Tar Pamlico River Basin Flood Risk Management Feasibility Study

Appendix B. Economic Analysis

US Army Corps of Engineers

June 2024

Page Intentionally Left Blank

Summary

Purpose and Justification

The Pittsburgh District requests a policy exception from Engineer Regulation (ER) 1105-2-100, paragraph 2-3(f)(1) which states, "The National Economic Development (NED) Plan. For all project purposes except ecosystem restoration, the alternative plan that reasonably maximizes net economic benefits consistent with protecting the Nation's environment, the NED plan, shall be selected. The Assistant Secretary of the Army for Civil Works (ASA (CW)) may grant an exception when there are overriding reasons for selecting another plan based upon comprehensive benefits or other Federal, State, local and international concerns." This policy exception is requested to allow for a recommended plan justified by comprehensive net benefits as described by the Other Social Effects (OSE) account—in this case, benefits that would increase resilience and community cohesion within disadvantaged and socially vulnerable communities.

The "Comprehensive Documentation of Benefits in Decision Document" Memorandum, dated 5 January 2021, directs study teams to consider the total benefits of project alternatives, including equal consideration of economic, environmental, and social benefits, when making decisions and recommendations. The "Implementation of Environmental Justice and the Justice40 Initiative" Memorandum, dated 15 March 2022, directs USACE studies and planning efforts to put disadvantaged communities front and center in the planning process to implement environmental justice (EJ) initiatives. Through the comprehensive accounting of benefits and a thorough assessment of EJ considerations, the Pittsburgh District is recommending a tentatively selected plan (TSP) that incorporates comprehensive benefits and provides disadvantaged communities with assistance; however, the TSP does not represent the plan that maximizes net economic benefits (i.e., the NED plan). This issue paper provides the analysis to support that recommendation.

NED Plan and Selected Plan

The NED plan includes elevation or floodproofing of 37 structures across 6 reaches (Table 1; Figure 1). This plan includes elevation of 2 residential structures, elevation and flood venting of 1 residential structure, and dry floodproofing of 34 commercial structures (Table 1). Floodplain aggregation varied across the 6 reaches, ranging from the 0.1 to the 0.01 AEP floodplains (Table 1). Regardless of floodplain aggregation, structures would be elevated to the 0.01 AEP flood elevation plus 2 feet. Structures would be dry floodproofed to the 0.01 AEP floodplain plus 2 feet, or a maximum height of 4 feet. The NED Plan is estimated to produce $2,043,000 in average annual benefits at an average annual cost of $1,382,000, producing $661,000 in net annual benefits and a benefit cost ratio (BCR) of 1.48.

Table 1. Reach, aggregation floodplain, number of structures, and net economic benefit for each reach in the NED plan.

Reach	Aggregation	Dry Floodproof	Elevate	Elevate Flood Vent	Total
STC1B	0.01 AEP Floodplain	14	1	0	15
TP10A	0.1 AEP Floodplain	2	0	0	2
TP10C	0.1 AEP Floodplain	1	0	1	2
TP10D	0.01 AEP Floodplain	1	0	0	1
TP3F	0.04 AEP Floodplain	15	1	0	16
TP9A	0.02 AEP Floodplain	1	0	0	1
	NED Plan	34	2	1	37

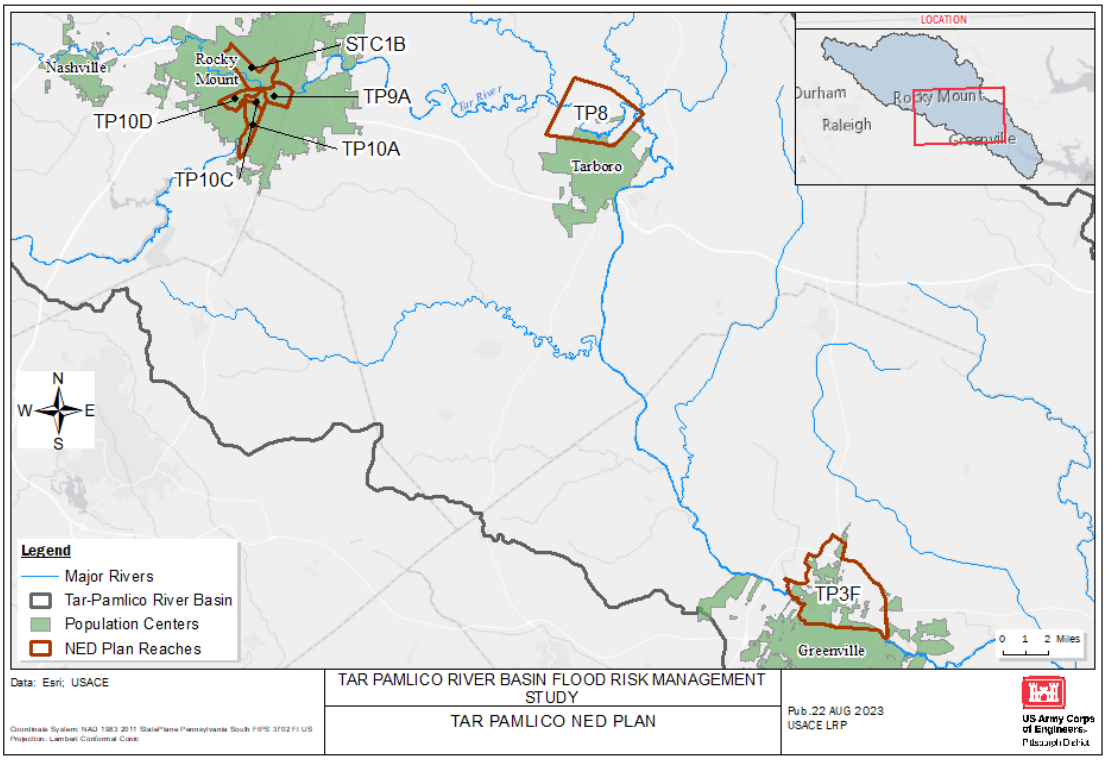

Figure 1. Reaches included in the NED plan.

The TSP includes all 155 structures identified as being at-risk within the 0.01 AEP floodplain across 13 study reaches. The TSP includes elevation of 35 residential structures, flood venting of 8 residential structures, elevation and flood venting of 18 residential structures, and dry floodproofing of 94 commercial structures (Table 2; Figure 2). All structures would be elevated to the 0.01 AEP flood elevation plus 2 feet. Structures would be dry floodproofed to the 0.01 AEP floodplain plus 2 feet, or a maximum height of 4 feet. The TSP is estimated to produce $2,945,000 in average annual benefits at an average annual cost of $3,667,000, producing -$723,000 in net annual benefits and a benefit cost ratio (BCR) of 0.8.

Table 2. Number of structures recommended for structure elevation, flood venting, structure elevation and flood venting, and dry floodproofing within each of the 13 study reaches included in the TSP. Location of the 13 reaches is presented in Figure 2. All structures would be elevated or floodproofed to the 0.01 AEP flood elevation.

Reach	Dry Floodproof	Elevate	Elevate Flood Vent	Flood Vent	Total
STC1B	14	1	0	0	15
STC1C	7	1	7	4	19
STC1F	1	0	0	0	1
TP10A	2	0	1	1	4
TP10B	1	1	0	0	2
TP10C	1	0	3	1	5
TP10D	1	0	0	0	1
TP3C	0	22	0	0	22
TP3F	52	10	5	0	67
TP8	9	0	1	0	10
TP9A	2	0	0	2	4
TP9C	1	0	0	0	1
TP9D	3	0	1	0	4
Total	**94**	**35**	**18**	**8**	**155**

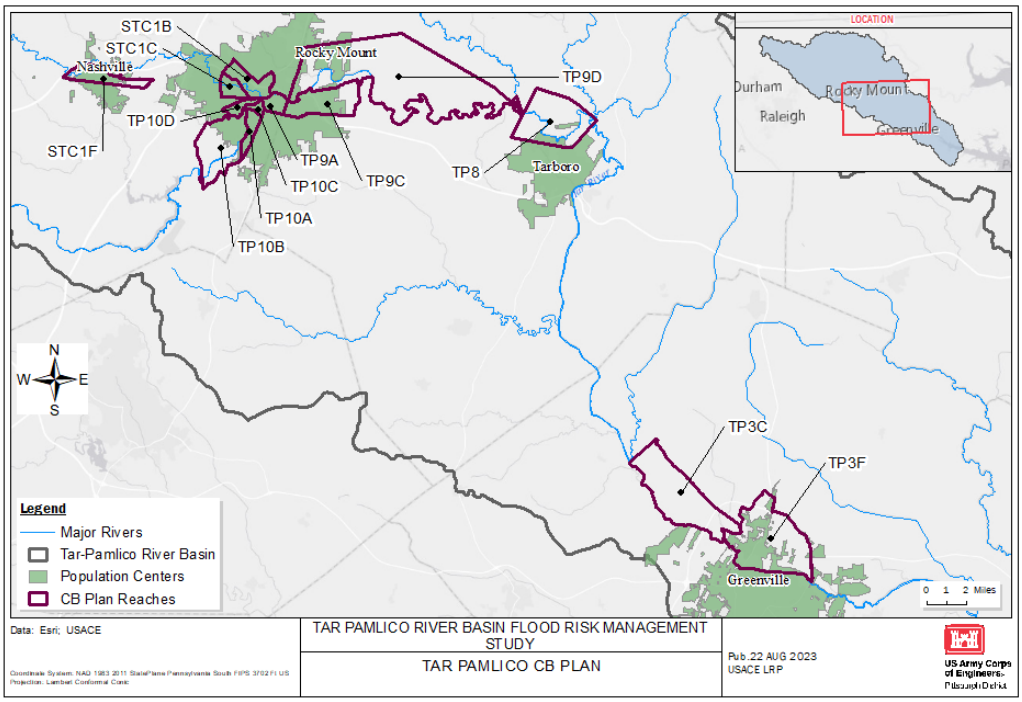

Figure 2. Reaches included in the TSP. Number of structures recommended for application of nonstructural measures within each reach are presented in Table 2.

Comparison to the NED Plan

The NED plan consists of structure elevation and dry floodproofing for 37 structures across six study reaches. The NED plan is estimated to produce $2,043,000 in average annual benefits at an average

annual cost of $1,382,000, resulting in $661,000 in net annual benefits and a BCR of 1.65. A comparison of the costs and benefits associated with the NED plan and selected plan are shown in Table 2.

Table 2. Costs and NED benefits for the NED plan and TSP. Costs were calculated using FY24 price levels.

	Costs ($000s)	
Construction Item	**Alt. 3A. Maximum Net Economic Benefits**	**Alt. 3B. Comprehensive Benefits**
Investment Cost		
Total Project First Cost	$37,193	$98,701
Interest During Construction	$115	$305
Total Investment Cost	$37,308	$99,006
Annual Cost		
Annualized First Cost	$1,382	$3,667
Estimated OMRR&R	$0	$0
Total Average Annual Cost	$1,382	$3,667
Average Annual Benefits	$2,043	$2,944
Net Annual Benefits	$661	($723)
Benefit-Cost Ratio	1.48	0.80

*Interest during construction was calculated at 2.75% over a 3-month construction period per structure. Costs were annualized over a 50-year period of analysis. BCR assumes a 100% participation rate.

Definitions:

- Total Project First Costs: Construction costs, Project Management, Engineering & Design, Construction Management, Real Estate Contingency
- Interest during construction: Opportunity cost of capital incurred during the construction period.
- Total Investment Cost: Cost of interest during construction plus total project first costs
- Annualized First Costs: Total investment costs annualized over 50 years using FY24 interest rate of 2.75%
- OMRR&R: Operations, Maintenance, Repair, Replacement, and Rehabilitation costs
- Average Annual Benefits: Without-project expected annual damages minus with-project expected annual damages.
- Net Annual Benefits: annualized benefits minus annualized costs

The selected plan includes application of nonstructural measures to an additional 118 structures beyond those included in the NED plan—structures located within disadvantaged and socially vulnerable communities [e.g., minority and/or elderly populations or populations with high poverty and/or unemployment, as defined by EJ Screen and the Climate and Economic Justice Screening Tool (CEJST)] that are characterized by both high expected annual damages (EAD) and low resilience in the face of future flood risk (Table 3). This plan includes all 155 structures identified as being at-risk within the 0.01 AEP floodplain across 13 study reaches. Thus, the incremental cost difference between the NED plan and TSP (i.e., approximately three-fold for the TSP) provides benefit to nearly four times as many structures, promoting increased resilience and community cohesion within the most socially vulnerable and disadvantaged communities across the study area.

Table 3. Comparison of EAD, average annual benefits, and social vulnerability as described by the EJ Screen tool (demographic index, minority population, population over 64, unemployment) and Climate and Economic Justice Screening Tool (CEJST; climate vulnerability).

Reach	Total EAD ($000s)		Average Annual Benefits ($000s)	EJ Screen	Climate Vulnerability (CEJST)
STC1B*†	$1,154.94	$896	Minority		-
STC1C	$446.10	$270	Unemployment		-
STC1F	$27.64	$17	Unemployment		-
TP10A*†	$176.23	$120	Demographic Index		Yes
TP10B	$208.76	$10	Over 64		Yes
TP10C*†	$241.83	$168	Demographic Index		Yes
TP10D*	$118.33	$39	Unemployment		-
TP3C	$74.91	$9	Demographic Index		Yes
TP3F*†	$2,717.52	$1,235	Demographic Index		Yes
TP8	$208.10	$84	Demographic Index		Yes
TP9A*	$75.55	$43	Demographic Index		Yes
TP9C	$12.70	$1	Demographic Index		Yes
TP9D	$148.25	$52	Demographic Index		Yes
TOTAL	**$5,610.86**	**$2,944**	-		-

* Indicates reaches that are also part of the NED plan
† Indicates reaches that have positive net economic benefits within the TSP

History of flooding impacts in the region

Natural disasters effect the livelihoods of people living in the impacted community, but being exposed to numerous inundation events hamper the resilience of the community as a whole. The communities in the study area have been impacted by high water events numerous times, hindering the economic viability of the community, and creating an ongoing cycle of recovery. Several events are listed below in Table 3.

Table 3. Flood history of the Rocky Mount and Greenville areas.

Hurricane	Rain Event
Bertha (1996)	Rocky Mount Area (April 25, 2017)
Fran (1996)	Greenville Area (June 2019)
Bonnie (1998)	Rocky Mount Area (June 16,2020)
Dennis (1999)	Rocky Mount Area (July 14, 2023)
Floyd (1999)	
Isabel (2003)	
Irene (2011)	
Matthew (2016)	

Figure 3. Images of flooding in Rocky Mount (top) from Hurricane Matthew (2016) and Greenville (bottom, June 2019).

Many structures in the study reaches in Greenville, Tarboro, and Rocky Mount have already been built with, or have been retrofitted with, non-structural flood mitigation measures (Figure 4). Structures with existing flood mitigation measures were not considered in this study. The prevalence of these structures in the region, however, speaks to the frequent flood history and local efforts to mitigate.

Figure 4. Examples of houses in the project area elevated to minimized flood risk. Left, Residential Elevated structures in Greenville (Study reach TP3D) Right, an Elevated and Vented Residential Structure located in Greenville (study reach TP3F)

As a result of the persistent flooding, buyout and relocation programs have been initiated in these areas and funded by FEMA and State of North Carolina. For example, in the Rocky Mount region, 446 homes were purchased, and the residents relocated after flooding that was caused by Hurricane Floyd (University of North Carolina Institute for the Environment). Buyouts and relocations were prioritized to focus on the most affected homes and those located in the floodway. Strategies such as these, while moving the most affected community members out of the reach of floods, may also fragment communities. The relocation program led to the break-up of some communities, as local housing stock was depleted by the flooding event, and replacement trailers from FEMA were not suitable for long-term habitation as the community rebuilt (University of North Carolina Institute for the Environment).

Although the NED plan does provide assistance to 34 commercial structures and 3 residential structures in communities identified as disadvantaged in some aspect, there are still structures in those reaches where vulnerable peoples live and work. With the repetitive flooding disrupting the daily life of these individuals and the stress put on the community, the TSP better addresses the problems the community faces. These areas have faced several floods in the past decade, and the comprehensive benefits plan allows for less disruption in the daily life for people in these vulnerable and disadvantaged areas by elevating 61 homes out of the floodplain and floodproofing 94 commercial businesses where the members of the community work and shop.

Taken together, these conditions emphasize the increased burden that flood risk places on disadvantaged and socially vulnerable communities—underserved and disadvantaged communities have historically experienced among the greatest impacts and have increased vulnerabilities in the face of climate change. Socially vulnerable communities typically have less resources to cope with crises and natural disasters, making them less resilient to the effects of severe weather events. Residents may be less able to afford preparedness actions such as purchasing flood insurance or making home improvements to increase resilience to flooding and other disasters. Pre-disaster hazard mitigation has not been equally available to all communities. More affluent communities have received a greater proportion of these resources. As a result, vulnerable communities are less resilient to the impact of natural disasters. Thus, the TSP would maximally benefit the least resilient communities within the basin.

The TSP would also improve community cohesion in the face of continued flood risk. Community cohesion would be ensured by keeping communities intact by providing equal assistance to all individuals affected by the calculated flood risk, including those individuals that represent socially

vulnerable and historically underserved populations. In doing so, the TSP would promote and preserve diversity and equal opportunity within affected communities.

In addition to greater social benefits, the selected plan also has greater regional economic benefits as compared to the NED plan. Implementation of the selected plan is expected to provide 1,756 full-time equivalent jobs and $118,385,000 in labor income as compared to the NED plan, which is expected to provide 662 full-time equivalent jobs and $44,610,000 in labor income. Thus, the selected plan represents a plan that provides positive economic benefits to the nation and the greatest economic benefits to the region, while also maximizing, to the extent practicable, benefits to disadvantaged and socially vulnerable communities.

Assessment

The requested policy exception neither eliminates nor alters procedures that are based on official rule making; does not violate policy, delegation, or guidance from Higher Authority (outside USACE); does not reduce the quality and performance of the project over its authorized lifetime; and does not materially increase the probability or severity of a loss of life.

The Pittsburgh District assessed the risks associated with pursuing a policy exception from 1105-2-100, paragraph 2-3(f)(1) and determined the overall risk to be low. Below is a summary of individual risk assessment categories and, where warranted, measures the Pittsburgh District will employ to manage risks.

USACE/Army Reputation. Opportunity. Flood Risk Management is recognized as being vital to the Nation's economic growth and security. Flood risk reduction in all communities—not just those where application of flood risk reduction measures is economically justified—reduces disparate environmental burdens, removes barriers to participation in decision-making, and increases access to benefits provided by Civil Works programs to disadvantaged communities within USACE authorities. This improves the reputation of USACE with the public, stakeholders, and cooperating agencies, among others.

Participation Rates. Low Risk. Participation rates in the selected plan will affect the total project costs and benefits. Participation is completely voluntary and up to the individual structure owner. While the BCR is calculated using a 100% participation rate, actual participation rates may be lower. However, decreased participation in the EJ communities is unlikely to impact the overall economic viability because structures in those reaches tend to provide fewer benefits. The economic benefits would be more affected by participation of structures in reaches within both the NED Plan and selected plan.

