilities of occurrence. The depth-damage functions applied for the analysis are representative of post storm surveys of residential damages in multiple areas exposed to flooding. Depth-damage functions used for this study were the generic depth-damage functions for residential structures developed by USACE, and the damage functions for nonresidential structures that were developed following an expert opinion solicitation exercise carried out by FEMA and USACE/Institute for Water Resources:

- Single-family residential structures (and two- or multi-family structures with similar physical characteristics) without basements: *Economic Guidance Memorandum (EGM) 01-03, "Generic Depth-Damage Relationships", December 4, 2000.*
- Single-family residential structures (and two- or multi-family structures with similar physical characteristics) with basements: *Economic Guidance Memorandum (EGM) 04-01," Generic Depth-Damage Relationships for Residential Structures with Basements", October 10, 2003.*
- Nonresidential Content Value and Depth-Damage for Flood Damage Reduction Studies (IWR Report 96-R-12 May 1996).

The Generic Depth Damage Relationships within EGM 04-01, dated October 2003, are derived from comparable riverine floodplains. The Generic Depth Damage Relationships are derived by evaluating structure damages in riverine floodplains. The model outputs as well as the occupancies were compared to historic events and confirmed to be appropriate for use. A sample of depth-damage relationships for structures and contents is found in Table 4 below. The percentages damages to structures and their content values in Table 4 are based upon occupancy type and inundation depth.

3.5 Risk and Uncertainty

USACE regulations require the use of a risk and uncertainty (R&U) analysis for flood damage reduction studies at the feasibility level of detail and above. R&U analysis provides decision-makers with more information to select the appropriate project. The economic portion of R&U pertains to the extent of damages associated with various levels of flooding. Flooding damages were developed by stage or height of water over the ground. However, estimates of damages are subject to error. The study was conducted in accordance with Engineering Manual EM 1110-2-1619, "Risk-Based Analysis for Flood Damage Reduction Studies" (USACE, August 1, 1996), which requires that primary elements of the damage estimation computations be explicitly subjected to probabilistic analyses. Estimates of annual flood damage were computed for this study using version 1.4.2 of HEC-FDA, which applies Monte Carlo simulation techniques to calculate expected damage values while explicitly accounting for uncertainty in the input data. Uncertainty was incorporated into the following components of the flood damage calculations:

- Stage-frequency and discharge-frequency functions
- Inflow/outflow transform functions
- Stage-discharge functions
- Structure first floor elevation
- Structure Depreciated Replacement Value
- Depth-damage functions

Table 4: Depth-Damage Relationship of the Structures and Content in Denville, NJ

Occupancy Type	Category Name	Damage Type	Stage												
			-2	-1	0	1	2	3	4	5	6	7	8	9	10
One Story, No Basement															
IWR1	Residential	Structure	0	2.5	13.4	23.3	32.1	40.1	47.1	53.2	58.6	63.2	67.2	70.5	73.2
IWR1	Residential	Contents	0	2.4	8.1	13.3	17.9	22	25.7	28.8	31.5	33.8	35.7	37.2	38.4
Two Stories, No Basement															
IWR2	Residential	Structure	0	3	9.3	15.2	20.9	26.3	31.4	36.2	40.7	44.9	48.8	52.4	55.7
IWR2	Residential	Contents	0	1	5	8.7	12.2	15.5	18.5	21.3	23.9	26.3	28.4	30.3	32
Split-Level, No Basement															
IWR3	Residential	Structure	0	6.4	7.2	9.4	12.9	17.4	22.8	28.9	35.5	42.3	49.2	56.1	62.6
IWR3	Residential	Contents	0	2.2	2.9	4.7	7.5	11.1	15.3	20.1	25.2	30.5	35.7	40.9	45.8
One Story, With Basement															
IWR4	Residential	Structure	13.8	19.4	25.5	32	38.7	45.5	52.2	58.6	64.5	69.8	74.2	77.7	80.1
IWR4	Residential	Contents	10.5	13.2	16	18.9	21.8	24.7	27.4	30	32.4	34.5	36.3	37.7	38.6
Two Stories, With Basement															
IWR5	Residential	Structure	10.2	13.9	17.9	22.3	27	31.9	36.9	41.9	46.9	51.8	56.4	60.8	64.8
IWR5	Residential	Contents	8.4	10.1	11.9	13.8	15.7	17.7	19.8	22	24.3	26.7	29.1	31.7	34.4
Split-Level, With Basement															
IWR6	Residential	Structure	10.4	14.2	18.5	23.2	28.2	33.4	38.6	43.8	48.8	53.5	57.8	61.6	64.8
IWR6	Residential	Contents	7.3	9.4	11.6	13.8	16.1	18.2	20.2	22.1	23.6	24.9	25.8	26.3	26.3
Nonresidential, No Basement															
N13	Nonresidential	Structure	0	0	0	9	16.8	23.7	29.7	35	39.6	43.7	47.2	50.3	53
N13	Nonresidential	Contents	0	0	0	21.6	36.6	47.1	54.4	59.5	63	65.5	67.2	68.4	69.2
Nonresidential, With Basement															
N14	Nonresidential	Structure	0	0	6.7	14.9	22	28.2	33.7	38.5	42.7	46.3	49.5	52.3	54.8
N14	Nonresidential	Contents	0	0	9.7	28.3	41.3	50.4	56.7	61.1	64.1	66.3	67.7	68.8	69.5
Emergency Flood Fighting															
T77	Emergency	Structure	0	0	3.7	3.7	3.7	9.3	50	50	50	50	50	50	50
T77	Emergency	Contents	0	0	0	0	0	0	0	0	0	0	0	0	0

3.6 Future Without-Project Conditions

The future without-project condition was determined by projecting conditions in the study area over a 50-year period of analysis, and the annualized damages were computed with 2.5% discount rate. The period of analysis is determined to be from 2026 to 2075. In the absence of federal action, flooding problems associated with rainfall events in the study area are expected to continue. These problems may be exacerbated by increased damage potential in the floodplain of the Township of Denville, New Jersey within the Upper Rockaway River Basin and its tributary, Den Brook, related to climate change, which is expected to lead to an increase in intensity and frequency of storm events. It is expected, based on future land use projections in the study area, there will be limited additional development within the basin in the future period of analysis. The existing condition water surface profiles and the future without project condition water surface profiles were similar. In general, no significant changes are expected. A summary of Equivalent Annual Damages (EAD) for the without-project condition is presented in Table 5.

Table 5: Summary of EAD for the Without-Project Conditions (Base Year 2026)

Damage Reach	Annual Damages by Reach	Total Annual Damages
Den Brook	$343,000	$2,381,000
Upper Rockaway	$2,038,000	

3.7 Future With-Project Conditions

The study has been conducted in accordance with ER 1105-2-101, "Risk Assessment for Flood Risk Management Studies (USACE, July 15, 2019), which states that the risk assessment will quantify the performance of all alternatives and evaluate the residual risk, including the consequences of the project's capacity exceedance.

The economic performance analysis has been completed on physical infrastructure by using the HEC-FDA model.

3.7.1 Description of Each Alternative

Overview

Alternatives for the proposed action were formulated in consideration of study area problems and opportunities, as well as study goals, objectives, and constraints with consideration of four criteria: completeness, effectiveness, efficiency, and acceptability.

- Completeness is the extent to which a given alternative plan provides and accounts for all necessary investments or other actions to ensure the realization of the planned effects.
- Effectiveness is the extent to which an alternative plan alleviates the specified problems and achieves the specified opportunities.
- Efficiency is the extent an alternative plan is the most cost-effective means of alleviating the specified problems and realizing the specified opportunities, consistent with protecting the Nation's environment.
- Acceptability is the workability and viability of the alternative plan with respect to acceptance by state and local entities and the public and compatibility with existing laws, regulations, and public policies.

At a minimum, the potential FRM measures examined in this economic analysis included the “no action” alternative, structural measures, and nonstructural measures. This included variations of the recommended plan’s components such as floodwalls, road raising, and bypass culverts. Nonstructural measures such as elevation, flood-proofing, and relocation were also considered in light of changes to existing conditions and changes to environmental policy. The report is constrained by technical, environmental, economic, and social considerations. Once existing conditions were assessed and the *without*-project conditions established, the analysis proceeded to a *with*-project conditions assessment. Plan formulation techniques were employed to guide the development, screening, and selection of opportunities for improvement to the recommended plan, in accordance with local interests’ needs, while meeting planning objectives and within the aforementioned constraints. Formulation sought to maintain the recommended plan’s purposes of FRM, while employing environmentally sound solutions. Refer to Section 4.2 of the main report for maps of the alternatives described below.

3.7.2 Alternative 1a

3.7.2.1 Description

Alternative 1a consists of a floodwall around the perimeter of the study area exposed to high floodwaters from the Upper Rockaway River and Den Brook. The alternative is designed to keep floodwaters associated with the 100-year storm from inundating the Township of Denville, NJ. Ten closure structures or stop log structures are proposed within Alternative 1a. The closure structures would be designed to allow the floodwall to pass through a deed restricted area held by FEMA, to cross major roads, or to allow access to the business center. The total length of the floodwall is approximately 7,026 feet. The floodwall has three segments along the Upper Rockaway reach. The first segment of the floodwall has an average height of 12.54 feet above grade. The second segment of the floodwall has an average height of 9.03 feet above grade and the third segment of the floodwall has an average height of 7.82 feet above grade. The floodwall segment along the Den Brook reach, adjacent to Route 46, has an average height of 5.10 feet above grade.

3.7.2.2 Residual Damages and Benefits

Using HEC-FDA, the EAD were calculated for the base year and future years with Alternative 1a in place, and the EAD were calculated for the 50-year period of analysis, using the 2021 fiscal year USACE project evaluation discount rate of 2.5 percent. The future without-project condition water surface profiles were similar to the existing condition water surface profiles. Hence, the Expected Annual Damages and the EAD yielded the same value.

Annual Exceedance Probability (AEP) of the project is the likelihood that a target elevation is exceeded by flood waters in any given year and can be considered as an indication of the risk reduction provided by the alternative. The target elevation in the *with*-project conditions is the stage associated with the 1% AEP event. A summary of EAD and benefits for Alternative 1a is presented in Table 6.

Table 6: Summary of Damages and Benefits for Alternative 1a

Plan	Damage Reach	*Without*-Project Annual Damages	*With*-Project Annual Damages	Annual Benefits by Reach	Total Annual Benefits
Alt-1a: 1% AEP (100-year) Risk Reduction With 10 Stop Log Structures	Den Brook	$343,000	$138,000	$205,000	$937,000
	Upper Rockaway	$2,038,000	$1,306,000	$732,000	

3.7.3 Alternative 1b

3.7.3.1 Description

The flood protection systems and the dimensions of Alternative 1b are the same as in Alternative 1a. The only difference is that four closure structures are eliminated. Hence, six closure structures or stop log structures were proposed within Alternative 1b. The elimination of the closure structures would limit access to some businesses along Route 46.

3.7.3.2 Residual Damages and Benefits

Using HEC-FDA, Expected Annual Damages were calculated for the base year and future year with Alternative 1b in place, and EAD were calculated for the 50-year period of analysis, using the 2021 fiscal year USACE project evaluation discount rate of 2.5 percent.

The AEP event of the project is the likelihood that a target elevation is exceeded by flood waters in any given year and can be considered as an indication of risk reduction provided by the alternative. The target elevation in the *with*-project conditions is 1% AEP event. A summary of EAD and benefits for Alternative 1b is presented in Table 7.

Table 7: Summary of Damages and Benefits for Alternative 1b

Plan	Damage Reach	***Without*-Project Annual Damages**	***With*-Project Annual Damages**	Annual Benefits by Reach	Total Annual Benefits
Alt-1b: 1% AEP (100-year) Risk Reduction With 6 Stop Log Structures	Den Brook	$343,000	$138,000	$205,000	$937,000
	Upper Rockaway	$2,038,000	$1,306,000	$732,000	

3.7.4 Alternative 1c

3.7.4.1 Description

Alternative 1c was designed to keep floodwaters associated with the 50-year storm from inundating the Township of Denville, NJ. As in Alternative 1a, Alternative 1c contains ten closure structures or stop log structures. The floodwall of Alternative 1c also has three segments along the Upper Rockaway reach, although each segment has a lower average height than Alternative 1a. The first segment of the floodwall has an average height of 11.1 feet above grade. The second segment of the floodwall has an average height of 8.09 feet above grade and the third segment of the floodwall has an average height of 6.29 feet above grade. The floodwall segment along the Den Brook reach, adjacent to Route 46, has an average height of 5.10 feet above grade.