Project Scope. Low Risk. The project scope would be larger under the TSP using comprehensive benefits (155 structures) as compared to NED benefits (37 structures). However, the scope of work for the TSP is well within previous nonstructural plans executed by USACE and the does not place execution of the TSP at risk.

Project Schedule. Low Risk. The policy exception will allow the project to maintain current schedule with minimal impacts.

Real Estate. Risk. Additional real estate requirements for nonstructural plans, including the potential requirement to obtain easements, would result in a much larger effort for the non-federal sponsor under the TSP as compared to the NED plan. This could delay implementation moving forward.

Local/State/Federal Considerations. Low Risk (Positive Outcome) Opportunity. The Pittsburgh District has received positive feedback on the current recommended plan. During the TSP Milestone Meeting, which was held on 17 July 2023, the non-federal sponsor (North Carolina Department of Environmental Quality) expressed support for the selected plan and completion of the feasibility phase. The non-federal sponsor continues to be supportive of the selected plan and would like to maximize benefits to socially vulnerable and disadvantaged communities—a result that is in line with state efforts to promote environmental justice.

Environmental Concerns. No Risk. The granting of the policy exception will not alter the findings of the Environmental Assessment. Neither the selected plan nor the NED plan will result in significant or permanent impacts to environmental resources.

Health & Safety. Opportunity. The granting of the policy exception will improve health and safety by reducing flood risk to a greater number of structures—all of which are within communities identified as socially vulnerable or disadvantaged.

Conclusion

The selected plan includes structure elevation and dry floodproofing of 155 structures across 13 study reaches. The nonstructural measures proposed include elevation of 35 structures, flood venting of 8 structures, elevation and flood venting of 18 structures, and dry floodproofing of 94 structures. The TSP is estimated to produce $2,944,000 in average annual benefits at an average annual cost of $3,667,000, producing -$723,000 in net annual benefits and a benefit cost ratio of 0.8. In addition to the positive net economic benefits, the TSP also maximizes regional economic development and benefits to socially vulnerable and disadvantaged communities as compared to the NED plan. These additional benefits—particularly increased resilience and community cohesion among socially vulnerable and disadvantaged communities in the face of continued and worsening flood risk—justify the incremental inclusion of nonstructural features lacking positive net economic benefits.

The Pittsburgh District has received positive feedback on the current recommended plan. During the TSP Milestone Meeting, which was held on 17 July 2023, the non-federal sponsor (North Carolina Department of Environmental Quality) expressed support for the selected plan and completion of the feasibility phase. The non-federal sponsor continues to be supportive of the selected plan and would like to maximize benefits to socially vulnerable and disadvantaged communities—a result that is in line with concurrent state efforts to promote environmental justice.

Recommendation

Selection of the TSP based on the calculation of comprehensive benefits is consistent with current Enterprise guidance. It is recommended that a policy exception from ER 1105-2-100 2-3(f)(1) be granted for the Tar-Pamlico Flood Risk Management Study to provide a recommendation that has positive value to the Nation while maximizing value to the region by utilizing comprehensive benefits and promoting EJ.

TABLE OF CONTENTS

Table of Contents x
List of figures xiii
List of tables xiv
1. Introduction 1
1.1. Purpose and Overview 1
1.2. Location 1
1.3. Historical Background 1
1.4. Study Guidance 2
1.5. The System of Accounts 2
1.5.1. National Economic Development (NED) 3
1.5.2. Regional Economic Development (RED) 3
1.5.3. Other Social Effects (OSE) 4
1.5.4. Environmental Quality (EQ) 4
2. Study Area 5
2.1. Land Use 5
2.2. Population and Socioeconomics 6
3. NED Methodology 14
3.1. Framework of Economic Analysis 14
3.1.1. Price Level, Period of Analysis, and Discount Rate 14
3.1.2. Economic Analysis Tool: HEC-FDA Risk Analysis Program 14
3.1.3. Economic Damage Reaches and Index Stations 16
3.2. Data Development 22
3.2.1. Initial Database Development 22
3.2.2. Damage Categories and Structure Occupancy Types 24
3.2.3. Elevations and Stationing 24
3.2.4. Structure Valuation 25
3.2.5. Contents Valuation 26
3.2.6. Depth-Damage Functions: Residential 27
3.2.7. Depth-Damage Functions: Nonresidential 28
3.2.8. Other Potential Damage Categories 28
3.2.9. Vehicles 28
3.2.10. Emergency Costs, Disaster Relief, and Infrastructure Damages 28
3.3. Final Economic Database 29
3.3.1. Study Area Investment 29
4. Damage Analysis Modeling 29
4.1.1. Model Hydraulic and Hydrologic Inputs 30
4.2. Exceedance Probability-Discharge Functions 30
4.3. Stage-Discharge Functions 31
4.4. Levee Features 33
5. Existing and Future Without-Project Conditions 34
5.1. FWOP Flooding Characteristics 34

5.2. AEP Event Damages 37
5.3. Expected Annual Damages 38
5.4. Project Performance 42
5.5. Without-Project Equivalent Annual Damages 45
5.6. Other Social Effects Without-Project Condition 46
5.6.1. Health and Safety 47
5.6.2. Economic Vitality 47
5.6.3. Social Connectedness 48
5.6.4. Identity 48
5.6.5. Social Vulnerability and Resiliency 48
5.6.1. Summary of Baseline Profile 49
5.6.2. CEQ Tool 49
5.6.3. EJ Screen Tool 51
5.7. Life Safety Without and Future Without Project 52
5.7.1. Life Safety Analysis 52
5.7.2. Life Safety Risk 53
5.7.3. Existing and Future Without Project Conditions 55
6. Without and FWOP Regional Economic Development (RED) 59
6.1. RED Effects under Without-Project Conditions 59
6.1.1. Threats to Existing Local/Regional Businesses 59
6.1.2. Threats to Economic Development Prospects 60
6.1.3. Residential Flood Insurance Premium Costs 60
7. Alternatives Screening 61
7.1. Initial Array of Alternatives 61
7.2. Alternative 1- No Action 61
7.3. Alternative 2- Dry Dams 62
7.4. Alternative 3- Nonstructural 62
8. With-Project Alternatives Analysis 62
8.1. With-Project Analysis Overview 62
8.2. Nonstructural Formulation 63
8.3. Nonstructural Methodology 67
8.4. Assumptions 69
8.5. Measures 70
8.5.1. Elevation/Basement Fill 70
8.5.2. Wet Floodproofing 71
8.5.3. Dry Floodproofing 73
8.5.4. Acquisitions/Relocations 75
8.6. Total Measure Selection 75
8.7. Nonstructural Economic Evaluation 76
8.7.1. Aggregation 76
8.7.2. Damage Reaches 76
8.7.3. Floodplains 76
8.8. Alternatives 77

8.8.1. 0.1 AEP Floodplain ... 78
8.8.2. 0.04 AEP Floodplain ... 80
8.8.3. 0.02 AEP Floodplain ... 82
8.8.4. 0.01 AEP Floodplain ... 86
8.9. Alternative 3A: NED Plan Analysis ... 90
8.10. Alternative 3B: Comprehensive Benefits Plan ... 92
9. Comprehensive Benefits Plan Development ... 98
9.1. Selection Criteria ... 98
9.1.1. Repetitive Flooding ... 98
9.1.2. Disadvantaged Populations ... 111
9.1.3. CEQ Tool ... 111
9.1.4. EJ Screen Tool ... 118
9.1.5. Summary of Comprehensive Benefit Plan Development ... 126
9.2. Life Safety NED Plan ... 127
9.2.1. Flood Depth ... 127
9.2.2. Risk Perception ... 127
9.3. Life Safety Comprehensive Benefits Plan ... 128
9.3.1. Flood Depth ... 128
9.3.2. Risk Perception ... 131
10. With Project Regional Economic Development ... 131
10.1. RED Alternative 3A NED Plan ... 132
10.2. RED Alternative 3B Comprehensive Benefits Plan ... 132
11. Benefits Summary and Tenativily Selected Plan ... 133
11.1. NED and Comprehensive Benefits Plan Comparison ... 133
11.2. Tentatively Selected Plan ... 136
11.3. Residual Risk ... 136
12. TSP Participation Sensitivity Analysis ... 139
12.1.1. Top 80% ... 139
12.1.2. Bottom 80% ... 140
12.1.3. Conclusion ... 141
13. Optimization of NED and Selected Plan ... 141
13.1. Refinements of the NED Modeling ... 141
13.1.1. Updated Interest, Study Year, and Structure Value Year ... 141
13.1.2. Removing Floodproofed Utilities ... 141
13.1.3. Emergency and Cleanup Costs ... 142
13.1.4. Costs ... 142
13.1.5. Target Stage Sensitivity Analysis ... 142
13.2. Updated NED Model Results ... 144
13.2.1. Existing ... 144
13.2.2. Alternative 3A NED Plan ... 145
13.2.3. Alternative 3B Comprehensive Benefits Plan ... 147
13.2.4. Emergency and Cleanup Costs ... 150
13.2.5. Participation Rate Sensitivity Analysis ... 152

13.3. Update Life Safety Analysis OSE 162
13.3.1. Life Loss Estimation Method 162
13.3.2. Existing and Future Without Project Conditions 165
13.3.3. Alternative 3A the NED Plan 168
13.3.4. Alternative 3B Comprehensive Benefits Plan 170
13.3.5. Conclusion 174
13.4. RED 174
13.4.1. RED Alternative 3A NED Plan 174
13.4.2. RED Alternative 3B Comprehensive Benefits Plan 175
14. Conclusion and selected plan 176
14.1. Selected Plan 7% Interest Rate 180

LIST OF FIGURES

Figure 1. Reaches included in the NED plan. ii
Figure 2. Reaches included in the TSP. Number of structures recommended for application of nonstructural measures within each reach are presented in Table 2. iii
Figure 3. Images of flooding in Rocky Mount (top) from Hurricane Matthew (2016) and Greenville (bottom, June 2019). vi
Figure 4. Examples of houses in the project area elevated to minimized flood risk. Left, Residential Elevated structures in Greenville (Study reach TP3D) Right, an Elevated and Vented Residential Structure located in Greenville (study reach TP3F). vii
Figure 5. Tar Pamlico River Basin Study Area Census Tracts 5
Figure 6. Study Area Land Use 6
Figure 7. Population Count by Census Tract, ACS 2020 5-year Estimates. 7
Figure 8. Median Household Income in 2020 Inflation Adjusted Dollars vs Household Size 8
Figure 9. Non-White Population Count by Census Tract, ACS 2020 5-year Estimates 9
Figure 10. Percent of Population Age 65 or Older, ACS 2019 5-year Estimates 10
Figure 11. Percent of Population under Poverty Line by Census Tract, 2015 ACS 5-year Estimates 11
Figure 12. CEQ Environmental Justice Tool 12
Figure 13. EAD Computation Process 15
Figure 14. Tar Pamlico Watershed Streams and Reaches 18
Figure 15. Tar Pam 3 Reaches Developed from 2020 Census Tracts 19
Figure 16. Tar Pam 9, Tar Pam 10, and Stoney Creek 1 Reaches Developed from 2020 Census Tracts 20
Figure 17. Tar Pamlico 0.002 AEP FWOP Flood Extent 35
Figure 18. CEQ Tool Categories Exceeded Tar Pamlico Study Area 51
Figure 19. EJ Screen Categories Exceeded Tar Pamlico Study Area 52
Figure 20. Risk Conceptualized 53
Figure 21. High Hazard Depth Chart 54
Figure 22. Structural Stability Threshold Curve (Wood-anchored) 55
Figure 23. Residential Elevated Greenville TP3D 63
Figure 24. Residential Raised with Flood Vents Greenville TP3D 64
Figure 25. Elevated and Vented Residential Structure Greenville TP3F 65
Figure 26. Apartments Rocky Mount Front and Back TP10D 66
Figure 27. Structures Identified for Nonstructural Analysis 68
Figure 28. Elevation 70
Figure 29. Wet Floodproofing 72
Figure 30. Dry Floodproofing 74
Figure 31. Structures in Rocky Mount Area in Alternative 3A NED Plan and 3B Comp Benefits Plan 97
Figure 32. Structures in Greenville Area in Alternative 3A NED Plan and 3B Comp Benefits Plan 97
Figure 33. Rocky Mount 1999 Hurricane Floyd 99

Figure 34. Rocky Mount 2016 Hurricane Matthew 100
Figure 35. Rocky Mount 2016 Hurricane Matthew 101
Figure 36. Rocky Mount Flooding April 2017 102
Figure 37. Rocky Mount Flooding June 2020 103
Figure 38. Rocky Mount Flooding June 2020 104
Figure 39. Rocky Mount Flooding June 2020 105
Figure 40. Rocky Mount Flooding June 2020 106
Figure 41. Rocky Mount Flooding July 2023 107
Figure 42. Greenville Airport Flooding 2016 Hurricane Matthew 108
Figure 43. Greenville Flooding 2016 Hurricane Matthew 109
Figure 44. Greenville Flooding June 2019 110
Figure 45. CEQ Tool Categories Exceeded Tar Pamlico Study Area 113
Figure 46. CEQ Tool Categories Exceeded Alternatives West of Rocky Mount 115
Figure 47. CEQ Tool Categories Exceeded Alternatives East of Rocky Mount 116
Figure 48. CEQ Tool Categories Exceeded Alternatives Greenville 117
Figure 49. EJ Screen Demographic Index Tar Pam Watershed 119
Figure 50. EJ Screen Demographic Index with Alternatives in Rocky Mount Area 120
Figure 51. EJ Screen Demographic Index with Alternatives in Rocky Mount Area Zoomed In 121
Figure 52. EJ Screen Demographic Index with Alternatives in Rocky Mount Area Zoomed In 123
Figure 53. EJ Screen Demographic Index with Alternatives in Greenville 123
Figure 54 High Hazard Depth Chart 162
Figure 55 Structural Stability Threshold Curve (Wood-Anchored) 163
Figure 56 Comprehensive Benefits Plan & NED Plan Structure Locations 165

LIST OF TABLES

Table 1. Reach, aggregation floodplain, number of structures, and net economic benefit for each reach in the NED plan. i
Table 2. Number of structures recommended for structure elevation, flood venting, structure elevation and flood venting, and dry floodproofing within each of the 13 study reaches included in the TSP. Location of the 13 reaches is presented in Figure 2. All structures would be elevated or floodproofed to the 0.01 AEP flood elevation. iii
Table 3. Flood history of the Rocky Mount and Greenville areas. v
Table 4. Study Area and Comparison Area Population Trends 12
Table 5. Selected Population Characteristics 13
Table 6. Household Demographics 13
Table 7. Income Demographics 2020 13
Table 8. Tar Pamlico Reach Index Stations 22
Table 9. First Floor Stage Uncertainty Determination 25
Table 10. Structure Value Errors by Occupancy Type 26
Table 11. Occupancy Types and Content-to-Structure Value Ratios 27
Table 12. Total Investment by Stream 29
Table 13. Equivalent Record Length 31
Table 14. Stage Standard Deviations by Reach 33
Table 15. Average Event Depth by Reach 36
Table 15. Tar Pamlico Study Area AEP Event Damages WOPand FWOP 38
Table 16. Without-Project Condition EAD 40
Table 17. Future Without-Project Condition EAD 41
Table 18. Tar Pamlico Watershed WOP Performance 43
Table 19. Tar Pamlico Watershed FWOP Performance 44
Table 20. WOP Equivalent Annual Damages 2.5% 46
Table 21. CEQ Tool Categories and Threshold Criteria 50
Table 22. Number of Census Tracts with Categories in the 70th Percentile Compared to the Nation 52
Table 23. Expected Annual Population Loss (NRI) 56
Table 24. FWOP - Depth by Structure 57
Table 24. Measures Screened 61

Table 25. Elevation Cost Matrix....70
Table 26. Basement Fill Costs....71
Table 27. Cost Parameters for Wet Floodproofing....73
Table 28. Cost Parameters of Dry Floodproofing....75
Table 29. Nonstructural Measures Identified....76
Table 30. Floodproofed Structures by Floodplain....77
Table 31. 0.1 AEP Floodproofing by Reach....78
Table 32. 0.1 AEP Benefits (In $1,000)....79
Table 33. 0.1 AEP Construction Costs by Reach....79
Table 34. 0.1 AEP Cost Benefit Summary....80
Table 35. 0.04 AEP Floodproofing by Reach....80
Table 36. 0.04 AEP Benefits (In $1,000)....81
Table 37. 0.04 AEP Construction Costs by Reach....81
Table 38. 0.04 AEP Floodplain BCR....82
Table 39. 0.02 AEP Floodproofing by Reach....83
Table 40. 0.02 AEP Benefits (In $1,000)....84
Table 41. 0.02 AEP Floodplain Construction Costs by Reach....85
Table 42. 0.02 AEP Floodplain BCR....86
Table 43. 0.01 AEP Floodproofing by Reach....87
Table 44. 0.01 AEP Benefits (In $1,000)....88
Table 45. 0.01 AEP Floodplain Construction Costs by Reach....89
Table 46. 0.01 AEP Floodplain BCR....90
Table 47. NED Plan Measures by Reach....90
Table 48. NED Nonstructural Plan BCR....91
Table 49. NED Plan Costs....91
Table 50. NED Plan Average Annual Costs and Benefit Summary (In $1,000)....92
Table 51. NED Plan Relocation and Buy-Out Analysis Net Benefits by Reach....92
Table 52. Comprehensive Benefit Measures by Reach....93
Table 53. Comprehensive Benefits Plan....94
Table 54. Comprehensive Benefits Plan Average Annual Costs and Benefits (In $1,000)....94
Table 55. Alternative 3B Comprehensive Benefit BCR....95
Table 56. Relocation and Buy-Out Analysis Net Benefits by Reach....95
Table 57. Flood History....98
Table 58. CEQ Tool Categories and Threshold Criteria....112
Table 59. CEQ Study Area Alternatives Categories Exceeded....114
Table 60. EJ Screen Percentages....124
Table 61. EJ Screen Percentiles in Comparison National Data....125
Table 62. EJ Screen and CEQ Tool Summary for Alternative 3B Comprehensive Benefits Plan....126
Table 63. Recommended Nonstructural Measure Breakdown by Reach....127
Table 64. Depth Change by Structure....127
Table 65. Recommended Nonstructural Measure Breakdown by Reach....128
Table 66. Depth Change by Structure....130
Table 67. Comprehensive Benefits Plan Summary....131
Table 68. RED Alternative 3A NED Plan....132
Table 69. RED Alternative 3B Comprehensive Benefits Plan....133
Table 70. Alternative Summary....133
Table 71. TSP Plan Summary....136
Table 72. Residual Damages by Reach....138
Table 73. Top 80% Comp Benefits Measures by Reach....139
Table 74. BCR of Top 80% Comp Benefit Structures....139
Table 75. Bottom 80% Comp Benefits Measures by Reach....140
Table 76. BCR of Bottom 80% Comp Benefit Structures....140
Table 77. Comprehensive Benefit Sensitivity Overview....141
Table 78. Target Stage Sensitivity Analysis (in $1,000s)....143
Table 79. Updated Existing Conditions Results....144
Table 80. Final Optimized NED Plan Measures by Reach....145