3.7.4.2 Residual Damages and Benefits

Using HEC-FDA, Expected Annual Damages were calculated for the base year and future year with Alternative 1c in place, and EAD were calculated for the 50-year period of analysis, using the 2021 fiscal year USACE project evaluation discount rate of 2.5percent.

The AEP event of the project is the likelihood that a target elevation is exceeded by flood waters in any given year and can be considered as an indication of risk reduction provided by the alternative. The target elevation in the *with*-project conditions is 2% AEP event. A summary of EAD and benefits for Alternative 1c is presented in Table 8.

Table 8: Summary of Damages and Benefits for Alternative 1c

Plan	Damage Reach	*Without*-Project Annual Damages	*With*-Project Annual Damages	Annual Benefits by Reach	Total Annual Benefits
Alt-1c: 2% AEP (50-year) Risk Reduction With 10 Stop Log Structures	Den Brook	$343,000	$181,000	$162,000	$850,000
	Upper Rockaway	$2,038,000	$1,350,000	$688,000	

3.7.5 Alternative 1d

3.7.5.1 Description

The flood protection systems and the dimensions of Alternative 1d are similar to Alternative 1c. The only difference is that four closure structures are eliminated. Hence, six closure structures or stop log structures are designed within Alternative 1d. The elimination of the closure structures would limit access to some businesses along Route 46.

3.7.5.2 Residual Damages and Benefits

Using HEC-FDA, Expected Annual Damages were calculated for the base year and future years with Alternative 1d in place, and EAD were calculated for the 50-year period of analysis, using the 2021 fiscal year USACE project evaluation discount rate of 2.5 percent.

The AEP event of the project is the likelihood that a target elevation is exceeded by flood waters in any given year and can be considered as an indication of risk reduction provided by the alternative. The target elevation in the *with*-project conditions is 2% AEP event. A summary of EAD and benefits for Alternative 1d is presented in Table 9.

Table 9: Summary of Damages and Benefits for Alternative 1d

Plan	Damage Reach	*Without*-Project Annual Damages	*With*-Project Annual Damages	Annual Benefits by Reach	Total Annual Benefits
Alt-1d: 2% AEP (50-year) Risk Reduction With 6 Stop Log Structures	Den Brook	$343,000	$181,000	$162,000	$850,000
	Upper Rockaway	$2,038,000	$1,350,000	$688,000	

3.7.6 Alternative 1e

3.7.6.1 Description

Alternative 1e is designed to keep floodwaters associated with the 25-year storm from inundating the Township of Denville, NJ. As in Alternative 1a, Alternative 1e contains the same flood control structures but with eight closure structures or stop log structures instead of ten due to the lower flood stage elevation associated with the 25-year event. The floodwall of Alternative 1e also has three segments along the Upper Rockaway reach. The first segment of the floodwall has an average height of 9.57 feet above grade. The second segment of the floodwall has an average height of 6.44 feet above grade and the third segment of the floodwall has an average height of 5.39 feet above grade. The floodwall segment along the Den Brook reach, adjacent to Route 46, has an average height of 3.69 feet above grade.

3.7.6.2 Residual Damages and Benefits

Using HEC-FDA, Expected Annual Damages were calculated for the base year and future years with Alternative 1e in place, and EAD were calculated for the 50-year period of analysis, using the 2021 fiscal year USACE project evaluation discount rate of 2.5 percent.

The AEP event of the project is the likelihood that a target elevation is exceeded by flood waters in any given year and can be considered as an indication of risk reduction provided by the alternative. The target elevation in the *with*-project conditions is 4% AEP event. A summary of EAD and benefits for Alternative 1e is presented in Table 10.

Table 10: Summary of Damages and Benefits for Alternative 1e

Plan	Damage Reach	*Without*-Project Annual Damages	*With*-Project Annual Damages	Annual Benefits by Reach	Total Annual Benefits
Alt-1e: 4% AEP (25-year) Risk Reduction With 8 Stop Log Structures	Den Brook	$343,000	$224,000	$119,000	$674,000
	Upper Rockaway	$2,038,000	$1,483,000	$555,000	

3.7.7 Alternative 1f

3.7.7.1 Description

The flood protection systems and the dimensions of Alternative 1f are similar to Alternative 1e. The difference is that four closure structures are eliminated. Hence, four closure structures or stop log structures are designed within Alternative 1f. The elimination of the closure structures would limit access to some businesses along Route 46.

3.7.7.2 Residual Damages and Benefits

Using HEC-FDA, Expected Annual Damages were calculated for the base year and future years with Alternative 1d in place, and EAD were calculated for the 50-year period of analysis, using the 2021 fiscal year USACE project evaluation discount rate of 2.5 percent.

The AEP event of the project is the likelihood that a target elevation is exceeded by flood waters in any given year and can be considered as an indication of risk reduction provided by the alternative. The target elevation in the *with*-project conditions is 4% AEP event. A summary of EAD and benefits for Alternative 1f is presented in Table 11.

Table 11: Summary of Damages and Benefits for Alternative 1f

Plan	Damage Reach	*Without*-Project Annual Damages	*With*-Project Annual Damages	Annual Benefits by Reach	Total Annual Benefits
Alt-1f: 4% AEP (25-year) Risk Reduction With 4 Stop Log Structures	Den Brook	$343,000	$224,000	$119,000	$674,000
	Upper Rockaway	$2,038,000	$1,483,000	$555,000	

3.7.8 Alternative 2a

3.7.8.1 Description

Alternative 2a is designed to protect a flood prone perimeter area associated with the 25-year storm inundation floodwaters. The design protection contains four closure structures. It also includes a combination of elevating five roads, the construction of a Jersey barrier, and floodwalls on the Upper Rockaway and Den Brook reaches.

Corey Road, Gardner Road, Hinchman Avenue, Orchard Street, and Diamond Spring Road are respectively raised by 4.12, 3.78, 3.32, 3.30, and 1.32 feet. Second Avenue Jersey barrier construction, floodwalls on the Upper Rockaway reach, and Den Brook reach have an average height of 3.41, 5.58, and 3.2 feet respectively.

3.7.8.2 Residual Damages and Benefits

Using HEC-FDA, Expected Annual Damages were calculated for the base year and future years with Alternative 2a in place, and EAD were calculated for the 50-year period of analysis, using the 2021 fiscal year USACE project evaluation discount rate of 2.5 percent.

The AEP event of the project is the likelihood that a target elevation is exceeded by flood waters in any given year and can be considered as an indication of risk reduction provided by the alternative. The target elevation in the *with*-project conditions is 4% AEP event. A summary of EAD and benefits for Alternative 2a is presented in Table 12.

Table 12: Summary of Damages and Benefits for Alternative 2a

Plan	Damage Reach	*Without*-Project Annual Damages	*With*-Project Annual Damages	Annual Benefits by Reach	Total Annual Benefits
Alt-2a: Combination of Road raising and Floodwall	Den Brook	$343,000	$295,000	$48,000	$454,000
	Upper Rockaway	$2,038,000	$1,632,000	$406,000	

3.7.9 Alternative 2b

3.7.9.1 Description

Alternative 2b is a modification of Alternative 2a. Alternative 2b does not include a Jersey barrier structure on Second Avenue and contains two closure structures. All roads and floodwalls elevation protection structures remain the same as in Alternative 2a.

3.7.9.2 Residual Damages and Benefits

Using HEC-FDA, Expected Annual Damages were calculated for the base year and future years with Alternative 2b in place, and Equivalent Annual Damages were calculated for the 50-year period of analysis, using the 2021 fiscal year USACE project evaluation discount rate of 2.5 percent.

The AEP event of the project is the likelihood that a target elevation is exceeded by flood waters in any given year and can be considered as an indication of risk reduction provided by the alternative. The target elevation in the *with*-project conditions is 4% AEP event. A summary of EAD and benefits for Alternative 2b is presented in Table 13.

Table 13: Summary of Damages and Benefits for Alternative 2b

Plan	Damage Reach	*Without*-Project Annual Damages	*With*-Project Annual Damages	Annual Benefits by Reach	Total Annual Benefits
Alt-2b: Combination of Road raising and Floodwall	Den Brook	$343,000	$265,000	$78,000	$924,000
	Upper Rockaway	$2,038,000	$1,192,000	$846,000	

3.7.10 Alternative 2b Sensitivity Analysis

3.7.10.1 Description

Alternative 2b sensitivity is a modification of Alternative 2b that includes two closure structures. In Alternative 2b sensitivity, the elevation of Orchard Street and Diamond Spring Road are eliminated. Snyder Road is raised to a top height of 4.28 feet. All other flood protection structures remain the same as Alternative 2b.

3.7.10.2 Residual Damages and Benefits

Using HEC-FDA, Expected Annual Damages were calculated for the base year and future years with Alternative 2b Sensitivity Analysis in place, and EAD were calculated for the 50-year period of analysis, using the 2021 fiscal year USACE project evaluation discount rate of 2.5 percent.

The AEP event of the project is the likelihood that a target elevation is exceeded by flood waters in any given year and can be considered as an indication of risk reduction provided by the alternative. The target elevation in the *with*-project conditions is 4% AEP event. A summary of EAD and benefits for Alternative 2b Sensitivity Analysis is presented in Table 14.

Table 14: Summary of Damages and Benefits for Alternative 2b Sensitivity Analysis

Plan	Damage Reach	*Without*-Project Annual Damages	*With*-Project Annual Damages	Annual Benefits by Reach	Total Annual Benefits
Alt-2b Sensitivity Analysis: Combination of Road raising and Floodwall	Den Brook	$343,000	$265,000	$78,000	$922,000
	Upper Rockaway	$2,038,000	$1,194,000	$844,000	

The difference between alternatives 2b and 2b Sensitivity Analysis is that Orchard Street would be elevated in Alternative 2b while the parallel street to the northeast, Snyder Ave, would be elevated in alternative 2b Sensitivity Analysis. The later alternative reduced damages on some structures, but induced flooding, especially near Snyder Ave on Upper Rockaway reach. Overall, more damages occurred with Alternative 2b Sensitivity analysis.

3.7.11 Alternative 3

3.7.11.1 Description

Alternative 3 includes a 20-foot wide by 8-foot high by-pass culvert that will take a substantial amount of the 25-year storm floodwaters away from the project area and redistribute it further downstream. This diversion structure will divert floodwater into the three-sided open bottom by-pass box culvert, approximately 6,600 linear feet long, and discharge that floodwater through an outlet structure designed to reduce excessive energy while discharging the waters.

3.7.11.2 Residual Damages and Benefits

Using HEC-FDA, Expected Annual Damages were calculated for the base year and future years with Alternative 3 in place, and EAD were calculated for the 50-year period of analysis, using the 2021 fiscal year USACE project evaluation discount rate of 2.5 percent.

The AEP event of the project is the likelihood that a target elevation is exceeded by flood waters in any given year and can be considered as an indication of risk reduction provided by the alternative. The target elevation in the *with*-project conditions is 4% AEP event. A summary of EAD and benefits for Alternative 3 is presented in Table 15.