Table 81. Final NED Nonstructural Plan BCR (In $1,000) 146
Table 82. Final NED Plan Costs 146
Table 83. Final NED Plan Average Annual Costs and Benefit Summary (In $1,000) 147
Table 84. Final Comprehensive Benefits Plan Measure by Reach 148
Table 85. Comprehensive Benefits Plan Final Costs 149
Table 86. Final Comprehensive Benefits Plan Average Annual Costs and Benefits (In $1,000) 149
Table 87. Final Alternative 3B Comprehensive Benefit BCR 150
Table 88. Cleanup Cost Benefits 151
Table 89. Comprehensive Benefits Plan BCR – With Cleanup Cost Benefits 152
Table 90. 75% Participation (Top Structures) by Reach 153
Table 91. 75% Participation (Bottom Structures) by Reach 153
Table 92. Top 75% Participation Benefits 154
Table 93. Bottom 75% Participation Benefits 154
Table 94. Top 75% Participation Benefit-Cost Ratio (In $1,000) 155
Table 95. BCR of Bottom 75% Comp Benefit Structures (In $1,000) 155
Table 96. Top 50% Comp Benefits Measures by Reach 156
Table 97. Bottom 50% Comp Benefits Measures by Reach 156
Table 98. Top 50% Participation Benefits 157
Table 99. Bottom 50% Participation Benefits 157
Table 100. BCR of Top 50% Comp Benefit Structures (In $1,000s) 158
Table 101. BCR of Bottom 50% Comp Benefit Structures (In $1,000s) 158
Table 102. Top 25% Comp Benefits Measures by Reach 158
Table 103. Bottom 25% Comp Benefits Measures by Reach 159
Table 104. Top 25% Participation Benefits 160
Table 105. Bottom 25% Participation Benefits 160
Table 106. BCR of Top 25% Comp Benefit Structures (In $1,000s) 161
Table 107. BCR of Bottom 25% Comp Benefit Structures (In $1,000s) 161
Table 108. Comprehensive Benefit Sensitivity Overview (In $1,000s) 162
Table 109 Persons Per Household – U.S. Census Bureau (2018-2022) 164
Table 110. FWOP - Depth by Structure 165
Table 111. FWOP Estimated Life Loss 167
Table 112. Recommended Nonstructural Measure Breakdown by Reach 168
Table 113. NED Plan - Depth by Structure 168
Table 114. NED Plan Estimated Life Loss 170
Table 115. Recommended Nonstructural Measure Breakdown by Reach 171
Table 116. Comprehensive Benefits Plan – Depth by Structure 172
Table 117. Comprehensive Benefits Plan Estimated Life Loss 173
Table 118. RED Alternative 3A NED Plan 175
Table 119. RED Alternative 3A NED Plan 176
Table 120. Summary of Accounts 177
Table 121.Alternative 3B Costs at 7% 181
Table 122. Alternative 3B Benefits with 7% Interest Rate 181
Table 123. Alternative 3B Summary 7% Interest Rate 181

Page Intentionally Left Blank

1. INTRODUCTION

The Tar Pamlico River Basin is a U.S. Army Corps of Engineers (USACE) feasibility study focused on evaluating potential flood risk management (FRM) alternatives to reduce flood and life safety risks in the Tar Pamlico River Basin. The State of North Carolina Department of Environmental Quality is the non-federal sponsor for the study. This study was authorized by the House Committee on Transportation and Infrastructure Resolution adopted July 23, 1997, and was funded under the 2019 Additional Supplemental Appropriations for Disaster Relief. Additional information regarding the study can be found in the main report and report appendices.

1.1. Purpose and Overview

The purpose of the economic appendix is to present the socioeconomic analysis completed to identify a recommended plan for a federal project for the study. The analysis follows the framework and methodology as directed by the USACE Planning Guidance Notebook (ER 1105-2-100) dated 22 April 2000 and as well as the guidance listed in Section 1.4 below. The economic appendix includes the following:

- A description of the framework of the economic analysis, including the major assumptions, data, methodologies, and analytical tools used.
- A discussion of relevant background information including demographic, social, economic, and housing data for the study area.
- A description of the flood risk analysis completed, in terms of probability and consequence of flooding, for the without-project and with-project conditions for the study area. The FRM analysis evaluates flood damages in the study area on an equivalent annualized basis and calculates project performance by simulating a large number of possible flood events, taking into account all pertinent economic and engineering data including risk and uncertainty factors.

1.2. Location

The Tar Pamlico River Basin covers approximately 6,148 square miles in North Carolina, with its upstream boundaries in Person, Granville, and Vance counties in north central part of the state and extending around 215 miles southeast where the river has a confluence with the Pamlico Sound. The mainstem of the Tar Pamlico flows through the entire basin, with several tributaries along the mainstem also contributing to flood events.

1.3. Historical Background

The study area is subject to severe flooding, particularly during the Atlantic hurricane season, which runs from June to November. In recent years, hurricanes caused severe flooding and federally recognized natural disasters were declared. Particularly severe impacts from Hurricane Florence (2018) and Hurricane Matthew (2016) were witnessed in North Carolina in the past decade. In addition, Hurrican Floyd (1999) and Fran (1996) caused significant flooding within the past 30 years. In addition, large rain events in June 2019, June 2020, and July 2023 caused significant flooding in the specific communities within the watershed.

In 2018, North Carolina reported 42 fatalities caused by Hurricane Florence, and estimated damages totaled $17 billion.(**https://www.weather.gov/ilm/HurricaneFlorence**) Approximately 75,000 structures were flooded in the state and over 5,000 individuals were

rescued from flooding. During Hurricane Matthew in 2016 a reported total of 25 deaths occurring in North Carolina and estimated damages totaled around $10.6 billion. (**https://www.weather.gov/ilm/Matthew**) Although the current study area is at low risk for life loss based on being far enough inland to avoid the life risk associated with hurricanes. Hurricanes and other large rain events leave the inland areas susceptible to flooding.

1.4. Study Guidance

The analysis completed for this study is consistent with current regulations and policies. Pertinent guidance governing economic analysis procedures includes:

- Engineer Regulation (ER) 1165-217, Civil Works Review Policy, 1 May 2021
- Engineer Circular (EC) 1165-2-218 USACE Levee Safety Program, 22 Apr 2021
- Economic Guidance Memorandum (EGM) 01-03, Generic Depth-Damage Relationships, 4 Dec 2000
- Economic Guidance Memorandum (EGM) 04-01, Generic Depth-Damage Relationships for Residential Structures with Basements, 10 Oct 2003
- Economic Guidance Memorandum (EGM) 09-04, Generic Depth-Damage Relationships for Vehicles, 22 Jun 2009
- Engineer Manual (EM) 1110-2-1619, Risk-Based Analysis for Flood Damage Reduction Studies, 1 Aug 1996
- Engineer Regulation (ER) 1105-2-100, Planning Guidance Notebook, 22 Apr 2000
- Engineer Regulation (ER) 1105-2-101, Risk Assessment for Flood Risk Management Studies, 17 Jul 2017
- Engineer Regulation (ER) 1110-2-1156, Safety of Dams – Policy and Procedures, 31 Mar 2014
- Engineer Regulation (ER) 1165-2-26, Implementation of Executive Order 11988 on Flood Plain Management, 30 Mar 84
- Institute for Water Resources (IWR) Report 96-R-12, Analysis of Nonresidential Content Value and Depth-Damage Data for Flood Damage Reduction Studies, May 1996
- Planning Bulletin (PB) 2019-04, Incorporating Life Safety into Flood and Coastal Storm Risk Management Studies
- Secretary of the Army (Civil Works) (SACW) POLICY DIRECTIVE – Comprehensive Documentation of Benefits in Decision Document, 5 Jan 2021
- Water Resources Development Act (WRDA) of 1990, Sec. 308 Flood Plain Management, 28 Nov 1990

1.5. The System of Accounts

Per the 5 January 2021 SACW POLICY DIRECTIVE – Comprehensive Documentation of Benefits in Decision Document, all USACE planning study project delivery teams (PDTs) must evaluate and provide a complete accounting, consideration, and documentation of the total benefits of alternative plans across all benefit categories. Total benefits involve a summation of monetized and/or quantified benefits, along with a complete accounting of qualitative benefits,

for project alternatives across national and regional economic, environmental, and social benefit categories.

In computing total benefits of a project alternative, it is imperative that any benefits reflected in more than one category are only counted once. The level of detail will vary based on study type and the decision-context for the specific problems identified, recognizing that not all benefits can be monetized, and some cannot be cost-effectively quantified. Even if non-monetary measures are used, these benefits and impacts must be accounted for in the most substantive way possible.

Each study must include, at a minimum, the following plans in the final array of alternatives for evaluation:

1) The "No Action" alternative.
2) A plan that maximizes net total benefits across all benefit categories.
3) A plan that maximizes net benefits consistent with the study purpose.
4) For flood-risk management studies, a nonstructural plan, which includes modified floodplain management practices, elevation, relocation, buyout/acquisition, dry flood proofing, and wet flood proofing.
5) A locally preferred plan, if requested by a non-federal partner, if not one of the aforementioned plans.

1.5.1. National Economic Development (NED)

Economic costs and benefits associated with an alternative are evaluated in terms of their impacts on national wealth, without regard to where in the United States the impacts may occur. National Economic Development (NED) benefits must result directly from a project and must represent net increases in the economic value of goods and services to the national economy, not simply to a region or locality. Using a 50-year period of analysis, and the current federal discount rate, expected annual damages (EAD) or damages reduced (i.e., benefits) are calculated.

NED costs represent the costs of diverting resources from other uses in implementing the project, as well as the costs of uncompensated economic losses resulting from detrimental effects of the project. NED annual benefits, the benefit-cost ratio, and the net NED annual benefits are calculated during the evaluation process. Net benefits represent the amount by which the annual NED benefits exceed annual NED costs, thereby defining the plan's contribution to the nation's economic output. A benefit-cost ratio of 1.0 or greater must be demonstrated for Federal interest. The plan with the highest net benefits is considered the recommended NED plan, assuming technical feasibility, environmental soundness, and acceptability.

1.5.2. Regional Economic Development (RED)

Studies must quantify the regional economic impacts on local and regional income, employment, and other measures of the regional economy from the construction of and operation of a project such as changes in property or land value, to the extent practicable for each alternative. Where impacts are anticipated to be the same across all alternatives or not play a significant role in the evaluation of alternatives and selection of a recommended plan, a qualitative assessment may suffice.

1.5.3. Other Social Effects (OSE)

Relevant factors must be described and analyzed in the most substantive manner possible, whether quantitative or qualitative. The analysis may present the same factor from multiple points of view. The analysis must also account for who benefits as well as who is adversely affected because of each alternative.

Flood and coastal storm risk management reports must include an assessment of potential mortality (life loss) for the future without project condition, as well as estimated changes in potential for and magnitude of mortality (life risk) for all alternatives in the final array. Where the change is anticipated to be the same across all alternatives or not play a significant role in the evaluation and selection of a recommended plan, a qualitative risk assessment will suffice.

The residual risk to life safety must be determined for the recommended plan and when changes in estimated life loss play a significant role in decision-making.

1.5.4. Environmental Quality (EQ)

For each alternative plan, positive and negative benefits to the environment must be analyzed consistent with current ecosystem restoration or environmental compliance guidance. The benefit assessment can be quantitative or qualitative and, if appropriate, monetized. The analysis must distinguish between national and regional benefits while ensuring benefits are not accounted for more than once.

2. STUDY AREA

The study area, shown in Figure 5 below, is located in Northeastern North Carolina and includes the entire Tar Pamlico River Basin, which commences in eastern Person County and continues toward the Pamlico Sound, where it ends southeast of Washington. The Washington area was screed out based on engineering constraints on modeling riverine hydraulic data for coastal areas but is included in this section. The study area intersects more than 145 census tracts, 19 counties, and covers approximately 6,148 square miles of land.

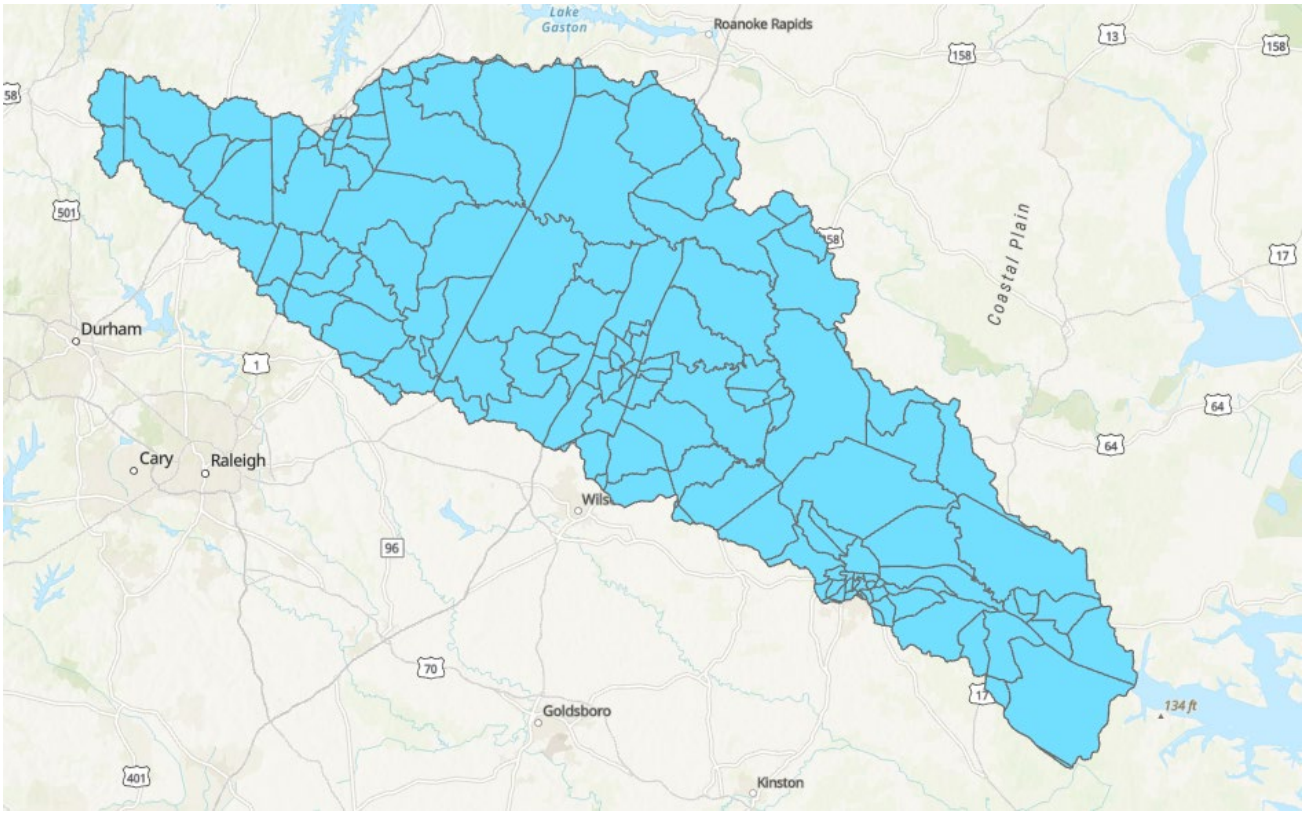

Figure 5. Tar Pamlico River Basin Study Area Census Tracts

2.1. Land Use

The study area includes agricultural, national forest, and built out (residential, commercial, and public/government) land use. The 2019 National Land Cover Database, depicted in Figure 6, shows higher intensity development in and around Raleigh, and near major urban areas throughout the basin. Land use was taken into consideration when evaluating where to focus the analysis for the study.

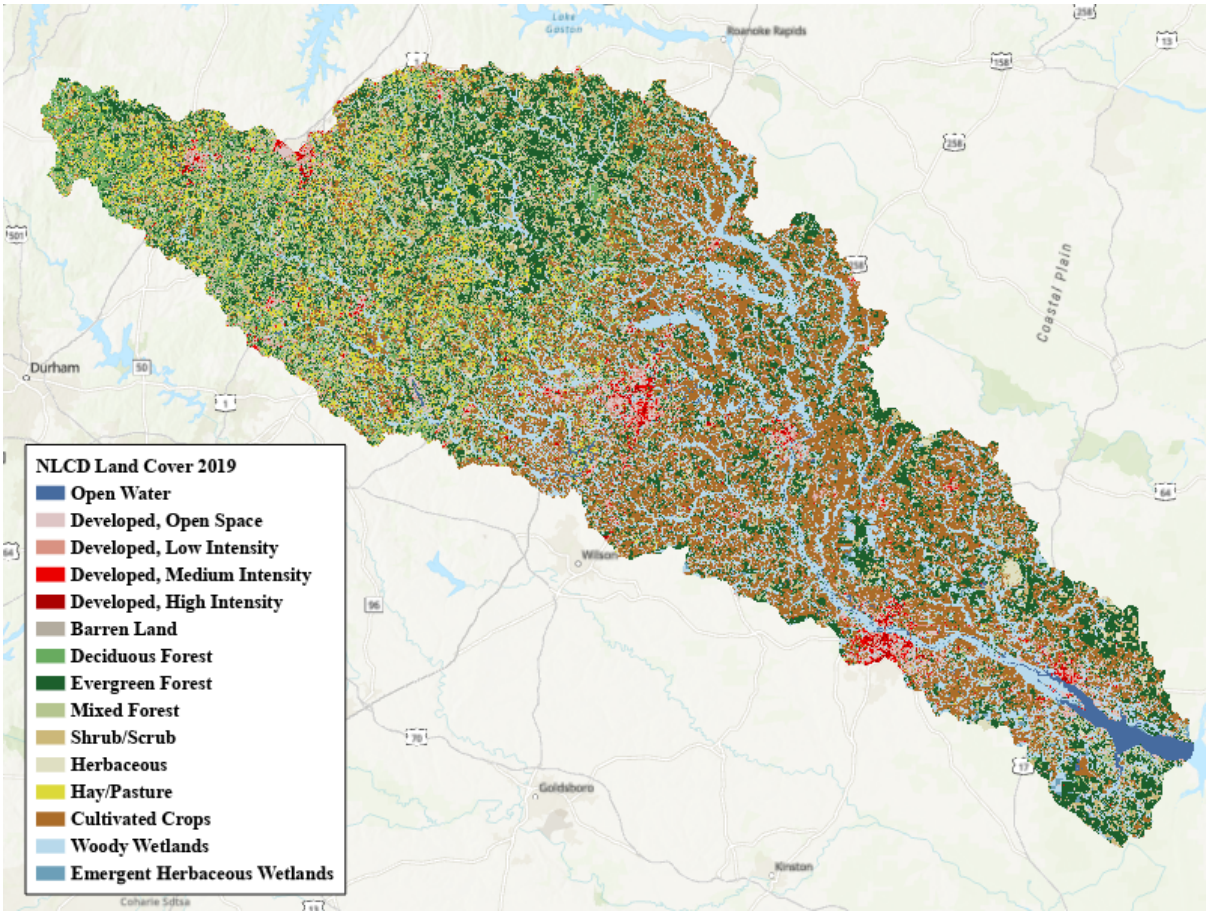

Figure 6. Study Area Land Use

2.2. Population and Socioeconomics

The total estimated population count in the Tar Pamlico River Basin is approximately 570 thousand as of 2020. The following figures display the distribution of the population by census tract, and other socioeconomic and demographic factors that impact the population at risk in the study area. Demographic data for the following maps was taken from the American Community Survey (ACS) 2016-2020 5-year estimates available on census.gov, unless otherwise indicated.