Table 15: Summary of Damages and Benefits for Alternative 3

Plan	Damage Reach	*Without*-Project Annual Damages	*With*-Project Annual Damages	Annual Benefits by Reach	Total Annual Benefits
Alt-3: Bypass Culvert	Den Brook	$343,000	$333,000	$10,000	$473,000
	Upper Rockaway	$2,038,000	$1,575,000	$463,000	

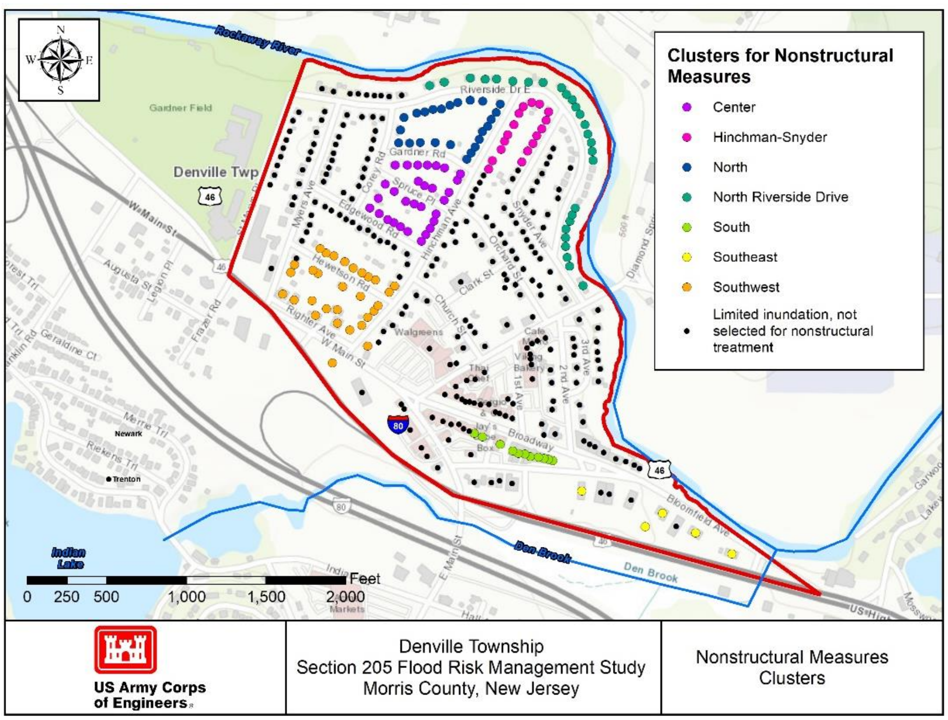
3.7.12 Alternative 4 - Nonstructural Measures

A nonstructural alternative is one in which the physical mechanism and extent of flooding is largely unchanged but the existing buildings within the floodplain are adapted and/or the regulatory framework that governs new development is modified to reduce the damage incurred during flood events.

An iterative process was performed to arrive at the selected plan for nonstructural measures. First, the structures within the study area were grouped into clusters by neighborhood blocks, generally bounded by roads, as they shared similar flood characteristics. The BCR for each cluster was computed and the clusters with negative net benefits were dropped. The structures within the seven clusters that remained (showed positive net benefits) were further evaluated. The annualized costs and benefits of nonstructural measures were developed for the remaining seven clusters, resulting in dropping 2 additional clusters from further study. Finally, the structures in the remaining five clusters were optimized per USACE policy. The purpose of the optimization was to reasonably maximize the net benefits of a chosen course of action.

The Southwest Cluster, containing 30 structures, was the first cluster to be evaluated to test the economic viability of the nonstructural measures. After briefing the non-Federal sponsor (NJDEP), the stakeholder (Township of Denville), and the USACE vertical team (VT) on the nonstructural measures, the Project Delivery Team (PDT) received consent to expand the nonstructural analysis to other structures in the study area. Several unique clusters were formed to account for all 372 structures in the study area. HEC-FDA models were run, and the BCR was computed for each cluster. According to the plan formulation, the clusters with negative net benefits were dropped; this included the removal of 227 structures from further study. Seven clusters: Southwest, Center, North Riverside Dr, North, Hinchman-Snyder, South, and Southeast yielded BCRs greater than one and were moved forward for further analysis in this appendix. Figure 5 shows the seven clusters that were moved forward in the study area.

Figure 5: Seven Clusters with Positive Net Benefits Selected to TSP Milestone



Nonstructural treatments were applied to structures in the clusters using an algorithm that considered physical characteristics including building configuration, usage, footprint size, foundation type, and existing main floor elevation in order to select and cost the most appropriate/feasible treatment for each structure. The nonstructural analysis considered three physical measures with a combination of relocation and various nonphysical measures such as evacuation plans, land use regulation, flood emergency preparedness plans, flood insurance, flood mapping, flood warning systems, risk communication, and zoning. The three physical measures can be described under the following:

- Elevation: the structure is physically raised so that the main floor of the structure is at or above the specified design protection level.
- Dry floodproof: all openings are sealed or fitted with moveable watertight barriers and the exterior walls are treated to make them waterproof to the design protection level
- Wet floodproof: wet floodproofing is generally applied to structures with a main floor elevation already above the design protection level but that still incur significant damages due to the presence of basements and vulnerable utilities. Treatments include the vacating or filling of basements, removal of utilities, and the provision of equivalent facilities above the design protection level. Wet floodproofing also includes several minor treatments such as the raising of exterior air conditioning units and the provision of louvers in crawlspace walls to allow the equalization of hydrostatic pressure.

3.7.12.1. Residual Damages and Benefits

3.7.12.1.1 Southwest Cluster

This cluster contains 30 structures, mostly residential. Six of these structures do not flood during a 1% AEP event, so they are not considered for further treatment. Fourteen structures will be elevated, six structures have been identified to receive dry floodproofing treatments, and four structures will receive wet floodproofing treatments. The six dry floodproofing structures have a large masonry construction or a slab foundation. Dry floodproofing has hydraulic limitations of 3 feet of impermeable barrier measured from the ground. A risk reduction to 1% AEP event would require impermeable barrier height of at least 3 feet, which is not acceptable hydraulically. Therefore, these structures would receive high risk reductions only. Table 16 shows the treatments applied to the structures and the HEC-FDA module assignments in the analyzed nonstructural alternative, and Table 17 summarizes damages and benefits in Upper Rockaway reach for the Southwest cluster.

Table 16: Measures and HEC-FDA Modules assigned to Southwest Structures

Structures Count	Nonstructural Measures	Module Assignment
6	Will not be subject to Treatment	Base
6	Will be dry flood proofed	Floodproof
4	Will be wet flood proofed	Floodproof
14	Will be elevated	Raise

Table 17: Summary of Damages and Benefits for Southwest Cluster

Cluster	Damage Reach	*Without*-Project	*With*-Project	Annual Benefits
Southwest	Upper Rockaway	409,000	17,000	392,000

3.7.12.1.2 Center Cluster

This cluster contains 30 residential structures. Seven of these structures do not flood during a 1% AEP event, so they are not considered for further treatment. Hence, they are not subject to treatments. Fourteen structures will be elevated, and nine structures have been identified to receive wet floodproofing treatments. Table 18 shows the treatments applied to the structures and the HEC-FDA module assignments in the analyzed nonstructural alternative, and Table 19 summarizes damages and benefits in Upper Rockaway reach for the Center cluster.

Table 18: Measures and HEC-FDA Modules assigned to Center Structures

Structures Count	Nonstructural Measures	Module Assignment
7	Will not be subject to Treatment	Base
None	Will be dry flood proofed	Floodproof
9	Will be wet flood proofed	Floodproof
14	Will be elevated	Raise

Table 19: Summary of Damages and Benefits for Center Cluster

Cluster	Damage Reach	*Without*-Project	*With*-Project	Annual Benefits
Center	Upper Rockaway	232,000	33,000	199,000

3.7.12.1.3 North Riverside Drive Cluster

This cluster contains 27 structures, mostly residential. Seven of these structures do not flood during a 1% AEP event, so they are not considered for further treatment. Hence, they are not subject to treatments. Eighteen structures will be elevated, one structure will receive dry floodproofing, and another one has been identified to receive wet floodproofing treatments. The dry floodproofing structure has a large masonry construction or a slab foundation and will receive a 10% AEP risk damage reduction, and one of the structures that has been elevated will be protected against 1 percent AEP plus one foot of confidence level. Twenty-six structures in this cluster are located within the floodway. Treatments can be applied to structures in the floodway if the nonstructural solutions do not increase the stage and/or the velocity of the water in the floodway downstream and upstream. The structure that is receiving dry floodproofing is a facility that contains a sewer pump station. Dry floodproofing is suitable for a sewer pump facility. It is worth noting that the development in a floodway is discouraged but not prohibited by FEMA. Table 20 shows the treatments applied to the structures and the HEC-FDA module assignments in the analyzed nonstructural alternative, and Table 21 summarizes damages and benefits in Upper Rockaway reach for the North River Drive cluster.

Table 20: Measures and HEC-FDA Modules assigned to North Riverside Drive Structures

Structures Count	Nonstructural Measures	Module Assignment
7	Will not be subject to Treatment	Base
1	Will be dry flood proofed	Floodproof
1	Will be wet flood proofed	Floodproof
18	Will be elevated	Raise

Table 21: Summary of Damages and Benefits for North Riverside Drive Cluster

Cluster	Damage Reach	*Without*-Project	*With*-Project	Annual Benefits
North Riverside Drive	Upper Rockaway	429,000	17,000	412,000

3.7.12.1.4 North Cluster

This cluster contains 24 residential structures. Seven of these structures do not flood during a 1% AEP event, so they are not considered for further treatment. Twelve structures will be elevated, and five structures have been identified to receive wet floodproofing treatments. Table 22 shows the treatments applied to the structures and the HEC-FDA module assignments in the analyzed nonstructural alternative, and Table 23 summarizes damages and benefits in Upper Rockaway reach for the North cluster.

Table 22: Measures and HEC-FDA Modules assigned to North Structures

Structures Count	Nonstructural Measures	Module Assignment
7	Will not be subject to Treatment	Base
None	Will be dry flood proofed	Floodproof
5	Will be wet flood proofed	Floodproof
12	Will be elevated	Raise

Table 23: Summary of Damages and Benefits for North Cluster

Cluster	Damage Reach	*Without*-Project	*With*-Project	Annual Benefits
North	Upper Rockaway	218,000	18,000	200,000

3.7.12.1.5 Hinchman-Snyder Cluster

This cluster contains 18 residential structures. Two of these structures do not flood during a 1% AEP event, so they are not considered for further treatment. Hence, they are not subject to treatments. Six structures will be elevated, and ten structures have been identified to receive wet floodproofing treatments. All the structures in this cluster are receiving 1% AEP risk reduction. Table 24 shows the treatments applied to the structures and the HEC-FDA module assignments in the analyzed nonstructural alternative, and Table 25 summarizes damages and benefits in Upper Rockaway reach for the Hinchman-Snyder cluster.

Table 24: Measures and HEC-FDA Modules assigned to Hinchman-Snyder Structures

Structures Count	Nonstructural Measures	Module Assignment
2	Will not be subject to Treatment	Base
None	Will be dry flood proofed	Floodproof
10	Will be wet flood proofed	Floodproof
6	Will be elevated	Raise

Table 25: Summary of Damages and Benefits for Hinchman-Snyder Cluster

Cluster	Damage Reach	*Without*-Project	*With*-Project	Annual Benefits
Hinchman-Snyder	Upper Rockaway	106,000	23,000	83,000

3.7.12.1.6 South Cluster

This cluster contains 11 nonresidential structures. All 11 structures have been identified to receive dry floodproofing treatments. Table 26 shows the treatments applied to the structures and the HEC-FDA module assignments in the analyzed nonstructural alternative, and Table 27 summarizes damages and benefits in Upper Rockaway reach for the South cluster.

Table 26: Measures and HEC-FDA Modules assigned to South Structures

Structures Count	Nonstructural Measures	Module Assignment
None	Will not be subject to Treatment	Base
11	Will be dry flood proofed	Floodproof
None	Will be wet flood proofed	Floodproof
None	Will be elevated	Raise

Table 27: Summary of Damages and Benefits for South Cluster

Cluster	Damage Reach	*Without*-Project	*With*-Project	Annual Benefits
South	Upper Rockaway	131,000	21,000	110,000

3.7.12.1.7 Southeast Cluster

This cluster contains 5 nonresidential structures. One structure will be elevated, and the remaining four structures have been identified to receive dry floodproofing treatments. Table 28 shows the treatments applied to the structures and the HEC-FDA module assignments in the analyzed nonstructural alternative, and Table 29 summarizes damages and benefits in Upper Rockaway reach for the Southeast cluster.

Table 28: Measures and HEC-FDA Modules assigned to Southeast Structures

Structures Count	Nonstructural Measures	Module Assignment
None	Will not be subject to Treatment	Base
4	Will be dry flood proofed	Floodproof
None	Will be wet flood proofed	Floodproof
1	Will be elevated	Raise

Table 29: Summary of Damages and Benefits for Southeast Cluster

Cluster	Damage Reach	*Without*-Project	*With*-Project	Annual Benefits
Southeast	Upper Rockaway	140,000	31,000	109,000

The total number of structures in the seven clusters is 145. Among them 116 are receiving nonstructural treatments because 29 are not in the 1% AEP floodplain.

3.7.12.2 Summary of Annualized Screening Benefits and BCRs

The *equivalent* annual benefits of the alternatives were compared to the annual costs to develop a BCR for the plans. The net benefits were calculated by subtracting the annual costs from the expected annual benefits. The net benefits were used to determine the economic justification of the project measures. With-project (2026) and future with-project hydraulic conditions (2075) were used to compute equivalent annual benefits over a 50-year project life using an interest rate of 2.50 percent.

Seven clusters of structures have been evaluated in the Denville Township floodplain. HEC-FDA models were run, and the BCR was computed for protection of each cluster to the 1 percent AEP level with the preliminary costs developed by the team prior to the TSP milestone. The clusters with negative net benefits were dropped. Five clusters; Southwest, Center, North River Side Dr, North, and Southeast shown in Figure 5 yielded BCRs greater than 1.0 and were moved forward for further analysis. Nonstructural cost estimates for the final array were developed through a joint effort between the Baltimore District Cost Engineering, Economics, Real Estate, Cultural Resources, and the Huntington District Cost Engineering Branches and were used to select the clusters with positive net benefits.

The tables below show the costs of non-structural treatments at the 1 percent AEP level to structures in each cluster. At this level of protection, the total cost is higher than the CAP 205 project funding limit of approximately $15 million ($10 million Federal with a 65/35 cost share). The amount of $1.2 million has already been used for this study. The remaining approximately $14 million will be used to finalize the design and to implement the project. It is necessary to point out that not all the property owners will be willing to participate in the nonstructural measures. In the event the project cost is higher than the CAP 205 project limits, USACE will authorize the final design and implementation if the Non-Federal sponsor agrees to pay the full surplus amount. Table 30 presents the cost summary for the clusters and Table 31 presents the annualized benefits, the annualized costs, the net benefits, and the BCR for each cluster.

Table 30: Nonstructural Cost by Cluster at 1% AEP Level

Cluster	First Cost	IDC	Investment Cost	Annual O&M Cost	Average Annual Cost
Southwest	$7,710,000	$16,000	$7,726,000	--	$272,000
Center	$5,360,000	$11,000	$5,371,000	--	$189,000
North Riverside	$5,616,000	$12,000	$5,628,000	--	$198,000
North	$3,941,000	$8,000	$3,949,000	--	$139,000
Hinchman-Snyder	$3,326,000	$7,000	$3,333,000	--	$118,000
South	$4,412,000	$9,000	$4,421,000	--	$156,000
Southeast	$1,883,000	$4,000	$1,887,000	--	$67,000

Table 31: Nonstructural Annualized Benefits & Cost, Net Benefits, and BCR at 1% AEP Level

Cluster	Total Benefits	Total Cost	Annual Benefits	Annual Costs	Net Benefits	BCR
Southwest	$11,118,000	$7,726,000	$392,000	$272,000	$120,000	1.44
Center	$5,644,000	$5,371,000	$199,000	$189,000	$10,000	1.05
North Riverside	$11,685,000	$5,628,000	$412,000	$198,000	$214,000	2.08
North	$5,672,000	$3,949,000	$200,000	$139,000	$61,000	1.44
Hinchman-Snyder	**$2,354,000**	**$3,333,000**	**$83,000**	**$118,000**	**($35,000)**	**0.70**
South	**$3,120,000**	**$4,421,000**	**$110,000**	**$156,000**	**($46,000)**	**0.71**
Southeast	$3,091,000	$1,887,000	$109,000	$67,000	$42,000	1.63

Hinchman-Snyder and South clusters yield negative net benefits in a 100-year floodplain, consequently BCRs are less than 1. They were not considered further in the analysis. Table 32 shows the aggregation of the five positive clusters.

Table 32: Aggregation of 5 Clusters with Positive Net Benefits in the 100-YR floodplain

Cluster	Total Benefits	Total Cost	Annual Benefits	Annual Costs	Net Benefits	BCR
Aggregation	$37,210,000	$24,561,000	$1,312,000	$865,000	$447,000	1.52

The total number of structures eligible for nonstructural measures in these five clusters is 116. Among them 89 structures are receiving treatments while 27 are not within the 100-year floodplain.

3.7.12.3 Recurrent Damages

Recurrent flood losses are potential damages that are expected to occur at various flood stages. The 1% AEP event could cause estimated damages to residential and nonresidential properties in the amount of $16.5 million in the without-project condition and $3.7 million in the with-project condition. Tables 33 and 34 present dollar amounts for recurring losses by different annual exceedance probabilities for without and with-project conditions, respectively.

Table 33: Existing Condition Damages by Flood Frequency

Annual Exceedance Probability (AEP)	Damage by Category ($000)		Total Damage ($000)
	Residential	Nonresidential	
50%	269	133	402
20%	881	435	1,317
10%	2,114	1,044	3,158
4%	6,058	2,993	9,050
2%	8,598	4,247	12,845
1%	11,069	5,468	16,537
0.5%	13,589	6,713	20,302
0.2%	15,776	7,794	23,570

Table 34: With-Project Condition Damages by Flood Frequency

Annual Exceedance Probability (AEP)	Damage by Category ($000)		Total Damage ($000)
	Residential	Nonresidential	
50%	0.01	0.00	0.01
20%	0.01	0.01	0.02
10%	2	1	3
4%	90	56	146
2%	505	312	817
1%	2,272	1,401	3,673
0.5%	5,591	3,446	9,037
0.2%	7,854	4,841	12,696

There is a total of 372 structures in the Township of Denville, NJ. Each structure falls in one of two categories, Residential or Nonresidential. Table 35 shows the number of structures in each flood event. A total of 31 (= 372 - 341) structures are getting wet above 0.20% AEP.

Table 35: Structures in Floodplain

Land Use Category	50% AEP	20% AEP	10% AEP	4% AEP	2% AEP	1% AEP	0.40% AEP	0.20% AEP
Residential	16	29	57	120	182	214	232	246
Nonresidential	2	5	11	43	72	83	91	95
TOTAL	**18**	**34**	**68**	**163**	**254**	**297**	**323**	**341**

The numbers of populations at risk in 2%, 1%, 0.4%, and 0.2% AEPs are respectively 473, 556, 603, and 637.

Tables 36, 37, and 38 show respectively the values of damageable property, single occurrence damages, and single occurrence damages as percentage of property value.

Table 36: Value of Damageable Property

	50% AEP	20% AEP	10% AEP	4% AEP	2% AEP	1% AEP	0.40% AEP	0.20% AEP
$/str	220	263	272	277	265	267	298	299
Residential	3,527	7,637	15,522	33,286	48,238	57,095	69,041	73,447
Residential Content	1,763	4,210	8,153	17,035	24,511	28,939	34,912	37,115
$/str	318	346	383	705	866	844	884	888
Nonresidential	637	1,732	4,218	30,304	62,339	70,041	80,477	84,402
Nonresidential Content	820	3,186	4,897	19,352	36,475	39,486	49,315	50,993

Note: Numbers are in $000s

Table 37: Single Occurrence Damages

	50% AEP	20% AEP	10% AEP	4% AEP	2% AEP	1% AEP	0.40% AEP	0.20% AEP
Residential Structure	270	1,050	2,814	6,898	11,513	16,693	21,810	27,040
Residential Content	98	345	890	2,143	3,476	4,853	6,266	7,553
Nonresidential Structure	72	269	806	4,132	8,606	14,214	18,615	24,973
Nonresidential Content	166	554	1,352	5,366	9,825	14,916	19,450	25,366

Note: Numbers are in $000s

Table 38: Single Occurrence Damages as Percentage of Property Value

	50% AEP	20% AEP	10% AEP	4% AEP	2% AEP	1% AEP	0.40% AEP	0.20% AEP
Residential Structure	7.66%	13.75%	18.13%	20.72%	23.87%	29.24%	31.59%	36.82%
Residential Content	5.55%	8.20%	10.92%	12.58%	14.18%	16.77%	17.95%	20.35%
Nonresidential Structure	11.34%	15.54%	19.11%	13.63%	13.80%	20.29%	23.13%	29.59%
Nonresidential Content	20.21%	17.40%	27.62%	27.73%	26.94%	37.78%	39.44%	49.74%

Structures are getting damages across all the annual exceedance probabilities.

4 Project Costs

4.1 Structural Costs

Structural cost estimates were developed by the Baltimore District Cost Engineering Branch in the FY 2021 (October 2021) price level. The Total Project Cost Summary (TPCS) was developed using 20 percent contingencies for Account 11 (Levees & Floodwalls), 10 percent for Account 30 (Planning Engineering & Design), and 10 percent contingencies for Account 31 (Construction Management) for all structural alternatives analyzed during the TSP milestone.

For comparison to the benefits, which are average annual flood damages reduced, the first costs were annualized and were based on the FY21 discount rate and a 50-year period of analysis. Interest during construction (IDC) was added to the first costs using 2026 as a base year. Interest during construction was calculated using an end of year payment schedule and 2.50 percent annual discount rate. Table 39 shows the duration of the construction for each alternative, Table 40 displays the IDC calculation for Alternative-1a, and Table 41 summarizes the project first cost, the IDC, investment cost, O&M cost, and the average annual cost. Note that the methodology for IDC calculation is the same for each alternative. Hence, the economic analysis does not show the detailed IDC computation for the rest of the alternatives.

Table 39: Interest During Construction (IDC) Period for Structural Alternatives

Alternative	IDC Period (Years)
Alt-1a	5
Alt-1b	5
Alt-1c	4
Alt-1d	4
Alt-1e	3
Alt-1f	3
Alt-2a	3
Alt-2b	3
Alt-2b Sensitive	3
Alt-3	3

Table 40: IDC Computation for Alternative-1a

Project First Cost:			$83,702,000
Construction Period in Months			60
Monthly payment			$1,395,033
Annual Discount Rate			2.50%
Monthly Interest Rate			0.002059836
Month	**Payment**	**Interest Factor**	**Interest**
1	1,395,033	0.12908249	180,074
2	1,395,033	0.12676154	176,837
3	1,395,033	0.12444537	173,605
.	.	.	.
.	.	.	.
.	.	.	.
59	1,395,033	0.00205984	2,874
60	1,395,033	0.00000000	0
		Total	**$5,295,000**

Table 41: Structural Project Cost Summary

Alternative	First Cost	IDC	Investment Cost	Annual O&M Cost	Average Annual Cost
Alt-1a	$83,702,000	$5,295,000	$88,997,000	$74,000	$3,212,000
Alt-1b	$81,171,000	$5,135,000	$86,306,000	$74,000	$3,117,000
Alt-1c	$71,770,000	$3,586,000	$75,356,000	$74,000	$2,731,000
Alt-1d	$69,412,000	$3,469,000	$72,881,000	$74,000	$2,644,000
Alt-1e	$62,105,000	$2,292,000	$64,397,000	$74,000	$2,345,000
Alt-1f	$59,788,000	$2,206,000	$61,994,000	$74,000	$2,260,000
Alt-2a	$22,036,000	$813,000	$22,849,000	$69,600	$875,000
Alt-2b	$25,850,000	$954,000	$26,804,000	$69,600	$1,015,000
Alt-2b Sensitive	$25,659,000	$947,000	$26,606,000	$69,600	$1,008,000
Alt-3	$58,743,000	$2,168,000	$60,911,000	$15,000	$2,163,000

4.2 Nonstructural Costs

Nonstructural cost estimates for the final array were developed through a joint effort between the Baltimore District Cost Engineering and the Huntington District Cost Engineering Branches. The costs were compared and adjusted based on the local contractors' costs. A 29% contingency was applied to all nonstructural cost estimates, excluding the real state contingency, during the final-level phase of the study. The contingency represents the uncertainty regarding the cost and schedule risk of these measures. The contingency amount was computed during an abbreviated cost risk analysis using some of the most significant factors impacting cost associated with the Township of Denville Feasibility Study.