Figure 7 displays population count by census tract. More densely populated census tracts include those near Rocky Mount, Greenville, and Princeville.

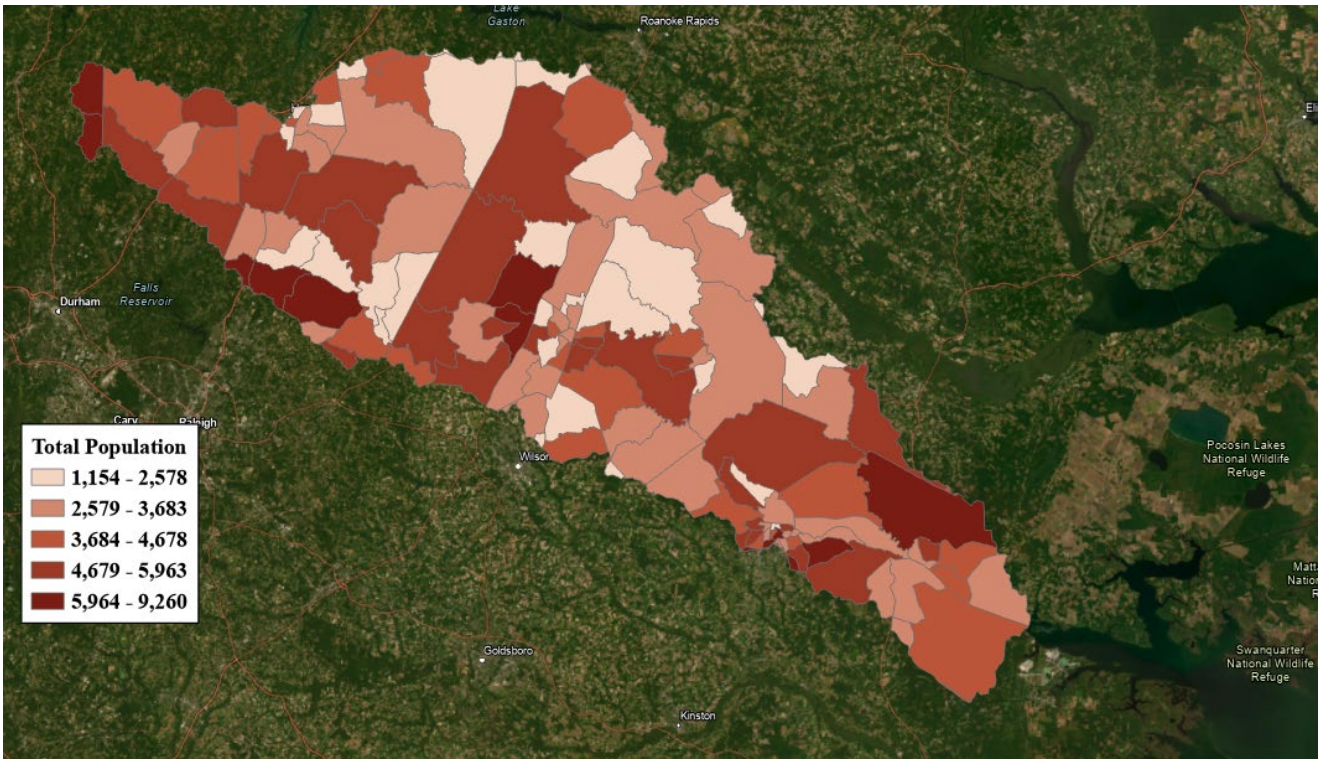

Figure 7. Population Count by Census Tract, ACS 2020 5-year Estimates.

Figure 8 displays median household income in 2020 inflation-adjusted dollars overlaid by average household size, by census tract. The average median household income by tract is $48,000 annually, while the lowest is $17,900 and the highest is $112,600.

The average household size is 2.5 individuals, but there doesn't appear to be a strong directional correlation between household income and household size. Smaller households tend to be near the confluence of the Tar with the Atlantic Ocean.

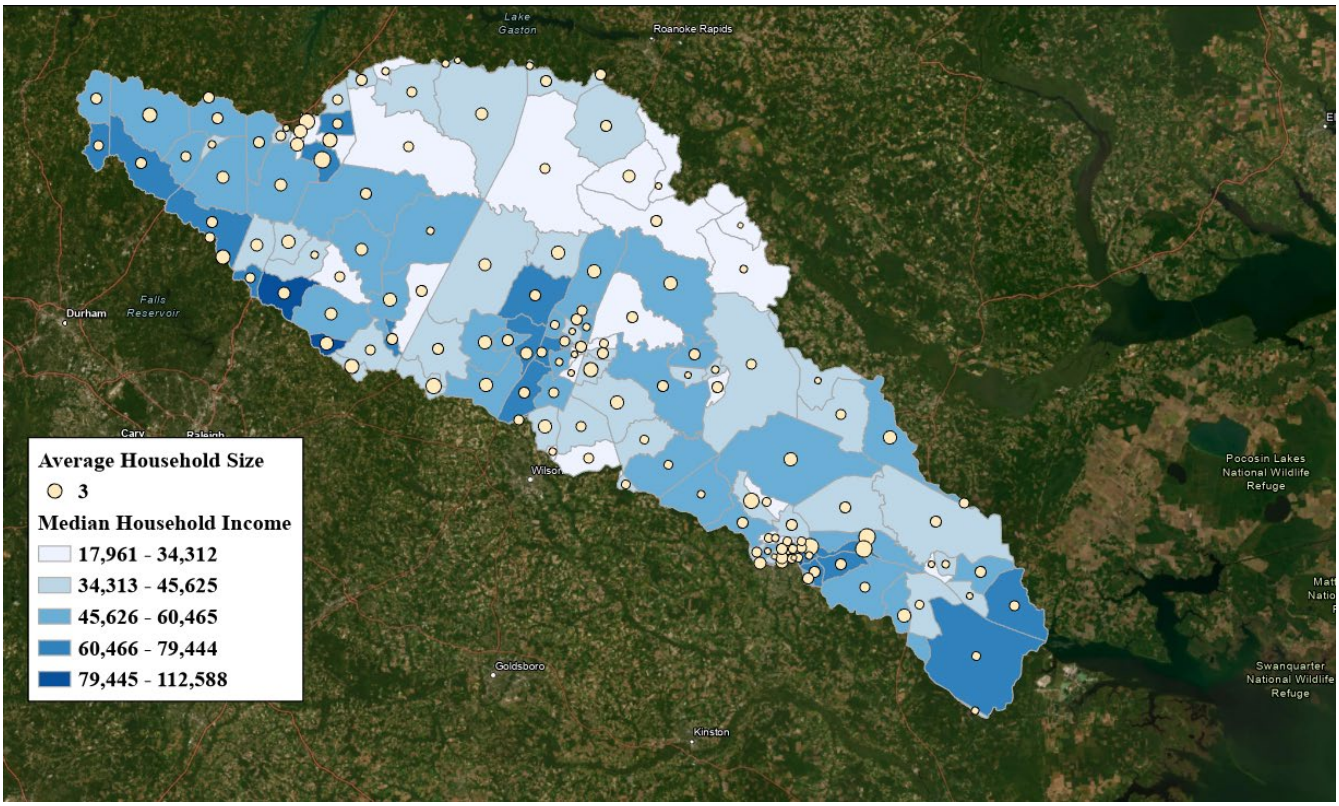

Figure 8. Median Household Income in 2020 Inflation Adjusted Dollars vs Household Size

Figure 9 shows the non-white population count by census tract. Census tracts located in northern part of the basin, Rocky Mount, and Greenville have the highest non-White populations. The census tracts in Rocky Mount and Greenville are also more densely populated than tracts in the lower part of the basin.

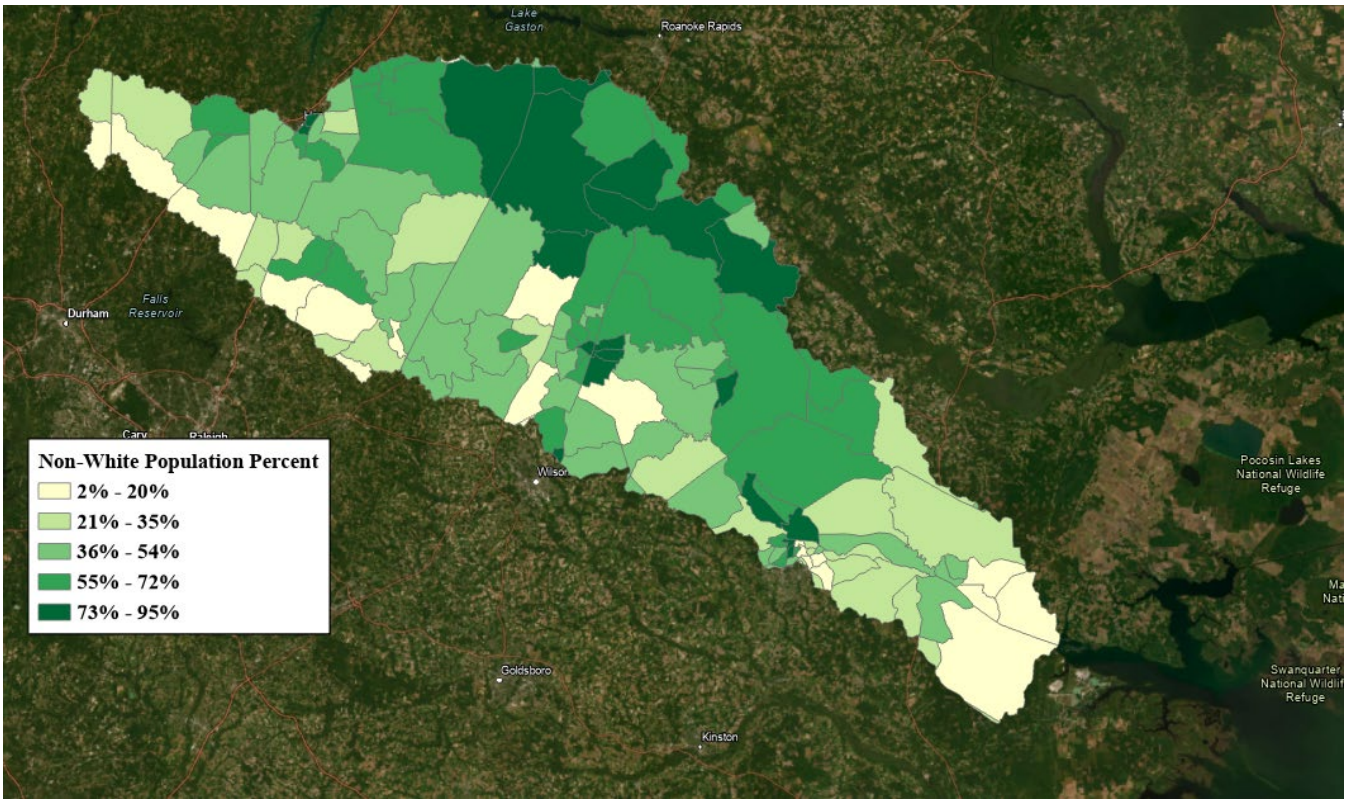

Figure 9. Non-White Population Count by Census Tract, ACS 2020 5-year Estimates

Figure 10 shows the percent of the population that is older than 65 and may be more vulnerable in event of a flood than younger individuals who often can more easily evacuate. The darkest green color shows census tracts where 31-44 percent of the population is older than 65. These tracts are located throughout the basin.

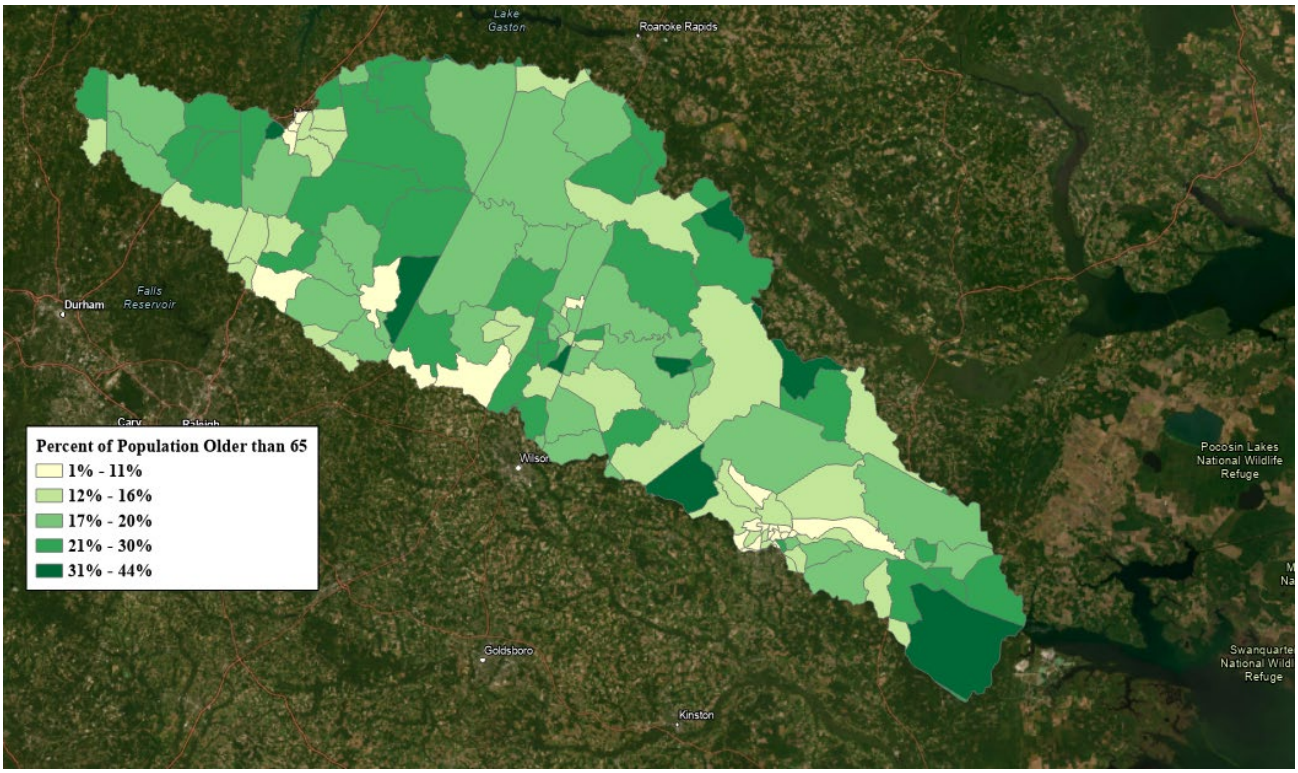

Figure 10. Percent of Population Age 65 or Older, ACS 2019 5-year Estimates

Figure 11 displays the percent of the population in each census tract under the poverty line, which was $26,496 for a household of four in 2020. The basin wide average poverty rate is 19.5 percent, which is higher than the 2020 national average of 11.4 percent. The highest tract level poverty rate occurs near Greenville, in Census Tract 1.01, where 60.5 percent of the population was under the poverty line in 2020 with several more with high poverty concentrated in the more densely populated tracts. One census tract, Census Tract 607.03 has a poverty rate below one percent and is located near Lake Royale.

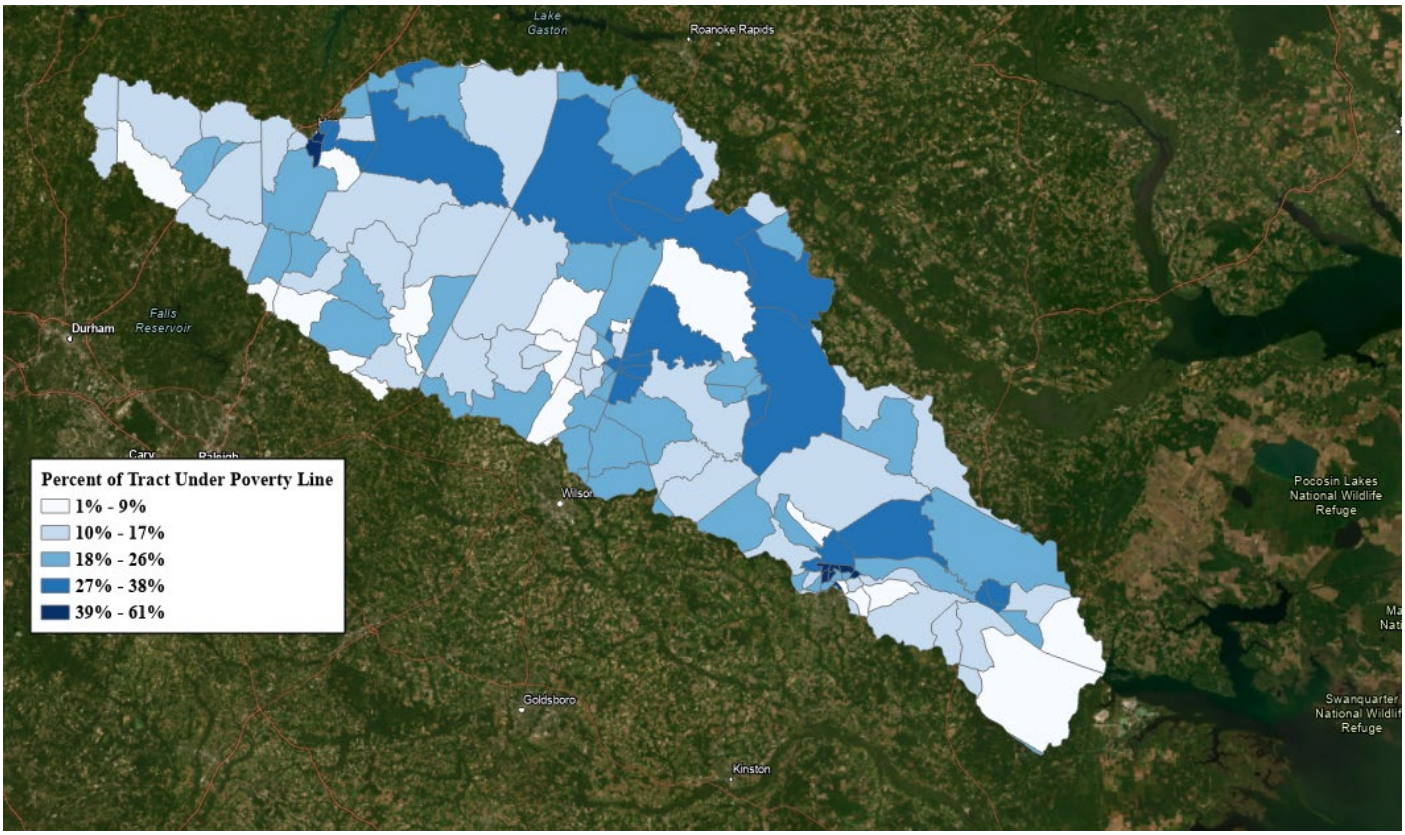

Figure 11. Percent of Population under Poverty Line by Census Tract, 2015 ACS 5-year Estimates

In January of 2021, President Biden issued Executive Order 14008. The order directed the Council on Environmental Quality (CEQ) to develop a new tool. This tool is called the Climate and Economic Justice Screening Tool. The tool has an interactive map and uses datasets that are indicators of burdens in eight categories: climate change, energy, health, housing, legacy pollution, transportation, water and wastewater, and workforce development. The tool uses this information to identify communities that are experiencing these burdens. These are the communities that are disadvantaged because they are overburdened and underserved. There are numerous tracts within the Tar Pamlico study area that are considered disadvantages as illustrated in Figure 12. A more detailed description of tracts being directly impacted by inundation is presented in Section 0.