Interest during construction was calculated for the nonstructural alternatives on an end-period basis payment schedule using a 2.50 percent federal discount rate. Based on the Township of Denville project, the construction period will last 90 days on a single structure.

Real estate costs were incorporated in the nonstructural analysis, which included relocation assistance costs for tenants, and administrative costs. While elevation is voluntary, homeowners are not qualified to receive relocation costs. This relocation cost is included in the project first cost. A 20 percent contingency was applied to the real estate costs, which is separate from the contingency applied to the square foot cost estimates for elevation and floodproofing. A 22.32 percent contingency was applied to Cultural Resources costs in the Township of Denville.

4.2.1 Elevation

The estimate of the cost to elevate the structures was computed once the model execution was completed. Elevation costs were based on the difference in the number of feet between the original first floor elevation and the target elevation for each structure in the HEC-FDA module, and the cost of fill in the basement if needed. The number of feet that each structure was raised was rounded to next highest one-foot increment. Elevation costs by structure were summed to yield an estimate of total structure elevation costs.

Composite costs were derived for structures by type: single floor slab on grade, multi-floor slab on grade, single floor crawl space, and multi-floor crawl space. These composite unit costs also vary by the number of feet that structures may be elevated. Table 42 displays the costs for each of the four categories analyzed and by the number of feet elevated. The costs in this table do not include contingency, or any other supporting cost such as construction management or pre-construction engineering and design (PED) phase.

The cost per square footage to raise an individual structure to the target height was multiplied by the average footprint square footage of each structure's occupancy type to compute the costs to elevate the structure. The total costs for all elevated structures were annualized over the 50-year period of analysis of the project using the FY21 federal discount rate of 2.50 percent.

4.2.2 Dry Floodproofing

The dry floodproofing costs were applied to non-residential structures, and some large masonry construction or slab foundation residential structures. Separate cost estimates were developed to dry flood proof based on square footage.

Table 42: Nonstructural Elevation Costs ($/Sq. Ft.)

Single Floor Crawl Space		
Lift	*AVG SF*	*SF Cost*
11	1394	$151
12	1069	$188
13	1352	$169
14	1363	$173
Multi-Floor Crawl Space		
Lift	*AVG SF*	*SF Cost*
11	1449	$152
12	1509	$156
13	1530	$161
14	1333	$175
15	1090	$206
Single Floor Slab on Grade		
Lift	*AVG SF*	*SF Cost*
7	1077	$155
11	1140	$179
12	1166	$184
13	1600	$164
14	1877	$159
15	1157	$203
16	1382	$187
Multi Floor Slab on Grade		
Lift	*AVG SF*	*SF Cost*
5	4337	$56
11	1670	$155
12	1434	$168
13	1665	$159
14	1682	$162
15	1244	$207

4.2.3 Wet Floodproofing

The wet floodproofing costs were applied to non-residential structures, and some large masonry construction or slab foundation residential structures. The envelope of the structure for wet floodproofing included installing engineered flood vents, tearing out existing sheetrock, batt insulation, electrical outlets, and installing rigid foam wall insulation, Hardie® dry board, and elevating electric outlets. Costs for wet floodproofing also included blasting existing coatings and rust and applying two coats of epoxy coating. Costs include elevating some contents inside of the building.

4.2.4 Acquisition and Relocation

4.2.4.1 Acquisition

The estimate of the cost of acquiring structures was evaluated during the plan formulation in the North Riverside Drive cluster. The treatment costs were compared to the maximum construction costs that the project can support based on BCR. One structure that has lower maximum construction supported costs relative to its treatment costs was selected. Acquisition costs are based on the cost of acquiring the parcel of land, the structure built on the land, and miscellaneous costs associated with the acquisition process. The cost of acquiring the parcel and the physical structure were provided by the Baltimore Real Estate Branch and was $481,125. Added to the acquisition cost was the cost of demolition and restoration, which was evaluated to be $220,000. Hence, the total acquisition cost was $701,125. The depreciated replacement value of the structure was used to represent the cost of the structure, which was previously described as being sourced from RS Means Square Foot Cost data. The structure elevated treatment cost was $96,425 which is less than $701,125, the total acquisition cost. The HEC-FDA model was run and the net benefits and the BCR were computed for the entire cluster, not on the single acquired structure because ER 1105-2-100 prohibits the formulation and evaluation of plans at the individual structure level. The net benefits without acquiring the structure were $330,000 while it was $310,000 with the acquisition of the structure. Hence, the acquisition alternative was ruled out before the TSP milestone.

4.2.4.2 Relocation

Relocation costs are based on the cost of relocating the occupant, as required per Uniform Relocation Assistance and Real Property Acquisition Act of 1970 (URA), that has been removed from the acquired parcel. Relocation costs include purchasing a suitable piece of property commensurate with the acquired parcel and the costs associated with the URA. The elevation of the structure is voluntary. Hence, in this analysis the costs associated with relocation include only assisting the tenants with moving costs and to stay in a hotel for a period of 90 days. Relocation costs by structure were summed to yield an estimate of total structure relocation cost that is added to the Real Estate costs.

5 Plan Evaluation and Comparison

The clusters that were determined to have positive BCRs for non-structural treatment at the 1 percent AEP level were reanalyzed at the 10 percent, 4 percent, and 2 percent levels. It was found that each of these were more cost effective than protection to the 1 percent AEP level. Similarly for the structural measures, the equivalent annual benefits were compared to the average annual cost to develop net benefits and a BCR for each alternative. The net benefits for each alternative were calculated by subtracting the average annual costs from the equivalent average annual benefits. A BCR was derived by dividing average benefits by average annual costs. Net benefits were used in conjunction with a BCR plan greater than 1.0 to identify the National Economic Development (NED) plan. For comparative purposes, Table 43 summarizes the equivalent annual benefits, average annual costs, the net benefits, and the BCR for each alternative.

The results in Table 43 show that the net benefits are optimized in the Nonstructural 4% AEP aggregation. Since no other AEP aggregation (10% AEP, 2% AEP, or 1% AEP) exceeded the net benefits of the 4% AEP aggregation, and the net benefits are negative for all the structural alternatives. It was determined that the 4% AEP aggregation was optimized and would be utilized going forward.

As a result of the comparison of the alternatives, the Nonstructural 4% AEP Alternative was identified as the tentatively selected plan. The Nonstructural 4% AEP plan yielded the highest net benefits with a BCR greater than 1, which is the criterion used for identification of the NED Plan in accordance with the Federal objective. Therefore, the NED Plan, Nonstructural Alternative, was recommended to be the TSP.

Table 43: Summary of Benefits, Costs, and BCR for each Alternative

Alternative	Total Benefits	Total Costs	Average Annual Benefits	Average Annual Costs	Net Benefits	BCR
No Action	---	---	---	---	---	---
Alt-1a	$26,575,000	$90,930,000	$937,000	$3,212,000	($2,269,000)	0.29
Alt-1b	$26,575,000	$88,405,000	$937,000	$3,117,000	($2,180,000)	0.30
Alt-1c	$24,108,000	$77,457,000	$850,000	$2,731,000	($1,881,000)	0.31
Alt-1d	$24,108,000	$74,990,000	$850,000	$2,644,000	($1,794,000)	0.32
Alt-1e	$19,116,000	$66,510,000	$674,000	$2,345,000	($1,671,000)	0.29
Alt-1f	$19,116,000	$64,099,000	$674,000	$2,260,000	($1,586,000)	0.30
Alt-2a	$12,876,000	$24,817,000	$454,000	$875,000	(421,000)	0.52
Alt-2b	$26,207,000	$28,788,000	$924,000	$1,015,000	(91,000)	0.91
Alt-2b Sensitive	$26,150,000	$28,589,000	$922,000	$1,008,000	(86,000)	0.91
Alt-3	$13,415,000	$61,348,000	$473,000	$2,163,000	($1,690,000)	0.22
Alt-4 Nonstructural 10% AEP (10YR)	$26,462,000	$8,411,000	$933,000	$297,000	$636,000	3.14
Alt-4 Nonstructural 4% AEP (25YR)	$35,368,000	$16,110,000	$1,247,000	$568,000	$679,000	2.20
Alt-4 Nonstructural 2% AEP (50YR)	$36,389,000	$18,257,000	$1,283,000	$644,000	$639,000	1.99

6 Tentatively Selected Plan

According the USACE Planning and Guidance Notebook (ER 1105-2-100), Chapter 2-3, (4):

Section 904 of the Water Resources Development Act of 1986 (WRDA of 1986) requires the Corps to address the following matters in the formulation and evaluation of alternative plans:

- *Protecting and restoring the quality of the total environment.*
- *The well-being of the people of the United States*
- *The prevention of loss of life.*
- *The preservation of cultural and historical values*

The ER goes on to state in Chapter 3-3 (11), Flood Damage Reduction:

… An essential element of the analysis of the recommended plan is the identification of residual risk for the sponsor and the flood plain occupants, including residual damages and potential for loss of life, due to exceedance of design capacity. …

Moreover, ER 1105-2-101, Planning, Risk Assessment for Flood Risk Management Studies, 5. Context:

…All flood risk managers must balance the insights of USACE's professional staff with stakeholder concerns for such matters as residual risks, life safety, reliability, resiliency and cost while acknowledging no single solution will meet all objectives, and trade-offs must always be made….

For projects to be considered in the federal (USACE) interest for construction, project benefits must be greater than the costs of project implementation, creating a BCR greater than 1.0 and positive net benefits. According to this guidance, when screening the alternatives in this study, Alternative 4 - nonstructural measures was selected as the tentatively selected plan for this study as it is the only alternative to return positive net benefits and a BCR greater than 1. None of the structural protection measures where economically viable and were dropped from further consideration. Table 43 above shows the breakdown of net benefits and BCRs. After selection, Alternative 4 was used for further evaluation. Later in this report, optimization of the nonstructural alternative is conducted to determine the specific optimal protection level by cluster and what treatment they will receive.

6.1 Discussion of Four Accounts

In the 1970 Flood Control Act, Congress identified four national accounts for use in water resources development planning: National Economic Development (NED), Regional Economic Development (RED), Environmental Quality (EQ), and Other Social Effects (OSE). NED and EQ are considered to be national objectives. For this study, these benefits are measured by looking at the changes between the with and without project conditions. RED benefits are described as benefits that would impact the region, but not have wider national affects such as local employment, income and revenue loss. EQ benefits are primarily driven by ecosystem restoration and are minimally present in this study area while OSE includes factors such as life loss, community identity, and traditions.

6.2 Regional Economic Development (RED)

Regional Economic Development changes are factors that have an impact on the local Denville economy but may not have wider effects in the outside region. A significant factor in this account is local businesses' revenue and job gain or loss as well as future business prospects. Localized flood events could lead to closure of businesses creating a loss in revenue for the business and income for its employees. Road and bridge closures due to flooding may also contribute to revenue/income loss for the area from the decreased ease of travel in and out of the study area. Flood prone areas are also much less attractive for potential new companies who want to move in and would bring employment opportunities with them. Preserving a tax base is also an important contributor for local economies and keeping viable industries and workforce sustained is a large factor in contributing to that goal. As mentioned earlier in this report, the township saw many people leave the area following large flood events that caused severe damage. Losses like this cause a reduction in the employment and tax base in the study area.

The Certified RECONS 2.0 model was used to estimate RED benefits for the nonstructural plan in the Township of Denville. The total cost the recommended plan ($19,045,000) was used as input into the RECONS model. This RED analysis, using RECONS, employs input-output economic analysis, which measures the interdependence among industries and workers in an economy. This analysis uses a matrix representation of a region’s economy to predict the effect of changes, the implementation of a USACE project, to the various industries that would be impacted. The greater the interdependence among industry sectors, the larger the multiplier effect on the economy.

Direct effects represent the impacts the new federal expenditures have on industries that directly support the new project. Labor and construction materials are direct components to the project. Indirect effects represent changes to secondary industries that support the direct industries.

Of the total expenditures, 99 percent will be captured within the local study area. The remainder of the expenditures will be captured within the state or national level. These direct expenditures generate additional economic activity, often called secondary or multiplier effects. The direct and secondary impacts are measured in output, jobs, labor income, and gross regional product (value added) as summarized in Table 44. The construction stimulus in the Township of Denville would generate 284 full-time equivalent jobs, $28,541,052 dollars labor income, and $51,221,903 dollars output in the national level.

Table 44: Summary of Regional Economic Development Impacts of the Recommended Plan

Area	Local Capture	Output	Jobs*	Labor Income	Value Added
Local					
Direct Impact		$18,980,628	110	$17,266,628	$16,215,189
Secondary Impact		$18,517,595	83	$7,277,543	$12,224,544
Secondary Impact	$18,980,628	$37,498,223	193	$24,544,171	$28,439,733
State					
Direct Impact		$18,980,628	121	$17,379,640	$16,215,189
Secondary Impact		$21,453,263	102	$8,021,794	$13,464,241
Total Impact	$18,980,628	$40,433,891	223	$25,401,434	$29,679,430
US					
Direct Impact		$19,016,152	132	$17,965,575	$16,234,920
Secondary Impact		$32,205,751	152	$10,575,477	$18,105,221
Total Impact	$19,016,152	$51,221,903	284	$28,541,052	$34,340,141

6.3 Environmental Quality (EQ)

Environmental quality can include factors such as ecosystem restoration, habitat creation, and endangered species protection. Cultural resources are also included in this account such as historic buildings and preservation sites. When compared to other plan alternatives presented in this report, the selected nonstructural plan has little effect on the environment in Denville Township as changes will be made to the structures affected and not the surrounding floodplain area. While this will not cause any damage to the environmental quality of the area, it is also unlikely to improve it in an impactful way. The nonstructural plan would be an effective measure to protect culturally or historically important buildings in the study area and while optional, the owners of these types of buildings may be more inclined to participate to preserve their cultural status.

Heathy Community Planning New Jersey (HCP-NJ) date shows concerns to Air Cancer Risk, Surface Water Quality, and Flooding that have the respective indicators 132, 71, and 11.7 in the Township of Denville.

Table 45: Environmental Indicators

Environmental Indicators	Units	Time Period	DENVILLE TOWNSHIP	MORRIS	County Comparison
Air Cancer Risk	Risk per Million	2017	132	115	49
Air Non Cancer	Combined Hazard Index	2017	2.1	1.7	64
Air Quality Index (AQI)	Days AQI above 100 (3 yr Avg)	2018 to 2020	3.5	3.4	49
Community Drinking Water	Number of MCL, TT and AL exceedances(3 yr)	2019 to 2021	0	8	0
Private Wells	% of Private Wells above Primary Standard	2002 to 2018	5.4	6.5	32
Ground Water/Soil	% Area Restricted Use	2022	0.5	4.7	41
Surface Water Quality	% Designated Uses Not Supported	2016	71.0	74.6	46
Flooding (Urban Land Cover)	% Urban Land Use Area Flooded	2021	11.7	6.1	84
Air Permit Sources	Sites per Sq Mile	2022	1.02	0.55	62
Combined Sewer Overflow	Number per Town	2019	0	0	0
Brownfield Development Areas	Number per Town	2019	0	0	0
Contaminated Sites	Sites per Sq Mile	2022	1.99	1.16	64
Scrap Metal Facilities	Sites per Sq Mile	2022	0.04	0.03	77

The numbers in the last three columns are numeric results for each indicator

The nonstructural plan selected will have a minor contribution of improving environmental quality of the community.

6.4 Other Social Effects (OSE)

The potential for flooding creates a life safety risk for people working in, living in or passing through an affected area such as Denville. As referenced earlier in this report, the population of Denville Township was around 18,000 people as of 2020. With limited warning time, the potential for life loss is present in the study area due to the concentration of homes and businesses along the path of the rivers. There are also risks associated with hindered deployment and cost of emergency vehicles from a flood event. While those affected will need to voluntarily participate in the nonstructural treatment, those who do, should gain from the investment in the form of increased structure value; however, once public investment is made to protect a structure there will be restrictions to future modifications to ensure continued effectiveness of the non-structural treatment. That could have a negative effect on value. The net result would be determined by the market.

With consultation with the local sponsor, the project delivery team evaluated the optimization of plans. In addition, as a result of the comparison of the alternatives, the nonstructural alternative was identified as the TSP. Its benefits were greater than its costs. In other words, the nonstructural alternative maximizes net benefits, which is the criterion used for identification of the NED Plan in accordance with the Federal objective. Therefore, the NED Plan, the nonstructural alternative, was recommended to be the TSP.

6.4.1 Life Loss

The other social effects (OSE) account includes impacts to life safety, vulnerable populations, local economic vitality, and community optimism. Impacts on these topics are a natural outcome of civil works projects and are qualitatively discussed. HEC-FIA and HEC-LifeSim modeling software quantify loss of life for alternatives, especially the structural alternatives, to determine if life safety risk decreases or increases as a result of federal investment. Hence, only the qualitative assessment was evaluated for the Township of Denville study.

6.4.2 Health and Safety

The health and safety of people living in the community within the project area were considered. Heathy Community Planning New Jersey (HCP-NJ) was used to assess social vulnerability of the population in the Township of Denville, NJ. Some indicators that have concerns in the recent years are Heart Attack, Cancer Deaths Stroke, Childhood Blood Lead, and Heat Related Illness, and were compared to the Morris County statistics as shown in Table 46.

Table 46: Demographics and Public Health Indicators

Demographics and Public Health Indicators	Units	Time Period	DENVILLE TOWNSHIP	MORRIS	County Comparison
Poverty	% Under 2 times Poverty	2016 to 2020	10.2	12.1	46
Minority	% Minority	2016 to 2020	19.4	29.5	41
Health Insurance	% with no Insurance	2016 to 2020	3.9	4.5	56
Low Birth Weight	% All Births < 5 lb, 8 oz	2016 to 2020	4.0	6.1	BELOW
Childhood Blood Lead	% Children tested > 5 µg/dL	2019 (SFY)	N/A	1.1	SUPPRESSED
Asthma (ED)	Age Adjusted Rate per 10,000	2016 to 2019	19.9	24.7	NO DIFFERENCE
Heart Attack (AMI) (IP)	Age Adjusted Rate per 10,000	2016 to 2019	16.1	12.5	ABOVE
Heart Disease Deaths	Age Adjusted Death Rate per 100,000	2015 to 2019	174.9	140.3	ABOVE
COPD (ED)	Age Adjusted Rate per 10,000	2016 to 2019	16.4	16.4	NO DIFFERENCE
Stroke (IP)	Age Adjusted Rate per 10,000	2016 to 2019	18.1	16.2	NO DIFFERENCE
All Cancer Deaths	Age Adjusted Death Rate per 100,000	2015 to 2019	143.6	131.5	NO DIFFERENCE
Lung Cancer Deaths	Age Adjusted Death Rate per 100,000	2015 to 2019	35.9	27.5	NO DIFFERENCE
Smoking	% of Adults	2018	11.7	12.4	NO DIFFERENCE
Obesity	% of Adults	2018	25.9	26.3	NO DIFFERENCE
Heat Related Illness (ED)	Age Adjusted Rate per 10,000	2016 to 2019	SUPPRESSED	0.6	SUPPRESSED

The numbers in the last three columns are numeric results for each indicator

7 Nonstructural Participation Rate Estimation and Sensitivity Analysis

7.1 Participation Rate Estimation

A participation rate sensitivity analysis was performed to describe the uncertainty of a voluntary mitigation program's effects on the net benefits, the BCR, and the total project cost.

Before the TSP milestone, the economics team and the PDT members utilized the National Nonstructural Committee's Best Practice Guide 03 (BPG 2020-03), which provides guidance on how to compute various participation rates. Two approaches were used to develop participation rates. The first approach used was the random selection, while the second approach focused on the net benefits to select the structures that will participate in nonstructural flood risk mitigations.

The logical structure selection method utilized for the first approach was the random number generator, which randomly selected structure records. Three sensitivities; 20 percent, 60 percent, and 80 percent participation rates were developed. The random approach did not bracket the potential for highest or lowest benefits. The random approach also did not select the structures based on being damaged during the specific AEP flood events. Incoherencies were found when comparing the random selection BCR's results for different participation rates.

In the final array, the team ruled out the random selection method and adopted the theory of the 80 percent best-case scenario and 80 percent worst-case scenario selection approach, where the structures selected were based on the net benefits. Table 47 presents the 80 percent best case scenario, the 80 percent worst case scenario, and the 100 percent participation rate results. 80 percent best case scenario includes the 80% of structures that bring the highest net benefits while the 80 percent worst case scenario includes the 80% of structures with the lowest net benefits.

Table 47: Participation Rates

Participation Rate	Total Benefits	Total Cost	Annual Benefits	Annual Cost	Net Benefits	BCR
80% Worst Case Scenario	$23,087,000	$12,192,000	$814,000	$430,000	$384,000	1.89
80% Best Case Scenario	$33,723,000	$13,470,000	$1,189,000	$475,000	$714,000	2.50
100% Full Participation	$35,368,000	$16,110,000	$1,247,000	$568,000	$679,000	2.20

The net benefits and the BCR are $384,000 and 1.89 for 80 percent worst case scenario, and $714,000 and 2.50 for 80 percent best case scenario, respectively. The total cost of construction in both cases is under the CAP 205 limit: $12,192,000 for the 80 percent Worst Case Scenario and $13,470,000 for the 80 percent Best Case Scenario. This analysis proves that the calculated BCR for non-structural is robust and not contingent on a small number of high-benefit properties.

7.2 Sensitivity Analysis: Local Factors

Local factors were considered that will lead the property owners within a portion of the study area to participate on the nonstructural measures.

The local populace has traditionally lived and established businesses in this area for an extended period and have family connections within the region potentially dating back generations. This investment of time and resources in the Township of Denville region will lead to an unwillingness to relocate, and therefore result in an increase in willingness to mitigate structures and maintain residency within the area.

The level of risk reduction for a structure after implementing the recommended NED plan will on average exceed 1% AEP event. Knowing a structure is mitigated multiple feet above the existing freeboard requirement will lead to homeowners being more willing to participate in the nonstructural measures because they will have a level of assurance that they will not need to mitigate a second time over a 50-year period with precipitation forecasts included in the analysis.

Elevating a residential structure higher than the local floodplain ordinance by multiple feet could lead to reductions in flood insurance premiums. Reductions in flood insurance premiums would expect to increase the level of voluntary mitigation given long-term affordability as flood insurance rates continue to increase exponentially.

Investing in flood mitigation to reduce future risk can have multiple impacts on the structures economic value. All else held constant, reducing the flood damage to a structure has the potential to increase the market value of a structure. Competing with this is that the tax assessor's office may determine the structure to be worth more and consequently require the homeowner to pay additional property taxes. Negotiating with local tax assessor offices to forgo increasing the values of properties for those who willingly participate in nonstructural measures could be a strategy to increase participation.

When examining the participation rate sensitivity analysis, the PDT members concluded that the Township of Denville would likely have a marginally higher participation rate than other study areas across the country based on the feedback received from the non-Federal sponsor (NJDEP) and the stakeholder (Township of Denville). These property owners and communities are the ones that need these mitigation opportunities the most, as they are the ones that take the longest to recover after a flooding event. This study needs to have a strong public outreach component to help educate the community on the long-term benefits of flood risk mitigation to be successful and live up to the expected participation rates presented above.