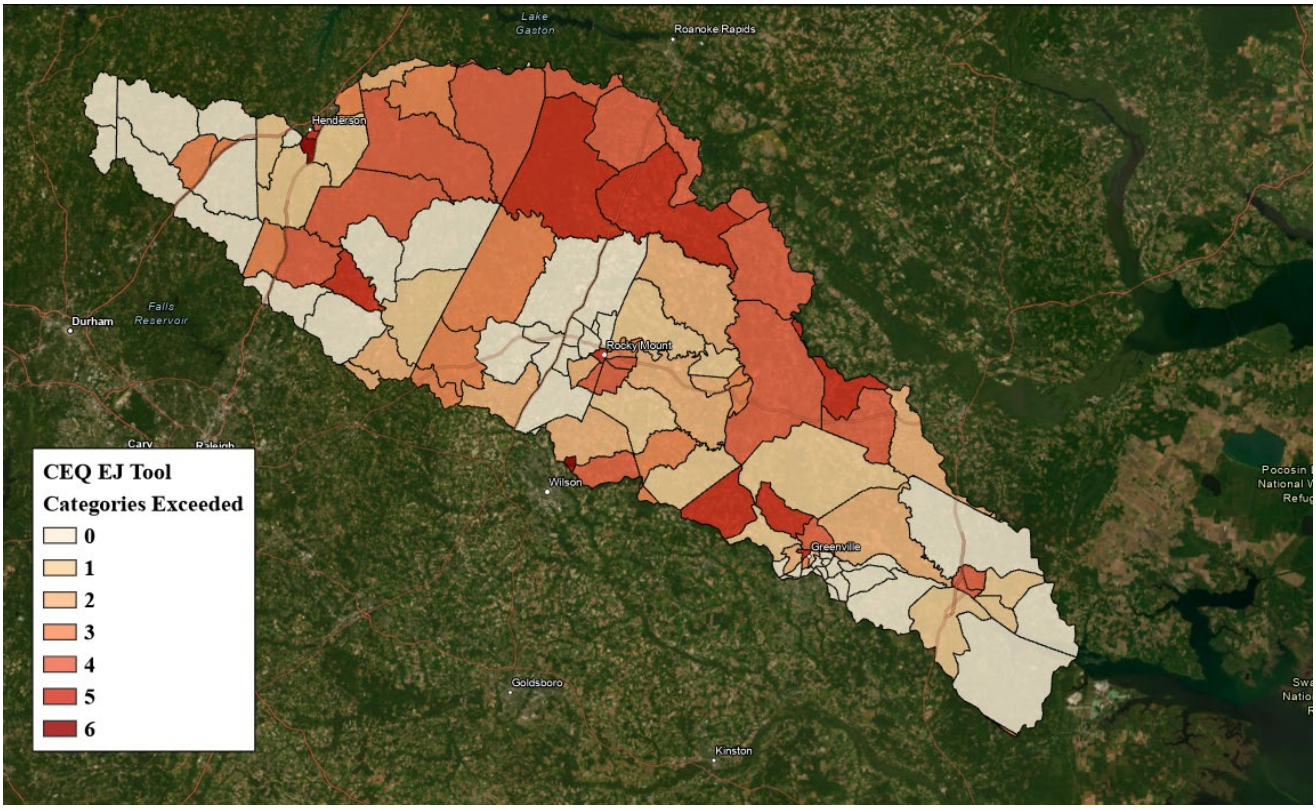

Figure 12. CEQ Environmental Justice Tool

The following tables display demographic data taken from the ACS 5-year estimates (2016-2020). Table 4 displays population data from 2010 and 2020 for North Carolina and the U.S. The growth rate for the study area in the past decade was similar to that of the entire U.S.

Table 4. Study Area and Comparison Area Population Trends

Geography	2010	2020	Percent Change 2010-2020
North Carolina	9,535,486	10,439,388	9%
U.S.	308,745,538	331,449,281	7%

Source: census.gov/quickfacts

Table 5 shows the distribution of race and income in North Carolina and the U.S. North Carolina has a larger percent of African American people than the U.S., on average, and a lower percent of Hispanic, Latino, or Asian people. The age distribution is roughly equal to that of the entire U.S.

Table 5. Selected Population Characteristics

Demographic	North Carolina	U.S.
Population	10,439,388	331,449,281
% 65 and above	16.7	16.5
% 18 and under	21.9	22.3
Two or more races, %	2.3	2.8
Hispanic or Latino (of any race) %	9.8	18.5
White alone %	70.6	76.3
Black or African American alone %	22.2	13.4
American Indian and Alaska Native alone%	1.6	1.3
Asian %	3.2	5.9

Source: census.gov/quickfacts

Table 6 displays household demographics for North Carolina and the U.S. The median value of owner-occupied housing is lower than that of the national average, as is the percent households that speak a language other than English at home. Other demographic traits are similar to the national average.

Table 6. Household Demographics

Demographic	North Carolina	U.S.
Total Housing Units, 2019	4,747,943	139,684,244
% Owner Occupied	65	64
Median Value of Owner-occupied housing	172,500	217,500
Median gross rent	907	1,062
Average household size	2.52	2.62
Language other than English spoken at home (%)	11.80	21.60
Bachelor's degree or higher, percent of persons age 25+	31.30	32.10

Source: census.gov/quickfacts

Table 7 displays income demographics for North Carolina and the U.S. North Carolina's unemployment rate is similar to that of the national average, while the per capita and median household income is lower than the national average. The poverty rate is approximately 1.5 percentage points above the average U.S. rate.

Table 7. Income Demographics 2020

Geography	Unemployment Rate 2019	Per Capita Income, last 12 months	Median Household Income 2019 dollars	Percent of Individuals Living Below Poverty
North Carolina	3.50%	30,783	54,602	12.9
U.S.	3.60%	34,103	62,843	11.4

Source: census.gov/quickfacts

3. NED METHODOLOGY

This section provides an overview of the economic analysis used to evaluate the flood risk management alternatives developed to identify the national economic development (NED) plan, along with the models and tools used to compute NED economic benefits.

3.1. Framework of Economic Analysis

3.1.1. Price Level, Period of Analysis, and Discount Rate

Values listed in this analysis are based on fiscal year (FY) 2022 price levels. Annualized benefits and costs were computed using a 50-year period of analysis and the FY 2023 federal discount rate of 2.5 percent. For the whole Tar Pamlico River Basin equivalent annual damages are presented. Annualized values are presented in thousands of dollars unless otherwise noted.

3.1.2. Economic Analysis Tool: HEC-FDA Risk Analysis Program

The economic analysis uses the Hydrologic Engineering Center Flood Damage Analysis (HEC-FDA) program to compute damages. Economic damages serve as a basis for computing net economic benefits, and the benefit-cost ratio (BCR). HEC-FDA is a USACE certified risk-based program and is standard for economic computations for flood risk management studies. HEC-FDA integrates engineering data (hydrologic, hydraulic, and geotechnical when applicable) and economic data (structure/content inventory and depth-percent damage curves) to model the potential flood risk for the without project condition and study alternatives. HEC-FDA version 1.4.3 is used in this analysis.

ER 1105-2-101 requires incorporating risk and uncertainty in calculating damage estimates for flood events. This is best represented by a range of possible damage values and their likelihood of occurring, or a probability distribution. HEC-FDA uses Monte Carlo simulation to obtain a random sample of the contributing relationships and computes stage-damage functions, exceedance probability discharge curves, and conditional stage-discharge relationships to generate expected annual damage (EAD) values. EAD estimates capture the mean of the probability distribution of annual damage and are the basis for calculating equivalent annual damages and benefits. Uncertainty is incorporated into EAD estimates using Monte Carlo simulation: each iteration of a simulation randomly samples the uncertainty distributions, and the resulting values are used to transform the flow and stage distributions to a damage distribution. The area under the curve of the distribution is integrated to compute EAD. Thousands of iterations of this process are repeated to infer the EAD distribution and estimate EAD as the probability weighted average of all possible peak annual damages, where damage is a continuous random variable.[1] This process is depicted in Figure 13.

[1] This process is described in more detail in the HEC-FDA User's Manual Version 1.4.1 available at **http://www.hec.usace.army.mil/software/hec-fda/documentation/CPD-72_V1.4.1.pdf** and the HEC-FDA update notes Version 1.4.3 available at https://www.hec.usace.army.mil/software/hec-fda/documentation/HEC-FDA_ReleaseNotes_Jun2021.pdf.

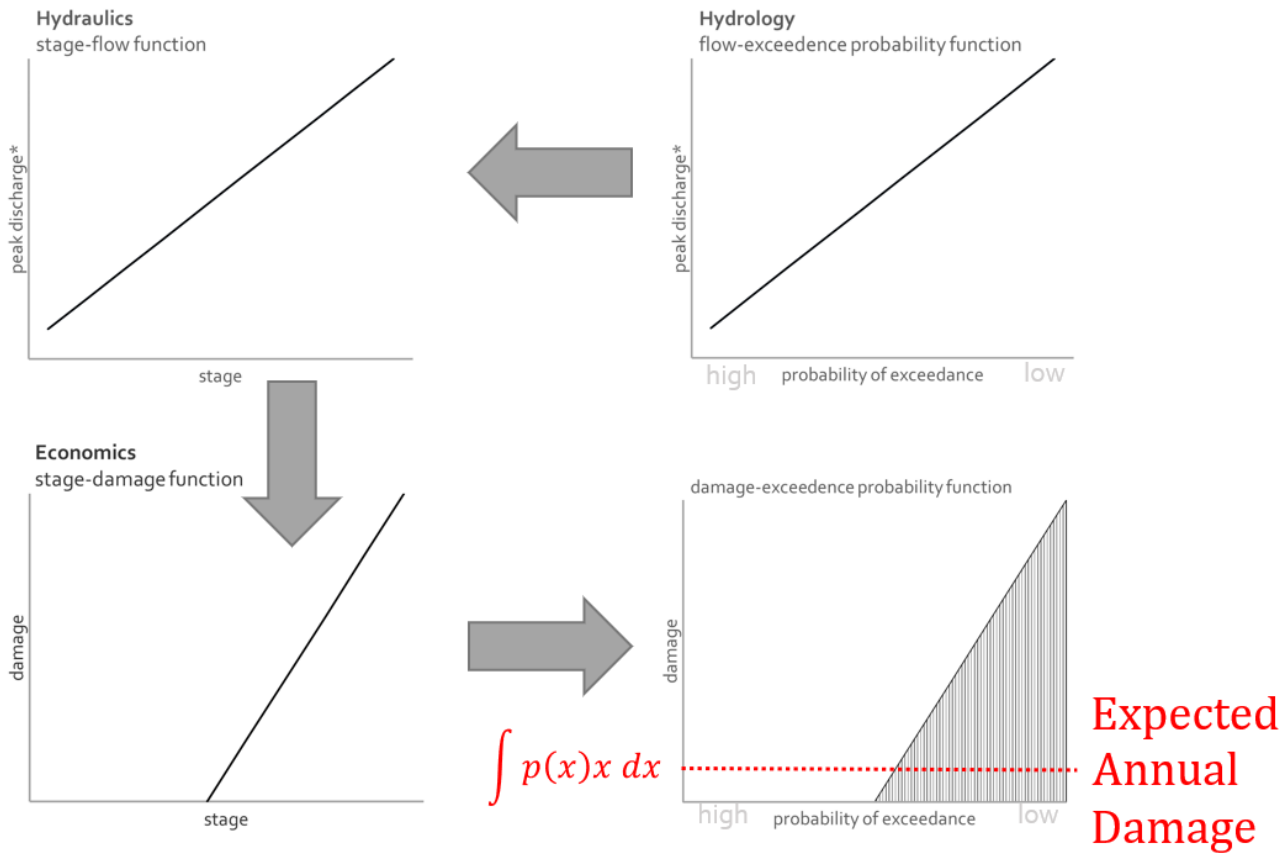

Figure 13. EAD Computation Process

To compute EAD values, HEC-FDA requires the following data:

1. **Structure Inventory Data –** This includes a structure identification number, a use category (industrial, commercial, single-family residence, etc.), stream location identified by cross sectional or grid data, first floor elevation, and depreciated structure and content values. This data was compiled using ArcGIS Pro 2.9, Google Earth, and Microsoft Excel, and imported into HEC-FDA.

2. **Hydrologic and Hydraulic Data** – This data includes water surface profiles, exceedance probability discharge relationships, and stage/discharge relationships. Water surface profiles were developed in Hydrologic Engineering Center River Analysis System (HEC-RAS), processed in ArcGIS Pro and Excel to combine with the structure inventory, and then imported into the HEC-FDA program.

   An index location is a required input for HEC-FDA. The index location is used to specify discharge-probability, stage-discharge, and stage-damage functions for alternative evaluations for each reach. The index location assignments were based on hydrologic and economic parameters, and a close examination of hydraulic conditions specific to each reach. Hydraulic conditions were mapped, providing water surface elevations for the eight flood events. The assigned index location generally represents the water surface conditions occurring in the reach.

3. **Depth/Damage Functions for Residential Structures and Structure Contents –**

Depth-damage curves relate the percent of structure and content value that is damaged given the depth of inundation. Economic Guidance Memorandum (EGM) 04-01, *Generic Depth-Damage Relationships for Residential Structures with Basements*, October 2003, represented the depth-damage functions for residential structures in HEC-FDA.

This EGM summarized data developed by the Institute for Water Resources (IWR) using post-flood residential damage claim records provided by the Federal Emergency Management Agency (FEMA). The functions account for both structural and content damage to homes with and without basements.

A depth-damage curve for mobile homes is not included in EGM 04-01. Instead, the damage curve for mobile homes based on 2006 data from the New Orleans district is used. This curve was used because it is reasonable to assume that mobile homes across the nation would face similar depth-damage functions from various heights of freshwater flooding and would also have similar CSVRs.

4. **Depth/Damage Functions for Non-residential Structures and Structure Contents –**

   The depth-damage functions for non-residential structures and contents were based on the data presented from the draft report Solicitation of Expert Opinion Depth-Damage Function Calculations for the Benefit-Cost Analysis Tool (URS Group, 2008). Twenty-one core non-residential structure types were evaluated by a panel of experts from across the United States. The resulting data from the panel included nationally relevant depth-damage functions (DDFs) for use in estimating the value of damages from flooding to commercial, industrial, and public structures.

   Uncertainty measures were incorporated into the commercial and public depth-damage functions. For non-residential structures, depth-damage function uncertainties are expressed as a triangular distribution.

5. **Risk and Uncertainty Parameters –** Uncertainty parameters discussed in Section 3.2. of this report were also entered into HEC-FDA.

Discharge-exceedance probability, stage-discharge, and damage-stage functions derived at a damage reach index location are used to compute the damage-exceedance probability function. Monte Carlo simulation is a computationally efficient method of obtaining the damage-exceedance probability function due to uncertainty in input parameters. This numerical integration process requires all these relationships, and risk and uncertainty parameters to be input into HEC-FDA. Expected annual damage values are obtained from the cumulative distribution function produced in successive iterations of the Monte Carlo process.

3.1.3. Economic Damage Reaches and Index Stations

There were 39 reaches (shown in Figure 14) delineated in the Tar Pamlico study area for the TSP screening analysis. Geographic areas are often outlined as economic damage reaches based on similar hydromorphology, hydraulic characteristics, and economic considerations (such as land use and socioeconomic characteristics). Initially 23 reaches were developed, then four of those reaches (TarPam 3, TarPam 9, TarPam 10, and StonyCk1) were split based on 2020 Census Tracts bringing the total to 39 as exhibited in Figure 14-Figure 16. In addition, due to the coastal nature of Reaches TarPam1, TarPam2, and JackCk and complexities that arose after initial modeling in HEC-RAS and HEC-FDA, these reaches were removed from the study and

recommended to be evaluated in a separate study. As a result, damages for these three reaches are not shown in the tables below.