8 Project Performance

ER 1105-2-101, Risk Assessment for Flood Risk Management Studies, provides the requirement to describe project performance by annual exceedance probability (AEP), assurance (conditional non-exceedance probability), and long-term exceedance probability (LTEP). Project performance describing these attributes is computed within HEC-FDA and is based on a target stage 1% AEP plus one foot of confidence levels. Table 48 presents the project performance consistent with ER 1105-2-101 for the existing. The future without project conditions provides the same results and is not shown in this appendix because it did not impact the stages of the nonstructural treatments as the hydraulic stages would not change in the future condition.

Table 48: Project Performance Without Project Conditions

Reach Name	Target Stage AEP		Long-Term Risk (Years)			Conditions Non-Exceedance Probability by Events					
	Median	**Expected**	**10**	**30**	**50**	**10%**	**4%**	**2%**	**1%**	**0.4%**	**0.2%**
Upper Rockaway	32	32	98	100	100	0.51	0.04	0.02	0.02	0	0
Den Brook	100	100	100	100	100	0	0	0	0	0	0

In the recommended plan, no structures are located on Den Brook reach. It is worth noting that reaches were not developed to provide responses to the nonstructural project performance analysis.

9 Optimization of the TSP

During the TSP optimization, structure values and measure costs were updated to FY22. For comparison to the benefits, which are average annual flood damages reduced, the costs were annualized. They were based on the FY22 discount rate of 2.25 percent and a 50-year period of analysis. Structure values were indexed using the Building Cost Index (BCI) comparing October 2020 (FY21) price levels to October 2021 (FY22) price levels. Structure values increased about 7.5% from FY21 to FY22.

In the current fiscal year 2023, the optimization was updated to reflect October 2022 (FY23) price levels using a discount rate of 2.50 percent. Each cluster was analyzed to determine the most efficient aggregation of structures with three aggregations explored: 1% AEP, 2% AEP, and 4% AEP. The aggregation includes the structures in each floodplain but does not impact the level of performance (LOP) the structure would receive. All structures would be either raised to the 1% AEP plus 1 foot of confidence levels or floodproofed to a level at 3 feet above ground elevation. Nonstructural measures for each structure were determined by the initial analysis and carried forward. All H&H data was also carried forward.

RS Means Book was used to escalate benefits from FY22 to FY23 using Paterson City, NJ indices, the closest city found in RS Means Book to the study area. The benefits increase by 19 percent from FY22 to FY23 as shown below.

$$2023\ Benefits = \frac{Index\ 2023}{Index\ 2022} \times 2022\ Benefits$$

$$2023\ Benefits = \frac{332.9}{280.0} \times 2022\ Benefits$$

$$2023\ Benefits = 1.19 \times 2022\ Benefits$$

Interest during construction was calculated for the nonstructural alternatives on an end-period basis payment schedule using a 2.50 percent federal discount rate, fiscal year 2023. Based on the Township of Denville project, the construction period will last 90 days on a single structure while it may take up to two years to implement nonstructural treatments for eligible structures. Table 49 shows the cost of nonstructural treatments for each cluster.

Table 49: FDY 2023 Nonstructural Costs

Clusters	First Cost	IDC	Total Cost	Average Annualized Costs
Center	$5,114,000	$11,000	$5,125,000	$181,000
Hinchman Snyder	$4,776,000	$10,000	$4,786,000	$169,000
North	$5,219,000	$11,000	$5,230,000	$184,000
North Riverside Dr	$6,611,000	$14,000	$6,625,000	$234,000
South	$5,037,000	$10,000	$5,047,000	$178,000
Southeast	$2,710,000	$6,000	$2,716,000	$96,000
Southwest	$7,175,000	$15,000	$7,190,000	$254,000

Updated costs were provided by the Baltimore District Cost Engineering. This update indicated about a 91% increase in costs from original costs developed in FY21.

Table 50 presents FY21 and FY23 cost comparison in each cluster.

Table 50: Construction Cost Comparison

	Center	Hinchman-Snyder	North	North Riverside	South	Southeast	Southwest	Total
2023 Costs	$5,125	$4,786	$5,230	$6,625	$5,047	$2,716	$7,190	$36,719
Original Cost	$3,240	$2,006	$2,382	$3,395	$2,561	$1,088	$4,570	$19,242
% Change	58%	139%	120%	95%	97%	150%	57%	91%

Note: $ in 000s

FDA version 1.4.3 was used during optimization. The aggregations were based on various AEPs. The aggregation with the highest net benefits was selected for the final array.

9.1 Southwest Cluster

The Southwest cluster consists of 30 structures. Six of these structures do not flood during a 1% AEP event, so they are not considered for further treatment. The without-project EAD was estimated at just over $500,000. The 4% AEP aggregation was determined to maximize net benefits with 12 of the 30 structures being selected for nonstructural measures and annual net benefits above $151,000. The specific breakdown of structures by AEP aggregation can be found in Table 51 below. Eleven additional structures were outside of the 1% AEP floodplain and were not included in any aggregation.

Table 51: Southwest Aggregation Optimization

Southwest								
	Nonstructural Treatments Count	Raise	Floodproof	Expected Annual Damages	Average Annualized Benefits	Average Annualized Costs	BCR	Average Annualized Net Benefits
Without				$500.50	$ -	$ -		$ -
1% AEP	13	7	6	$78.53	$421.97	$276.02	1.53	$145.95
2% AEP	13	7	6	$78.53	$421.97	$276.02	1.53	$145.95
4% AEP	12	6	6	$95.41	$405.09	$254.00	1.59	$151.09

Note: $ in 000s

9.2 Center Cluster

The Center cluster consists of 30 structures. Seven structures do not flood during a 1% AEP event, so they are not considered for further treatment. The without-project EAD was nearly $294,000. The 4% AEP aggregation was determined to maximize net benefits with 12 of the 30 structures being selected for nonstructural measures and annual net benefits are $61,800. The specific breakdown of structures by AEP aggregation can be found in Table 52 below.

Table 52: Center Aggregation Optimization

Center								
	Nonstructural Treatments Count	Raise	Floodproof	Expected Annual Damages	Average Annualized Benefits	Average Annualized Costs	BCR	Average Annualized Net Benefits
Without				$293.60	$ -	$ -		$ -
1% AEP	23	14	9	$30.92	$262.68	$346.92	0.76	($84.24)
2% AEP	15	11	4	$40.90	$252.70	$226.25	1.12	$26.45
4% AEP	12	10	2	$50.80	$242.80	$181.00	1.34	$61.80

Note: $ in 000s

9.3 North Riverside Cluster

The North Riverside cluster consists of 27 structures. Eight of these structures do not flood during a 1% AEP event, so they are not considered for further treatment. The without-project EAD was estimated at $543,000. The 4% AEP aggregation was determined to maximize net benefits with 14 of the 27 structures being selected for nonstructural measures and annual net benefits above $269,000. The specific breakdown of structures by AEP aggregation can be found in Table 53 below.

Table 53: North Riverside Aggregation Optimization

North Riverside								
	Nonstructural Treatments Count	Raise	Floodproof	Expected Annual Damages	Average Annualized Benefits	Average Annualized Costs	BCR	Average Annualized Net Benefits
Without				$543.48	$ -	$ -		$ -
1% AEP	19	18	1	$19.35	$524.14	$318.20	1.65	$205.94
2% AEP	15	14	1	$28.63	$514.85	$250.84	2.05	$264.01
4% AEP	14	13	1	$40.00	$503.49	$234.00	2.15	$269.49

Note: $ in 000s

9.4 North Cluster

The North cluster consists of 24 structures. Seven structures do not flood during a 1% AEP event, so they are not considered for further treatment. The without-project EAD was estimated to be $274,000. The 4% AEP aggregation was determined to maximize net benefits with 12 of the 24 structures being selected for nonstructural measures and annual net benefits just above $60,000. The specific breakdown of structures by AEP aggregation can be found in Table 54 below.

Table 54: North Aggregation Optimization

North								
	Floodproofed Structure Count	Raise	Floodproof	Expected Annual Damages	Average Annualized Benefits	Average Annualized Costs	BCR	Average Annualized Net Benefits
Without				$273.70	$ -	$ -		$ -
1% AEP	17	12	5	$18.60	$255.10	$261.04	0.98	($5.94)
2% AEP	15	12	3	$21.21	$252.49	$230.01	1.10	$22.48
4% AEP	12	11	1	$29.46	$244.24	$184.00	1.33	$60.24

Note: $ in 000s

9.5 Hinchman-Snyder Cluster

The Hinchman-Snyder cluster consists of 18 structures. Two of these structures do not flood during a 1% AEP event, so they are not considered for further treatment. The without-project EAD was estimated to be $133,000. The 4% AEP aggregation was determined to maximize net benefits with 13 of the 18 structures being selected for nonstructural measures and annual net benefits are negative, ($58,000). The specific breakdown of structures by AEP aggregation can be found in Table 55 below.

Table 55: Hinchman-Snyder Aggregation Optimization

Hinchman-Snyder								
	Floodproofed Structure Count	Raise	Floodproof	Expected Annual Damages	Average Annualized Benefits	Average Annualized Costs	BCR	Average Annualized Net Benefits
Without				$133.28	$ -	$ -		$ -
1% AEP	16	6	10	$18.83	$114.45	$208.00	0.55	($93.55)
2% AEP	14	6	8	$20.52	$112.76	$182.00	0.62	($69.24)
4% AEP	13	6	7	$22.05	$111.23	$169.00	0.66	($57.77)

Note: $ in 000s

9.6 South Cluster

The South cluster consists of 11 structures. The without-project EAD was estimated to be $163,000. The 4% AEP aggregation was determined to maximize net benefits with eight of 11 structures being selected for nonstructural measures and annual net benefits are negative, ($71,000). The specific breakdown of structures by AEP aggregation can be found in Table 56 below.

Table 56: South Aggregation Optimization

South								
	Floodproofed Structure Count	Raise	Floodproof	Expected Annual Damages	Average Annualized Benefits	Average Annualized Costs	BCR	Average Annualized Net Benefits
Without				$162.73	$ -	$ -		$ -
1% AEP	11	0	11	$25.05	$137.68	$244.75	0.56	($107.07)
2% AEP	11	0	11	$27.43	$135.30	$244.75	0.55	($109.45)
4% AEP	**8**	**0**	**8**	**$55.83**	**$106.90**	**$178.00**	**0.60**	**($71.10)**

Note: $ in 000s

9.7 Southeast Cluster

The Southeast cluster consists of five structures. The without-project EAD was estimated to $172,000. The 2% AEP aggregation was determined to maximize net benefits with four of the five structures being selected for nonstructural measures and annual net benefits were $34,000. The specific breakdown of structures by AEP aggregation can be found in Table 57 below.

Table 57: Southeast Aggregation Optimization

Southeast

	Floodproofed Structure Count	Raise	Floodproof	Expected Annual Damages	Average Annualized Benefits	Average Annualized Costs	BCR	Annualized Net Benefits
Without				$171.69	$ -	$ -		$ -
1% AEP	5	1	4	$37.88	$133.82	$120.00	1.12	$13.82
2% AEP	4	0	4	$41.89	$129.81	$96.00	1.35	$33.81
4% AEP	4	0	4	$44.27	$127.43	$96.00	1.33	$31.43

Note: $ in 000s

Table 58 summarizes various AEP aggregations that maximize net benefits in each cluster. A total of 75 structures are in the clusters.

Table 58: Maximum Net Benefits in Each Cluster

Final Array by Cluster								
Cluster	**Aggregation**	**Raise**	**Floodproof**	**Total Floodproofing Costs**	**Average Annualized Costs**	**Average Annualized Benefits**	**BCR**	**Annualized Net Benefit**
Center	4% AEP	10	2	$5,125	$181.00	$242.80	1.34	$61.80
Hinchman Snyder	4% AEP	6	7	$4,786	$169.00	$111.23	0.66	($57.77)
North	4% AEP	11	1	$5,230.00	$184.00	$244.24	1.33	$60.24
North Riverside	4% AEP	13	1	$6,625	$234.00	$503.49	2.15	$269.49
South	4% AEP	0	8	$5,047	$178.00	$106.90	0.6	($71.10)
Southeast	2% AEP	0	4	$2,716	$96.00	$129.81	1.35	$33.81
Southwest	4% AEP	6	6	$7,190	$254.00	$405.09	1.59	$151.09
Total		**46**	**29**	**$36,667**	**$1,293.00**	**$1,743.56**	**1.35**	**$450.56**

Note: $ in 000s

Hinchman Snyder and South clusters yield negative net benefits. Both clusters are not considered further in the analysis. Table 59 shows clusters with positive net benefits. There are a total of 54 structures.