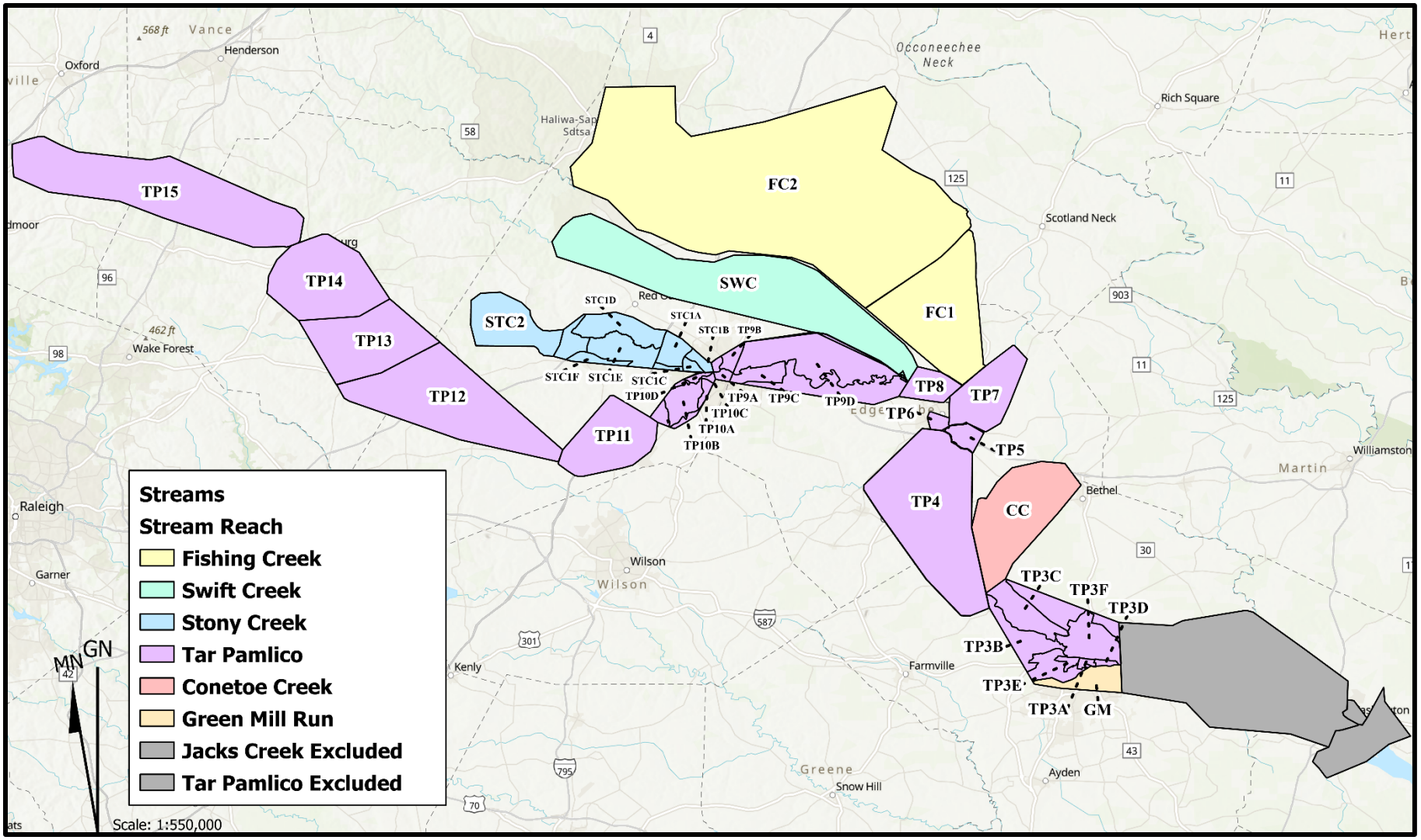

Figure 14. Tar Pamlico Watershed Streams and Reaches

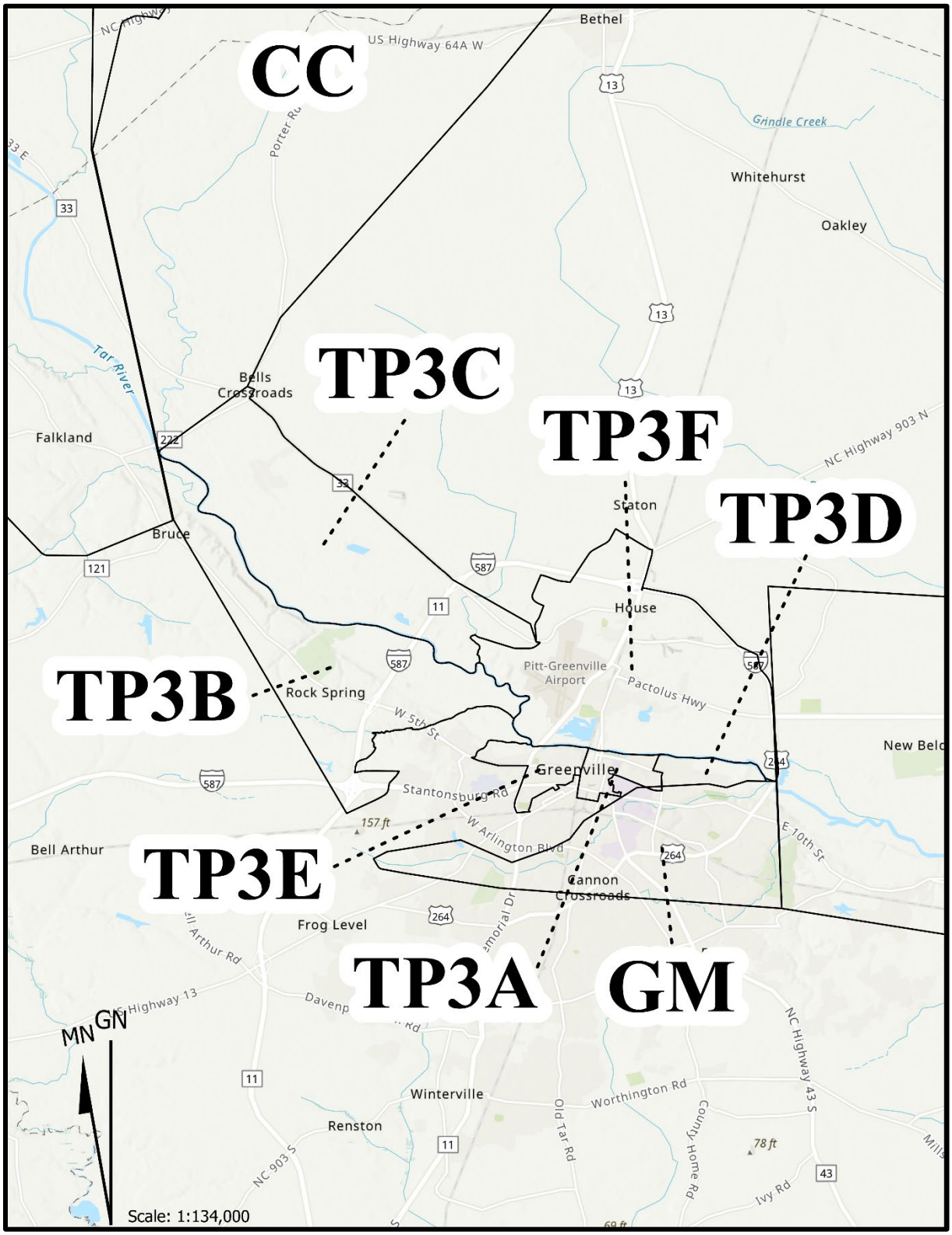

Figure 15. Tar Pam 3 Reaches Developed from 2020 Census Tracts

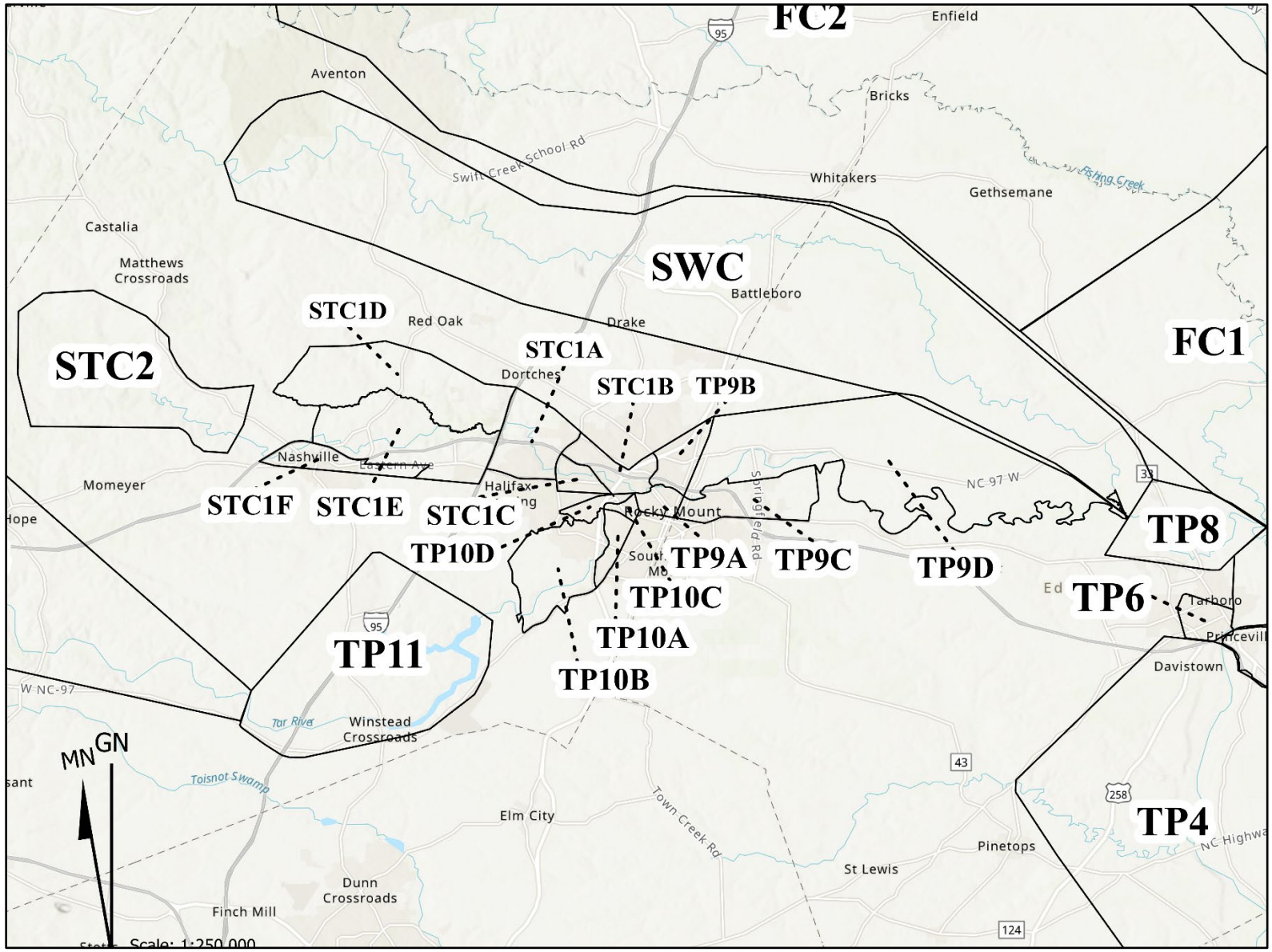

Figure 16. Tar Pam 9, Tar Pam 10, and Stoney Creek 1 Reaches Developed from 2020 Census Tracts

Each reach is associated with an index station, which is used to specify discharge-probability, stage-discharge, stage-damage functions, and top of bank elevations for each reach. The index station assignments are based on hydrologic parameters and hydraulic conditions specific to each reach. The assigned index station is generally representative of the conditions throughout the reach. Since there are multiple streams within the study area, station numbering in each reach reflects the station numbering associated with the stream in that reach. Table 5 presents reach index and downstream/upstream cross section information for the study area.

Table 8. Tar Pamlico Reach Index Stations

Economic Reach	Hydraulic Reach	Stream	Description	Bank	Index Station	Downstream Boundary	Upstream Boundary
TP1*	Tar_Pamlico1	Tar Pamlico	TarPam1	Both	0.01	35068.3	47940.5
TP2*	Tar_Pamlico1	Tar Pamlico	TarPam2	Both	0.02	47940.5	145043.4
TP3A	Tar_Pamlico1	Tar Pamlico	TarPam3A	Both	0.03	145043.4	217164.2
TP3B	Tar_Pamlico1	Tar Pamlico	TarPam3B	Both	0.03	145043.4	217164.2
TP3C	Tar_Pamlico1	Tar Pamlico	TarPam3C	Both	0.03	145043.4	217164.2
TP3D	Tar_Pamlico1	Tar Pamlico	TarPam3D	Both	0.03	145043.4	217164.2
TP3E	Tar_Pamlico1	Tar Pamlico	TarPam3E	Both	0.03	145043.4	217164.2
TP3F	Tar_Pamlico1	Tar Pamlico	TarPam3F	Both	0.03	145043.4	217164.2
TP4	Tar_Pamlico2	Tar Pamlico	TarPam4	Both	0.04	217164.2	291592.7
TP5	Tar_Pamlico2	Tar Pamlico	TarPam5L	Left	0.05	291592.7	295288.5
TP6	Tar_Pamlico2	Tar Pamlico	TarPam6R	Right	0.06	291592.7	301461.0
TP7	Tar_Pamlico2	Tar Pamlico	TarPam7	Both	0.07	295288.5	330409.0
TP8	Tar_Pamlico3	Tar Pamlico	TarPam8	Both	0.08	330409.0	372220.0
TP9A	Tar_Pamlico4	Tar Pamlico	TarPam9A	Both	0.09	372220.0	514446.4
TP9B	Tar_Pamlico4	Tar Pamlico	TarPam9B	Both	0.09	372220.0	514446.4
TP9C	Tar_Pamlico4	Tar Pamlico	TarPam9C	Both	0.09	372220.0	514446.4
TP9D	Tar_Pamlico4	Tar Pamlico	TarPam9D	Both	0.09	372220.0	514446.4
TP10A	Tar_Pamlico5	Tar Pamlico	TarPam10A	Both	0.1	514446.4	553326.4
TP10B	Tar_Pamlico5	Tar Pamlico	TarPam10B	Both	0.1	514446.4	553326.4
TP10C	Tar_Pamlico5	Tar Pamlico	TarPam10C	Both	0.1	514446.4	553326.4
TP10D	Tar_Pamlico5	Tar Pamlico	TarPam10D	Both	0.1	514446.4	553326.4
TP11	Tar_Pamlico5	Tar Pamlico	TarPam11	Both	0.11	553326.4	610070.6
TP12	Tar_Pamlico5	Tar Pamlico	TarPam12	Both	0.12	610070.6	715270.3
TP13	Tar_Pamlico5	Tar Pamlico	TarPam13	Both	0.13	715270.3	753058.3
TP14	Tar_Pamlico5	Tar Pamlico	TarPam14	Both	0.14	753058.3	807333.6
TP15	Tar_Pamlico5	Tar Pamlico	TarPam15	Both	0.15	807333.6	933557.3
JC*	Jacks_Creek	Jacks Creek	JackCk	Both	0.16	2234.0	9535.0
GM	Green Mill Run	Green Mill Run	GreenMill	Both	0.17	1485.0	40149.0
CC	Conetoe_Ck	Conetoe Creek	ConetoeCk	Both	0.18	1941.1	43911.1
FC1	Fishing_Ck	Fishing Creek	FishingCk1	Both	0.19	2094.0	112290.1
FC2	Fishing_Ck	Fishing Creek	FishingCk2	Both	0.2	112290.1	337651.8
SWC	Swift_Ck	Swift Creek	SwiftCk	Both	0.21	871.7	237253.7
STC1A	Stony_Ck	Stony Creek	STC1A	Both	0.22	500.5	95013.1
STC1B	Stony_Ck	Stony Creek	STC1B	Both	0.22	500.5	95013.1
STC1C	Stony_Ck	Stony Creek	STC1C	Both	0.22	500.5	95013.1
STC1D	Stony_Ck	Stony Creek	STC1D	Both	0.22	500.5	95013.1
STC1E	Stony_Ck	Stony Creek	STC1E	Both	0.22	500.5	95013.1
STC1F	Stony_Ck	Stony Creek	STC1F	Both	0.22	500.5	95013.1
STC2	Stony_Ck	Stony Creek	STC2	Both	0.23	95013.1	120420.3

* Were removed from the study based in the complexities of modeling costal influences.

3.2. Data Development

3.2.1. Initial Database Development

The economic database for the TSP analysis was based on data from the North Carolina State FRIS spatial data download site https://sdd.nc.gov/. The data includes building footprint polygons with corresponding points with several attributes that are a combination of tax assessor, census, HAZUS, and survey data, and was updated in 2019. The state of North Carolina completed HAZUS damage calculations for the entire Tar Pamlico River Basin, which were used

to identify high flood risk areas for pre-screening purposes only. The following datasets were the primary sources of structure and land use information:

1. North Carolina FRIS database: building footprint polygons with associated tabular data (GIS format).
2. Microsoft Building outlines shapefile: GIS layer including outlines of buildings and limited building characteristics.
3. Real property database: additional property characteristics such as year built or square footage obtained by using assessors' parcel number (not included in the GIS).

Initially, a GIS-based building outline shapefile was used to identify individual structures and create structure centroids in GIS. FRIS characteristics were then linked to the individual structures based on the centroids' locations relative to the parcel boundaries. The resulting structure inventory database includes all existing information for each parcel attributed to each structure.

The FRIS points were utilized to create a base structure inventory. These structure points were then refined through to verify structure location and associated attributes. This involved ensuring points in the structure shapefile actually represented a building. To do this the building footprints along with aerial imagery in Arc GIS Pro and Google Earth Street View were utilized to delete or add points for buildings within a boundary of the FWOP .002 ACE (500-year) with a 150-foot boundary. In addition, this structure iteration included buildings within damage reaches Tar Pam 1, Tar Pam 2, and Jacks Creek. In total, the initial structure inventory was around 11,700 structures which was used to initially screen alternatives. After the three coastal areas were removed, a majority of the structures were removed bringing the total to 4,423.

The edited FRIS inventory included supporting information describing the square footage, occupancy type, condition, number of stories, first floor, estimated year built, and estimated value of the structure. Using the Microsoft Building outlines assigned each structure an estimated square footage for the majority of the structures and the others were estimated using either the county assessor information or the measure tool within geospatial software. In addition, structure attributes such as year built, type, and foundation type were reviewed using the county assessor database for the county the structure was located in.

An additional step sometimes taken in structure placement is to identify the portion of the structure footprint that is prone to flood inundation when the entire structure is not inundated. A structure point is then moved from the center of the footprint to the portion identified. This step may help identify the onset of flooding at specific structures with more precision and accuracy. However, this additional step requires significantly more time to complete, especially if ensuring the portion of the structure being inundated has an opening that would allow for interior flooding that would cause content damages. Due to the geographic scale of this study, as well as the number of structures, this additional step was not feasible. By not taking this step, it's possible that flood damages are being understated, however it is assumed that the uncertainty in water surface elevations provided by hydraulic models and the uncertainty in structure elevations likely capture much of the difference between central point placement and perimeter point placement.

It should be noted that Section 308 of the Water Resources Development Act (WRDA) of 1990 has been observed in this analysis, and structures built since 1991 in the one percent AEP floodplain are assumed to be in compliance with Section 308 due to the study area's

communities' participation and good standing in the National Flood Insurance Program (NFIP). Assessor's data was used to determine the age of the structure.

3.2.2. Damage Categories and Structure Occupancy Types

For the TSP analysis, damage categories were broken out into residential, commercial, public, and industrial. A structure occupancy type in HEC-FDA is a subgroup of damage categories and is the name given to a similar set of structures used to define depth-percent damage functions, first-floor uncertainties, structure value uncertainties, content-to-structure value ratios with uncertainties, and other-to-structure value ratios with uncertainties for each type of structure. A full list of structure occupancy types can be found in Table 11.

3.2.3. Elevations and Stationing

Each structure point in a flood risk management economic analysis is assigned a ground elevation, first-floor elevation, and lowest opening elevation (if it differs from the first-floor elevation). To assign ground elevations, structure points utilized the same terrain grid from the hydraulic modeling. The structure points were projected in the NAD 1983 State Plane North Carolina FIPS 3200 horizontal coordinate system, matching the terrain grid and hydraulic modeling outputs (i.e. water surface elevation grids). Obtaining ground and water surface elevations from the terrain and hydraulic grids is accomplished by superimposing the structure points onto the grid cells and extracting the value from the grid. Using this method requires assigning each structure a unique stream station to link them to the corresponding hydraulic data at the structure's specific location.

First floor elevations were determined using Google Earth Street View with a resolution of 2048p for all structures being damaged. The first-floor elevations for each type of structure are assigned an uncertainty factor, usually expressed as a standard deviation around a normally distributed variable. A standard deviation of the error associated with the first-floor elevation is assigned in HEC-FDA to account for the uncertainty in the height of the first floor above ground.

There are two sources of uncertainty surrounding first-floor elevations: the use of the LiDAR data for the ground elevations and the methodology used to determine the structure foundation heights above ground elevation. The error surrounding the LiDAR data was assumed to be comparable to that of an aerial survey with 2-foot contour intervals. Based on EM 1110-2-1619, 2-foot contour interval aerial surveys have an error of plus or minus 0.59 feet. Errors for 2-foot contour interval aerial surveys were calculated at the 99 percent confidence level, assuming the deviations from the true elevation are normally distributed with zero mean and a standard deviation of 0.3 feet.

Foundation height estimates were made by visual inspection and assigned to structures in one quarter-foot increments based on the number of steps a structure had. Based on this level of precision, it was determined that a 0.25-foot standard deviation would capture the potential uncertainty as it was reasonably assumed that 95 percent of foundation heights would fall between plus or minus a half foot of the surveyed data. In addition, less than 2% of structures were not assessable using Street View and were supplemented with photos obtained from county assessor databases.

The standard deviations for the ground elevations and foundation heights were combined using the square root of sum of square method. This resulted in a 0.39 feet standard deviation for all structures. Table 9 displays the calculations used to combine the uncertainty surrounding the

ground elevations with uncertainty surrounding the foundation height to derive the uncertainty surrounding the first-floor elevations of structures.

Table 9. First Floor Stage Uncertainty Determination

Standard Deviation	Feet
Ground Standard Deviation	0.30
Ground Standard Deviation Squared	0.09
First Floor Standard Deviation	0.25
First Floor Standard Deviation Squared	0.06
Sum of Squared	0.15
Square Root of Sum of Squared = Combined Standard Deviation	0.39

3.2.4. Structure Valuation

USACE guidance requires the use of depreciated replacement value for structure valuation. Following USACE planning guidance, structure valuation for estimating flood damage is based on current depreciated replacement value. Depreciated replacement value is used to reflect the actual value subject to damage as opposed to full replacement cost which would reflect a betterment relative to the actual condition.

The TSP analysis relied on attributes within the edited FRIS inventory, assessor data, Microsoft Building Outlines, and other geospatial tools as a starting point. A detailed 2022 RSMeans analysis of depreciated replacement value was performed on nonresidential and single-family structures. The depreciated replacement value for structures was estimated using structure attribute data (construction material, quality of construction, square footage, and effective age), county assessor data, field observations, and a regional building cost data index for Rocky Mount (0.93 for residential and 0.85 for commercial) was included for the study area. The average square footage for nonresidential structures was 7,150 sq ft with an average value of $1.1 million, single family residences averaged 1,468 sq ft with an average value of $110 thousand, and multifamily residences or apartment complexes averaged 8,500 sq ft with an average value of $1.3 million. The average effective age or build date of nonresidential buildings was 1969, 1979 for single family residential structures, and 1981 for multifamily residences.

In addition to nonresidential and single-family structures, the study area includes 1,162 mobile homes. RSMeans does not have a mobile homes category for valuing each home individually and are not typically valued individually by county assessors as there often multiple mobile homes per parcel. Therefore, valuing each mobile home based on the attribute data was not possible as with other structure types. After comparing mobile homes in the study area to mobile homes in Papio GI study, it was determined to value all structures categorized as mobile home would be valued based on the similarities of the mobile homes valued in Papio and the mobile homes in the Tar Pam watershed. The amount in the Papio GI Study was based on 2018 values of $25,710 per mobile home. Using the Building Cost Index (BCI) published by Engineering News-Record an index of 1.27 was applied to the 2018 estimates to convert it into FY2022 values ($32,807). This estimate led to a conservative value of a conservative estimate of $30,000 per mobile home.

Even after sampling, there is uncertainty in the depreciated replacement values for structures. The structure value uncertainty initial to TSP analysis was assumed to be 25 percent for all structures. Further analysis was completed prior to TSP to determine structure value uncertainties by occupancy type. In the estimation of structure value, three variables were

considered to have a possible range of values: (1) dollar per square foot, (2) building square footage, and (3) percent of estimated depreciation. As part of the 2015 *American River Watershed General Reevaluation Report*, the Sacramento District used triangular distributions to describe the range of these three variables, then ran a Monte Carlo simulation of a typical structure to derive a coefficient of variation by dividing the standard deviation by the mean. This process was repeated for each occupancy type. In order to validate the applicability of using the structure value errors from the American River study, this approach was reproduced for a small sample of structures in the Tar Pamlico study area that were deemed representative based on professional judgment. This analysis resulted in marginal differences in the error values between representative structures in the two studies. Therefore, it was determined to use the structure values errors from the American River study as they were compiled from a more comprehensive set of structures. The structure value errors imported into the HEC-FDA model for each occupancy type are shown in Table 10 below.

Table 10. Structure Value Errors by Occupancy Type

Occupancy Type	Description	Structure Value Error
R01-R11	Residential Structures	17.00
NR01-NR02	Clothing Retail Store	12.00
NR03-NR04	Convenience Store	12.00
NR05-NR06	Correctional Facility	12.00
NR07-NR08	Electronic Retail Store	12.00
NR09-NR10	Fast Food Restaurant	12.00
NR11-NR12	Furniture Retail Store	12.00
NR13-NR14	Grocery	12.00
NR15-NR16	Hospital	12.00
NR17-NR18	Hotel	12.00
NR19-NR20	Industrial Light Manufacturing	12.00
NR21-NR22	Medical Office	11.00
NR23-NR24	Non-Fast-Food Restaurant	12.00
NR25-NR26	Office Building	13.00
NR27-NR28	Protective Services	14.00
NR29-NR30	Recreational Facility	12.00
NR31-NR32	Religious Facility	12.00
NR33-NR34	School	14.00
NR35-NR36	Service Station	15.00
NR37-NR38	Warehouse, Non-Refrigerated	14.00
NR39-NR40	Warehouse, Refrigerated	14.00

3.2.5. Contents Valuation

The generic content depth-damage curves for residential structures provided in the Economic Guidance Memorandum (EGM) 04-01, *Generic Depth-Damage Relationships for Residential Structures with Basements*, October 2003, were used to represent the content depth-damage functions for residential structures in HEC-FDA. Using these relationships, it is not necessary to define the value of contents for a residence in HEC-FDA. Uncertainty was applied to the content-to-structure value ratios (CSVR) as specified in EM 1110-2-1619 to account for

variation among structures within each occupancy type. Based on guidance from EGM 04-01, the error associated with the content/structure value is left blank, which implies that the error in CSVR is part of the content depth-damage function. For purposes of estimating investment only, residential contents (sans mobile homes) were valued at 50 percent of structure value. For mobile homes, which are not included in the IWR functions, a CSVR of 139 percent is used. This CSVR was taken from the 2006 *Final Report, Depth-Damage Relationships for Structures, Contents, and Vehicles and Content-to-Structure Value Ratios (CSVR) in Support of the Donaldsonville to the Gulf, Louisiana, Feasibility Study*.

CSVRs for nonresidential structures derived for the 2015 *American River Watershed General Reevaluation Report* by the Sacramento District were utilized for this study. As part of the report, the Sacramento District completed an expert elicitation to develop CSVRs. Upon review of these CSVRs, the Omaha District determined that they were an appropriate fit for this study as it was reasonably assumed that nonresidential contents would be similar nationwide. Table 11 below lists the occupancy types, respective CSVRs, and uncertainty values used in this analysis.

Table 11. Occupancy Types and Content-to-Structure Value Ratios

Occupancy Code	Description	CSVR	CSVR Error
R01-R06, R08-R11	Single and Multi-Family Residential	100.0	0.0
R07	Mobile Homes	139.0	0.0
NR01-NR02	Clothing Retail Store	66.8	12.6
NR03-NR04	Convenience Store	54.4	6.6
NR05-NR06	Correctional Facility	45.4	8.3
NR07-NR08	Electronic Retail Store	66.8	12.6
NR09-NR10	Fast Food Restaurant	54.6	8.2
NR11-NR12	Furniture Retail Store	72.0	14.4
NR13-NR14	Grocery	138.4	17.5
NR15-NR16	Hospital	120.1	0.0
NR17-NR18	Hotel	89.5	13.2
NR19-NR20	Industrial Light Manufacturing	244.0	55.1
NR21-NR22	Medical Office	192.3	25.2
NR23-NR24	Restaurant (Non-Fast-Food)	174.3	34.7
NR25-NR26	Office Building	44.4	9.2
NR27-NR28	Protective Services	45.4	8.3
NR29-NR30	Recreational Facility	171.9	356.4
NR31-NR32	Religious Facility	26.1	4.7
NR33-NR34	School	50.0	11.3
NR35-NR36	Service Station	251.1	46.3
NR37-NR38	Warehouse, Non-Refrigerated	116.3	25.3
NR39-NR40	Warehouse, Refrigerated	116.3	25.3

3.2.6. Depth-Damage Functions: Residential

Depth-damage curves relate the percent of structure and content value that is damaged given the depth of inundation. As noted above, the depth-damage functions developed for EGM 04-01, *Generic Depth-Damage Relationships for Residential Structures with Basements*, October 2003, were used for residential structures.

This EGM summarized data developed by the Institute for Water Resources (IWR) using post-flood residential damage claim records provided by the Federal Emergency Management Agency

(FEMA). The functions account for both structural and content damage to homes with and without basements.

A depth-damage curve for mobile homes is not included in EGM 04-01. Instead, the damage curve for mobile homes is based on the short duration freshwater depth-damage function developed as part of the Donaldsonville to the Gulf, Louisiana, Feasibility Study. It is reasonable to assume that mobile homes across the nation would face similar depth-damage functions from various depths of freshwater flooding and would also have similar CSVRs.

3.2.7. Depth-Damage Functions: Nonresidential

The depth-damage functions used for nonresidential structures and contents are based on the data presented in the 2008 URS Group draft report *Solicitation of Expert Opinion Depth-Damage Function Calculations for the Benefit-Cost Analysis Tool*. Twenty-one core nonresidential structure types were evaluated by a panel of experts from across the United States. The resulting data from the panel included nationally relevant depth-damage functions for use in estimating the value of damages from flooding to commercial, industrial, and public structures nationwide. For nonresidential structures, depth-damage function uncertainties are expressed as a triangular distribution. These curves have been used in numerous studies including Papillion Creek GI and Mill Creek GI studies. These studies have similar flooding and building characteristics and were determined to be appropriate to use in this study.

3.2.8. Other Potential Damage Categories

In addition to damages to structures and their contents, various other damages may occur in a flood event, including cleanup costs, other public assistance, and damages to vehicles. This section explains these categories in more detail but are not included in the TSP analysis.

3.2.9. Vehicles

Historical floods, including Hurricane Florence, inundated vehicles with mud and water and caused many automobile owners to file with their insurance companies as the hurricane caused total losses of vehicles. In just the first week after Hurricane Florence, State Farm Insurance received 2,400 automobile claims related to the storm in North Carolina.[2]

Based on 2021 American Community Survey data, there are, on average, approximately two vehicles per single family residential household in North Carolina. Although historical events have damaged vehicles in the past, they were not included in the TSP analysis and would be unlikely to change the decision-making process.

3.2.10. Emergency Costs, Disaster Relief, and Infrastructure Damages

Emergency costs and disaster relief include a wide range of flood impact costs, including emergency services costs, flood fighting costs, avoidance costs, debris cleanup, and damage to other infrastructure items otherwise not included in the damage analysis. Estimates of emergency costs at different magnitude flood events and corresponding damage functions are typically determined based on historical flood fight cost data for the local community or study area. The TSP analysis does not include emergency costs and disaster relief, but based on previous USACE studies is estimated to be around 10 percent of structure and content damages.

[2] https://www.npr.org/2018/09/26/651517127/florence-floodwaters-total-thousands-of-cars-stranding-locals

3.3. Final Economic Database

Completion of the tasks discussed above ultimately results in an economic structure inventory. The structure inventory is subsequently used for several purposes, but initially it serves as the basis for estimates of investment in the study area.

3.3.1. Study Area Investment

Investment for the Tar Pamlico Watershed study area is summarized in Table 12 by stream. The investment values below only include structures, contents, and vehicles. Total study area investment was estimated at around $3.3 billion. Investment along the Tar Pamlico River accounted for approximately 88.4 percent of the total value, respectively.

Table 12. Total Investment by Stream

Property Type	Conetoe Creek	Fishing Creek	Green Mill Run	Stony Creek	Swift Creek	Tar Pamlico	Total
Residential							
Total Structures	10	27	21	249	48	3,139	3,494
Value – Structures	$1,291	$3,021	$3,980	$44,509	$4,931	$326,796	$384,529
Value – Contents	$1,327	$3,045	$4,003	$44,347	$5,142	$339,941	$397,804
Value – Total	$2,618	$6,066	$7,983	$88,855	$10,073	$666,737	$782,332
Commercial							
Total Structures	2	0	11	105	2	487	607
Value – Structures	$649	$0	$4,519	$105,077	$413	$367,713	$478,371
Value – Contents	$511	$0	$5,055	$93,416	$540	$401,674	$501,196
Value – Total	$1,160	$0	$9,574	$198,493	$952	$769,387	$979,567
Industrial							
Total Structures	12	2	0	4	15	222	255
Value – Structures	$662	$44	$0	$1,431	$13,485	$244,356	$259,978
Value – Contents	$770	$51	$0	$3,456	$29,368	$460,477	$494,122
Value – Total	$1,431	$95	$0	$4,887	$42,853	$704,832	$754,100
Public							
Total Structures	0	4	3	1	1	58	67
Value – Structures	$0	$2,569	$24	$1,481	$1,338	$356,856	$362,269
Value – Contents	$0	$671	$20	$672	$349	$421,422	$423,134
Value – Total	$0	$3,239	$44	$2,153	$1,688	$778,279	$785,403
Total							
Total- Structures	24	33	35	359	66	3,906	4,423
Total-Value	$5,209	$9,400	$17,602	$294,389	$55,567	$2,919,235	$3,301,402
% Total by Stream	0.16%	0.28%	0.53%	8.92%	1.68%	88.42%	100.00%

Notes: $1,000s; FY23 price level

4. DAMAGE ANALYSIS MODELING

Damages modeled in HEC-FDA are the basis for calculating net National Economic Development (NED) benefits. The structure inventory (including values, elevations and depth-damage functions, and uncertainty parameters) for the study area were input into HEC-FDA along with sets of water surface profiles for damage computations. Damages in the analysis consist of physical inundation damages to commercial, industrial, residential, and public structures as well as respective contents.

4.1. Model Hydraulic and Hydrologic Inputs

Water surface profiles were modeled in HEC-RAS for the future without project (FWOP) and existing without-project (WOP) conditions for analysis years 2023 and 2073. Events included in the water surface profiles include the 0.5, 0.2, 0.1, 0.04, 0.02, 0.01, 0.004, and 0.002 AEP events. Water surface profiles were developed for the base and future years for the without-project conditions.

Gridded raster data from HEC-RAS was spatially joined to structures using ArcGIS Pro 3.1. Each grid cell represents a numbered "station" that is associated with a structure in HEC-FDA. In addition, water surface profiles for reach index stations were included in HEC-FDA. Reaches were spatially joined to structures in ArcGIS and the geospatial reach assignment was used in HEC-FDA to aggregate damages.

Geotechnical functions were not developed for the FDA models since there are no reaches with a potential levee failure. Water surface profiles were developed in HEC-RAS for the future without (FWOP) and future with-project (FWP) conditions. These included profiles for the 0.5, 0.2, 0.1, 0.04, 0.02, 0.01, 0.004, and 0.002 AEP events.

4.2. Exceedance Probability-Discharge Functions

For a flood or storm event with a given probability of occurrence, there is uncertainty regarding what the resulting discharge will be at a specific location along the stream or river. The reliability of frequency-discharge estimates is directly linked to the historical record of stream gauge data available. In cases where records are small or incomplete, the associated uncertainty is greater than in circumstances where lengthy records of observed data are available. To address this uncertainty, an analytical or graphical method is typically used to determine statistical distributions of discharge for a range of probabilities at index stations throughout the floodplain. According to the HEC-FDA manual, if an exceedance probability-discharge function can be fitted by a Log Pearson Type III distribution, it is considered an analytical function. When a function does not fit a Log Pearson Type III distribution, a graphical function is recommended. The TSP screening, all exceedance probability-discharge functions were analytical.

For the TSP screening, exceedance probability-discharge uncertainty was estimated based upon an equivalent record length as illustrated in Table 13 for each reach based on input from the hydrologic engineer that was developed in accordance with EM 1110-2-1619. While consideration was given to changing the equivalent record length for the future year, analysis of the hydrology showed that the change would be small and that the exceedance probability-discharge functions already incorporate a relatively high amount of uncertainty. More information can be found in Appendix A, Hydrology.

Table 13. Equivalent Record Length

Economic Reach	Stream	Description	Index Station	Equivalent Record Length
CC	Conetoe Creek	ConetoeCk	0.18	44
FC1	Fishing Creek	FishingCk1	0.19	105
FC2	Fishing Creek	FishingCk2	0.2	105
GM	Green Mill Run	GreenMill	0.17	50
STC1A	Stony Creek	STC1A	0.22	15
STC1B	Stony Creek	STC1B	0.22	15
STC1C	Stony Creek	STC1C	0.22	15
STC1D	Stony Creek	STC1D	0.22	15
STC1E	Stony Creek	STC1E	0.22	15
STC1F	Stony Creek	STC1F	0.22	15
STC2	Stony Creek	STC2	0.23	15
SWC	Swift Creek	SwiftCk	0.21	56
TP10A	Tar Pamlico	TarPam10A	0.1	39
TP10B	Tar Pamlico	TarPam10B	0.1	39
TP10C	Tar Pamlico	TarPam10C	0.1	39
TP10D	Tar Pamlico	TarPam10D	0.1	39
TP11	Tar Pamlico	TarPam11	0.11	15
TP12	Tar Pamlico	TarPam12	0.12	56
TP13	Tar Pamlico	TarPam13	0.13	56
TP14	Tar Pamlico	TarPam14	0.14	56
TP15	Tar Pamlico	TarPam15	0.15	80
TP3A	Tar Pamlico	TarPam3A	0.03	114
TP3B	Tar Pamlico	TarPam3B	0.03	114
TP3C	Tar Pamlico	TarPam3C	0.03	114
TP3D	Tar Pamlico	TarPam3D	0.03	114
TP3E	Tar Pamlico	TarPam3E	0.03	114
TP3F	Tar Pamlico	TarPam3F	0.03	114
TP4	Tar Pamlico	TarPam4	0.04	123
TP5	Tar Pamlico	TarPam5L	0.05	123
TP6	Tar Pamlico	TarPam6R	0.06	123
TP7	Tar Pamlico	TarPam7	0.07	15
TP8	Tar Pamlico	TarPam8	0.08	15
TP9A	Tar Pamlico	TarPam9A	0.09	43
TP9B	Tar Pamlico	TarPam9B	0.09	43
TP9C	Tar Pamlico	TarPam9C	0.09	43
TP9D	Tar Pamlico	TarPam9D	0.09	43

4.3. Stage-Discharge Functions

For a given level of discharge, there is uncertainty regarding what the resulting water surface elevation will be at a given location. Factors contributing to this uncertainty include, but are not limited to, bed forms, water temperatures, debris or other obstructions, unsteady flow effects, variation in hydraulic roughness with season, sediment transport, channel scour or deposition, or

changes in channel shape during or as a result of flood events. To address this uncertainty, standard deviation estimates are developed for stages associated with a range of discharges at index stations throughout the floodplain.

Further information is available in Appendix B, Hydraulics. The standard deviations for all streams are presented in Table 14 below.