Table 59: Clusters with Positive Nets Benefits

Cluster	**Aggregation**	**Raise**	**Floodproof**	**Total Floodproofing Costs**	**Average Annual Costs**	**Average Annual Benefits**	**BCR**	**Annualized Net Benefit**
Center	4% AEP	10	2	$5,125.00	$181.00	$242.80	1.34	$61.80
North	4% AEP	11	1	$5,230.00	$184.00	$244.24	1.33	$60.24
North Riverside	4% AEP	13	1	$6,625.00	$234.00	$503.49	2.15	$269.49
Southeast	2% AEP	0	4	$2,716.00	$96.00	$129.81	1.35	$33.81
Southwest	4% AEP	6	6	$7,190.00	$254.00	$405.09	1.59	$151.09
Total		**40**	**14**	**$26,886.00**	**$949.00**	**$1,525.43**	**$1.61**	**$576.43**

Note: $ in 000s

10 Recommended Plan

As discussed earlier in the report, Alternative 4, the nonstructural measure was presented as the tentatively selected plan (TSP). That measure was further evaluated by clustering the structures based on location and other similarities, and each cluster was optimized for protection level as shown in Section 9. CAP Section 205 has a maximum Federal cost for planning, design, and construction of $10 million with the non-federal sponsor contributing a maximum of approximately $5.4 million, or 35% of the total. Costs above this amount are the responsibility of the non-federal sponsor. Therefore, the recommended plan to implement non-structural flood risk management measures in the North, North Riverside, and Southwest clusters as shown in Table 60 with a total cost of $19 million assuming a 100 percent participation rate. The annualized net benefits are $481,000 and the BCR is 1.72.

Table 60: Recommended Plan

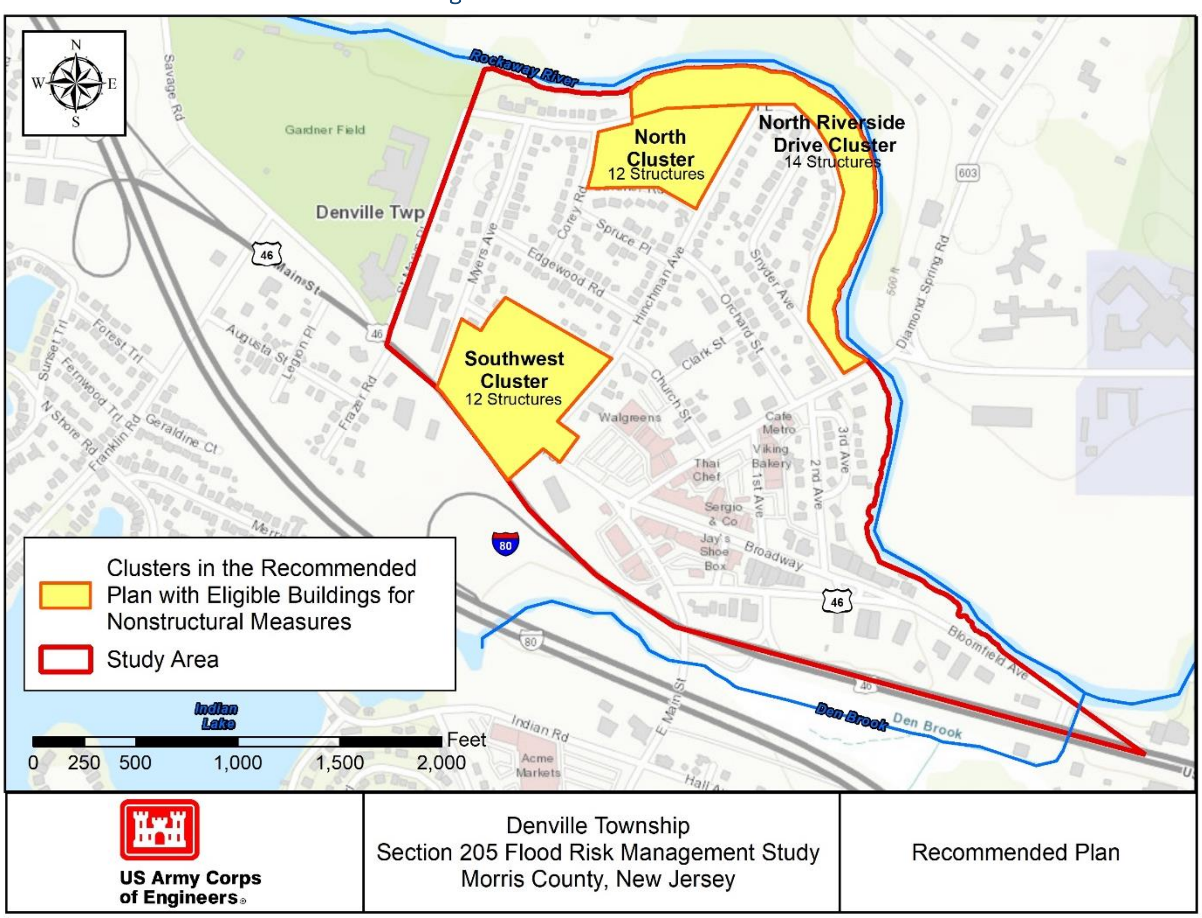
Cluster	Aggregation	Raise	Floodproof	Total Floodproofing Costs	Average Annual Costs	Average Annual Benefits	BCR	Annualized Net Benefit
North	4% AEP	11	1	$5,230	$184.00	$244.24	1.33	$60.24
North Riverside	4% AEP	13	1	$6,625	$234.00	$503.49	2.15	$269.49
Southwest	4% AEP	6	6	$7,190	$254.00	$405.09	1.59	$151.09
Total		**30**	**8**	**$19,045**	**$672.00**	**$1,152.82**	**1.72**	**$480.82**

Note: $ in 000s

Other aggregations can be proposed as recommended plans to align with the CAP 205 cost limits.

Public outreach should not be limited to these three clusters. Owners of structures that present the highest risk for flooding during frequent event storms (50% AEP, 20% AEP, 10% AEP…in general or structures with Base Flood Elevation below the ten percent water surface elevation) will likely be more willing to participate in implementing nonstructural treatments than those experiencing damages at 4% AEP or less frequently. Structures that are not in the recommended plan can be reconsidered during construction to receive treatments as long as the funding will allow.

Figure 6: Recommended Plan



Thirty structures are recommended to be raised and the remaining eight are recommended to be treated with floodproofing measures. Net benefits are maximized with $13,637,000 over a 50-year period of analysis with annualized net benefits of $481,000. These figures are summarized in Table 60. Table 61 shows the mitigation measure for the 38 structures receiving nonstructural treatments. The thirty structures proposed to receive elevation treatments will be raised to be protected against a 1% AEP flood plus 1 foot of confidence level and the remaining eight structures will be floodproofed at 3 feet above ground elevation.

Table 61: Mitigation Strategy for Recommended Plan

Mitigation Measure	Total Number of Structures	Residential	Non-residential
Elevation	30	28	2
Wet Floodproofing	2	2	0
Dry Floodproofing	6	0	6
TOTAL	**38**	**30**	**8**

11 Participation Rate Sensitivity Analysis

A participation rate sensitivity analysis was also performed during optimization. The highest and lowest 80% net benefit structures in each cluster were examined as well as based on updated net benefits in order to help illustrate the uncertainty involved in a voluntary program.

11.1 North Cluster

The top 80 percent best scenario participation rate has positive net benefits while the bottom 80 percent aggregation yields negative net benefits in the North Cluster.

Table 62: North Sensitivity Analysis at 4% AEP event

North 4% AEP									
	Floodproofed Structure Count	Raise	Floodproof	Expected Annual Damages	Average Annualized Benefits	Average Annualized Costs	Total Costs	BCR	Net Benefits
Without				$273.70	$ -	$ -			$ -
100%	12	11	1	$29.46	$244.24	$184.00	$5,230.00	1.33	$60.24
Top 80%	10	10	0	$31.23	$242.47	$153.70	$4,359.29	1.58	$88.77
Bottom 80%	10	10	0	$135.08	$138.62	$153.70	$4,359.29	0.90	($15.08)

Note: $ in 000s

11.2 North Riverside Cluster

Every participation rate for each event aggregation in the North Riverside Cluster continues to have positive net benefits and a BCR greater than 1.

Table 63: North Riverside Sensitivity Analysis at 4% AEP event

North Riverside 4% AEP									
	Floodproofed Structure Count	Raise	Floodproof	Expected Annual Damages	Average Annualized Benefits	Average Annualized Costs	Total Costs	BCR	Average Annualized Net Benefits
Without				$543.48	$ -	$ -			$ -
100%	14	13	1	$40.00	$503.49	$234.00	$6,608.42	2.15	$269.49
Top 80%	11	11	0	$46.18	$410.53	$183.97	$5,217.81	2.23	$226.56
Bottom 80%	11	11	0	$257.44	$199.27	$183.97	$5,217.81	1.08	$15.30

Note: $ in 000s

11.3 Southwest Cluster

Below are the tables showing the participation rate sensitivity analysis at 4% AEP for the Southwest Cluster. Every participation rate for each event aggregation in the Southwest Cluster continues to have positive net benefits and a BCR greater than 1.

Table 64: Southwest Sensitivity Analysis at 4% AEP event

Southwest 4% AEP									
	Floodproofed Structure Count	Raise	Floodproof	Expected Annual Damages	Average Annualized Benefits	Average Annualized Costs	Total Costs	BCR	Average Annualized Net Benefits
Without				$500.50	$ -	$ -			$ -
100%	12	6	6	$95.41	$405.09	$254.00	$7,175.66	1.59	$151.09
Top 80%	10	5	5	$91.13	$409.37	$211.73	$5,979.63	1.93	$197.64
Bottom 80%	10	5	5	$237.39	$263.11	$211.73	$5,979.63	1.24	$51.38

Note: $ in 000s

11.4 Center Cluster

The table below shows the results of the sensitivity analysis for the Center Cluster. The top 80 percent best scenario participation rate yields positive net benefits while the bottom 80 percent aggregation indicates negative net benefits in the Center Cluster.

Table 65: Center Sensitivity Analysis at 4% AEP event

Center 4% AEP									
	Floodproofed Structure Count	Raise	Floodproof	Expected Annual Damages	Average Annualized Benefits	Average Annualized Costs	Total Costs	BCR	Average Annualized Net Benefits
Without				$293.60	$ -	$ -			$ -
100%	12	10	2	$50.80	$242.80	$181.00	$5,133.58	1.34	$61.80
Top 80%	10	8	2	$31.17	$262.43	$122.14	$3,464.17	1.77	$140.29
Bottom 80%	10	9	1	$189.02	$104.58	$147.52	$4,184.01	0.72	($42.94)

11.5 Southeast Cluster

Table 66 presents the results of the sensitivity analysis for the Southeast Cluster. The top 80 percent best scenario participation rate has positive net benefits while the bottom 80 percent aggregation yields negative net benefits in this Cluster.

Table 66: Southeast Sensitivity Analysis at 4% AEP event

Southeast 4% AEP									
	Floodproofed Structure Count	Raise	Floodproof	Expected Annual Damages	Average Annualized Benefits	Average Annualized Costs	Total Costs	BCR	Average Annualized Net Benefits
Without				$171.69	$ -	$ -			$ -
100%	4	0	4	$41.89	$129.81	$96.00	$2,722.78	1.35	$33.81
Top 80%	3	0	3	$46.70	$124.99	$73.10	$2,073.28	1.71	$51.89
Bottom 80%	3	0	3	$106.46	$65.23	$72.00	$2,042.09	0.91	($6.77)