Table 14. Stage Standard Deviations by Reach

Economic Reach	Hydraulic Reach	Stream	Description	Index Station	Stage Standard Deviation at 0.01 AEP (feet)
TP3A	Tar_Pamlico2	Tar Pamlico	TarPam3A	0.03	1.5
TP3B	Tar_Pamlico2	Tar Pamlico	TarPam3B	0.03	1.5
TP3C	Tar_Pamlico2	Tar Pamlico	TarPam3C	0.03	1.5
TP3D	Tar_Pamlico2	Tar Pamlico	TarPam3D	0.03	1.5
TP3E	Tar_Pamlico2	Tar Pamlico	TarPam3E	0.03	1.5
TP3F	Tar_Pamlico2	Tar Pamlico	TarPam3F	0.03	1.5
TP4	Tar_Pamlico2	Tar Pamlico	TarPam4	0.04	1.5
TP5	Tar_Pamlico2	Tar Pamlico	TarPam5L	0.05	1.5
TP6	Tar_Pamlico2	Tar Pamlico	TarPam6R	0.06	1.5
TP7	Tar_Pamlico2	Tar Pamlico	TarPam7	0.07	1.5
TP8	Tar_Pamlico3	Tar Pamlico	TarPam8	0.08	1.5
TP9A	Tar_Pamlico4	Tar Pamlico	TarPam9A	0.09	1.5
TP9B	Tar_Pamlico4	Tar Pamlico	TarPam9B	0.09	1.5
TP9C	Tar_Pamlico4	Tar Pamlico	TarPam9C	0.09	1.5
TP9D	Tar_Pamlico4	Tar Pamlico	TarPam9D	0.09	1.5
TP10A	Tar_Pamlico5	Tar Pamlico	TarPam10A	0.1	1.41
TP10B	Tar_Pamlico5	Tar Pamlico	TarPam10B	0.1	1.41
TP10C	Tar_Pamlico5	Tar Pamlico	TarPam10C	0.1	1.41
TP10D	Tar_Pamlico5	Tar Pamlico	TarPam10D	0.1	1.41
TP11	Tar_Pamlico5	Tar Pamlico	TarPam11	0.11	1.41
TP12	Tar_Pamlico5	Tar Pamlico	TarPam12	0.12	1.41
TP13	Tar_Pamlico5	Tar Pamlico	TarPam13	0.13	1.41
TP14	Tar_Pamlico5	Tar Pamlico	TarPam14	0.14	1.41
TP15	Tar_Pamlico5	Tar Pamlico	TarPam15	0.15	1.41
GM	Green Mill Run	Green Mill Run	GreenMill	0.17	1.50
CC	Conetoe_Ck	Conetoe Creek	ConetoeCk	0.18	1.5
FC1	Fishing_Ck	Fishing Creek	FishingCk1	0.19	2.89
FC2	Fishing_Ck	Fishing Creek	FishingCk2	0.2	2.89
SWC	Swift_Ck	Swift Creek	SwiftCk	0.21	1.68
STC1A	Stony_Ck	Stony Creek	STC1A	0.22	1.5
STC1B	Stony_Ck	Stony Creek	STC1B	0.22	1.5
STC1C	Stony_Ck	Stony Creek	STC1C	0.22	1.5
STC1D	Stony_Ck	Stony Creek	STC1D	0.22	1.5
STC1E	Stony_Ck	Stony Creek	STC1E	0.22	1.5
STC1F	Stony_Ck	Stony Creek	STC1F	0.22	1.5
STC2	Stony_Ck	Stony Creek	STC2	0.23	1.5

4.4. Levee Features

One reach in the Tar Pamlico (TP5L) watershed has an existing levee that offers protection and is currently in the process of being raised. The levee was not an input into the FDA modeling since it was reflected in the hydraulic modeling.

5. EXISTING AND FUTURE WITHOUT-PROJECT CONDITIONS

This section describes the analysis of damages that are expected to occur in the absence of a Federal project to address flood risks in the study area. These damages include damages to structure and structure contents and other damages, which include vehicle damages and cleanup and emergency costs associated with flooding. WOP flooding also impacts OSE, which includes loss of life, and is quantified in this section.

HEC-FDA software was used to calculate economic damages for this study. Expected annual flood damages are the basis for calculating WP benefits and are crucial to the evaluation of the project. EAD are equal to the mean of all possible values of damage that are derived through Monte Carlo sampling of discharge-exceedance probability relationships, stage-discharge relationships, and stage-damage relationships and their uncertainties. This section presents EAD, and as the result of time-dependent variance in hydrologic, hydraulic, and economic data, the values presented are estimates only. Uncertainty parameters for the exceedance-probability relationship and stage-discharge relationship were developed by H&H engineers as detailed in Section 4.3.

As discussed above, there is little distinction in the TSP analysis between existing, base year, and future conditions. Water surface profiles are the only difference between existing, base year, and future conditions. The other hydrologic/hydraulic data are considered stable over the period of analysis, as is the economic structure inventory. The results summarized in this section therefore represent existing conditions and future without-project conditions.

5.1. FWOP Flooding Characteristics

The WOP analysis and results are based predominantly on estimates of the flooding extent, the depth of flooding, and the property that may be damaged from flooding within a particular area. Flood extents for the 0.002 AEP event for each area on the Tar Pamlico watershed are shown below in Figure 17.

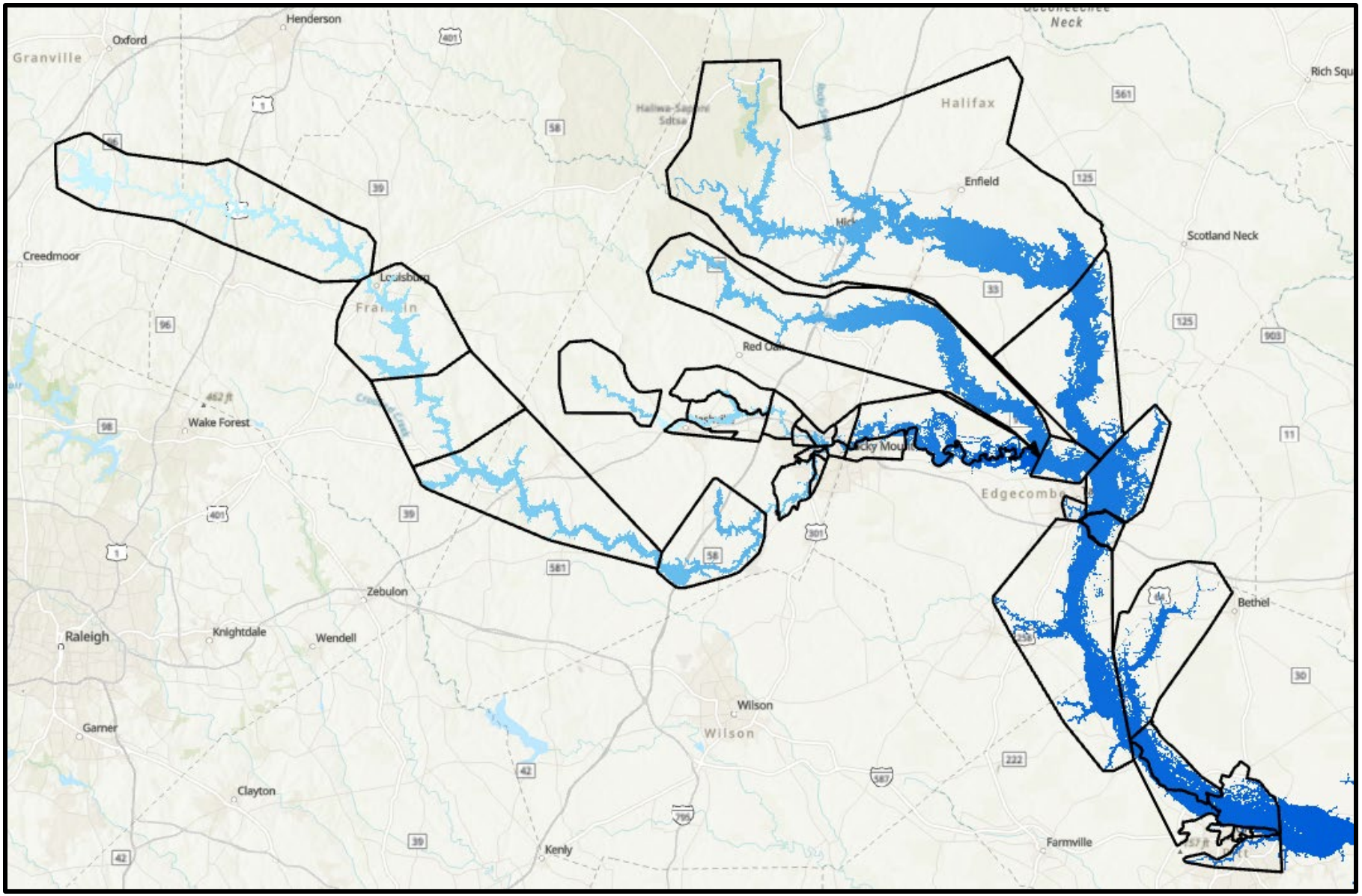

Figure 17. Tar Pamlico 0.002 AEP FWOP Flood Extent

Table 15 shows the average depth on structures by reach for each of the 8 events in the FWOP condition. Note that average depths may decrease at larger events as additional structures begin to see inundation. Section 5.2 will describe the change in magnitude in terms of number of structures and associated damages for the events to give this average depth table additional context.

Table 15. Average Event Depth by Reach

Reach	Average Depth at 0.5 AEP	Average Depth at 0.2 AEP	Average Depth at 0.1 AEP	Average Depth at 0.04 AEP	Average Depth at 0.02 AEP	Average Depth at 0.01 AEP	Average Depth at 0.004 AEP	Average Depth at 0.002 AEP
CC					0.84	2.08	1.39	1.72
FC1						0.47	2.50	1.78
FC2			1.22	4.53	7.23	1.09	2.09	2.02
GM							1.19	1.52
STC1A					0.95	1.88	3.43	3.87
STC1B			0.74	0.89	0.86	1.11	1.18	1.45
STC1C			0.49	0.76	0.76	0.91	1.45	1.41
STC1D							1.17	1.07
STC1E								0.63
STC1F						0.52	0.88	0.72
STC2				0.32	0.95	1.57	2.35	2.90
SWC					1.04	1.64	2.25	2.56
TP10A		0.16	1.25	2.45	3.24	3.12	3.41	3.37
TP10B				0.33	1.22	1.47	2.14	1.36
TP10C		0.95	1.86	2.88	3.56	4.22	3.46	2.94
TP10D				0.12	0.67	1.18	0.67	0.96
TP11								0.86
TP12		1.46	3.26	1.99	3.38	4.89	3.22	5.56
TP13								0.47
TP14					0.92	1.66	1.50	1.69
TP15								
TP3A							0.76	1.69
TP3B					0.66	2.24	2.54	3.29
TP3C						0.56	0.96	1.27
TP3D				0.92	1.45	1.37	0.98	2.07
TP3E					0.63	1.61	3.44	4.86
TP3F		1.59	2.23	1.32	1.81	2.06	1.93	1.75
TP4						0.77	1.16	1.57
TP5				1.19	1.74	2.81	2.96	3.10
TP6						1.60	2.34	1.67
TP7						0.64	1.05	1.49
TP8				0.47	1.26	2.18	3.84	3.39
TP9A					0.14	0.88	1.85	1.60
TP9B							0.47	0.84
TP9C						0.93	1.04	1.19
TP9D		0.62	1.56	1.99	2.34	2.00	2.20	2.37
Total	-	0.81	1.59	1.42	1.76	2.29	2.17	2.23

5.2. AEP Event Damages

Annual exceedance probability (AEP) event damages, sometimes referred to as single-event damages, were computed in HEC-FDA. Single-event damages are useful in that they show the magnitude of consequences, within a consequence area, should a specific flood event occur in that area.

Table 16 below shows the damages that may occur for a range of events within the Tar Pamlico study area; damages are displayed for each reach and tributary. These damage values include structures and contents. For the .01 AEP event, damages in the Tar Pamlico study area are estimated at just over $102 million. The reach with the largest amount of damages at the .01 AEP event is TP5 at just over $40 million. The differences in the WOP and FWOP are based only on uncertainties. Table 12 is presented without uncertainty and therefore represents both the WOP and FWOP.

Table 16. Tar Pamlico Study Area AEP Event Damages WOP and FWOP

Reach	0.1 AEP Structures	0.1 AEP Damages	0.02 AEP Structures	0.02 AEP Damages	0.01 AEP Structures	0.01 AEP Damages	0.002 AEP Structures	0.002 AEP Damages
Conetoe Creek	*0*	*$0*	*2*	*$29*	*2*	*$128*	*21*	*$1,042*
CC	0	$0	2	$29	2	$128	21	$1,042
Fishing Creek	*0*	*$0*	*10*	*$49*	*16*	*$222*	*28*	*$1,310*
FC1	0	$0	0	$0	1	$96	4	$478
FC2	0	$0	10	$49	15	$127	24	$831
Green Mill Run	*0*	*$0*	*2*	*$19*	*4*	*$130*	*22*	*$2,017*
GM	0	$0	2	$19	4	$130	22	$2,017
Stony Creek	*8*	*$116*	*20*	*$3,071*	*43*	*$7,089*	*111*	*$20,854*
STC1A	1	$9	1	$35	2	$50	12	$370
STC1B	2	$44	9	$2,748	15	$5,116	31	$12,847
STC1C	5	$64	9	$286	19	$1,621	34	$6,522
STC1D	0	$0	0	$0	4	$118	16	$718
STC1E	0	$0	0	$0	1	$0	15	$84
STC1F	0	$0	0	$0	1	$178	2	$306
STC2	0	$0	1	$3	1	$5	1	$8
Swift Creek	*0*	*$0*	*7*	*$172*	*16*	*$621*	*60*	*$7,888*
SWC	0	$0	7	$172	16	$621	60	$7,888
Tar Pamlico	*13*	*$1,300*	*256*	*$41,057*	*643*	*$93,888*	*2800*	*$364,304*
TP3A	0	$0	0	$0	0	$0	47	$3,872
TP3B	0	$0	1	$46	1	$78	4	$295
TP3C	0	$0	2	$1	57	$274	546	$8,022
TP3D	0	$0	35	$2,669	39	$3,883	110	$32,726
TP3E	0	$0	1	$0	1	$8	1	$17
TP3F	4	$591	34	$15,971	104	$38,876	678	$153,101
TP4	0	$0	1	$1	10	$463	129	$6,294
TP5	0	$0	157	$18,629	360	$40,330	855	$111,278
TP6	0	$0	0	$0	4	$1,136	30	$10,645
TP7	0	$0	0	$0	18	$303	229	$14,068
TP8	0	$0	4	$963	14	$3,908	31	$7,623
TP9A	0	$0	1	$212	4	$786	5	$2,112
TP9B	0	$0	0	$0	0	$0	1	$34
TP9C	0	$0	0	$0	1	$13	17	$256
TP9D	1	$9	2	$43	5	$721	36	$4,528
TP10A	2	$269	3	$556	4	$662	11	$854
TP10B	0	$0	1	$32	3	$105	11	$1,345
TP10C	2	$342	4	$641	5	$694	8	$961
TP10D	0	$0	1	$210	1	$298	7	$1,186
TP11	0	$0	0	$0	1	$2	10	$88
TP12	3	$88	5	$989	5	$1,200	8	$1,764
TP13	0	$0	0	$0	0	$0	1	$46
TP14	1	$1	4	$92	6	$150	23	$3,151
TP15	0	$0	0	$0	0	$0	2	$37
Total	**21**	**$1,416.08**	**297**	**$44,396.60**	**724**	**$102,078.83**	**3,042**	**$397,414.60**

5.3. Expected Annual Damages

The without-project conditions expected annual damages (EAD) calculated by the HEC-FDA model are summarized in Table 17 and FWOP conditions EAD are summarized in Table 18. WOP and FWOP project damages are similar. Total EAD for the study area is estimated at just over $7.8 million for both the without-project and FWOP conditions. With TP3F contributing the highest amount to total EAD at over $2.3 million for the WOP condition and $2.4 million for the FWOP condition.

Table 17. Without-Project Condition EAD

Reach	Commercial	Industrial	Public	Residential	Total
CC	$11	$20	$0	$6	$37
FC1	$0	$0	$8	$1	$9
FC2	$0	$1	$6	$31	$37
GM	$16	$0	$0	$4	$19
STC1A	$0	$0	$0	$28	$28
STC1B	$966	$45	$0	$6	$1,016
STC1C	$241	$80	$0	$72	$393
STC1D	$4	$0	$0	$25	$29
STC1E	$0	$0	$0	$7	$7
STC1F	$24	$0	$0	$0	$24
STC2	$0	$0	$0	$0	$0
SWC	$7	$114	$0	$42	$164
TP10A	$136	$0	$0	$19	$155
TP10B	$74	$47	$0	$60	$180
TP10C	$145	$15	$0	$52	$212
TP10D	$101	$0	$1	$0	$103
TP11	$0	$0	$0	$2	$2
TP12	$34	$0	$0	$28	$62
TP13	$0	$0	$0	$0	$0
TP14	$25	$0	$103	$20	$148
TP15	$0	$0	$0	$0	$0
TP3A	$14	$0	$0	$15	$28
TP3B	$0	$0	$0	$4	$4
TP3C	$11	$1	$0	$55	$67
TP3D	$306	$0	$0	$64	$370
TP3E	$0	$0	$0	$0	$0
TP3F	$565	$1,591	$125	$109	$2,391
TP4	$11	$20	$15	$16	$62
TP5	$938	$103	$42	$507	$1,591
TP6	$68	$0	$0	$0	$68
TP7	$87	$7	$21	$83	$198
TP8	$86	$90	$0	$4	$181
TP9A	$65	$0	$0	$1	$66
TP9B	$6	$9	$0	$0	$15
TP9C	$0	$5	$0	$5	$11
TP9D	$8	$113	$2	$7	$130
Total	**$3,947**	**$2,265**	**$323**	**$1,275**	**$7,810**

Notes: $1,000s; FY23 price level

Table 18. Future Without-Project Condition EAD

Reach	Commercial	Industrial	Public	Residential	Total
CC	$11	$20	$0	$6	$37
FC1	$0	$0	$8	$1	$9
FC2	$0	$1	$6	$31	$37
GM	$16	$0	$0	$4	$19
STC1A	$0	$0	$0	$28	$28
STC1B	$966	$45	$0	$6	$1,016
STC1C	$241	$80	$0	$72	$393
STC1D	$4	$0	$0	$25	$29
STC1E	$0	$0	$0	$7	$7
STC1F	$24	$0	$0	$0	$24
STC2	$0	$0	$0	$0	$0
SWC	$7	$114	$0	$42	$164
TP10A	$136	$0	$0	$19	$156
TP10B	$77	$50	$0	$62	$189
TP10C	$146	$16	$0	$52	$214
TP10D	$104	$0	$1	$0	$106
TP11	$0	$0	$0	$2	$2
TP12	$34	$0	$0	$28	$63
TP13	$0	$0	$0	$0	$0
TP14	$26	$0	$108	$20	$155
TP15	$0	$0	$0	$0	$0
TP3A	$14	$0	$0	$15	$28
TP3B	$0	$0	$0	$4	$4
TP3C	$11	$1	$0	$55	$67
TP3D	$308	$0	$0	$65	$373
TP3E	$0	$0	$0	$0	$0
TP3F	$571	$1,606	$125	$110	$2,412
TP4	$11	$20	$15	$16	$62
TP5	$938	$103	$42	$507	$1,591
TP6	$68	$0	$0	$0	$68
TP7	$87	$7	$21	$83	$198
TP8	$86	$90	$0	$4	$181
TP9A	$65	$0	$0	$1	$66
TP9B	$6	$9	$0	$0	$15
TP9C	$0	$5	$0	$5	$11
TP9D	$8	$113	$2	$7	$130
Total	**$3,965**	**$2,283**	**$329**	**$1,280**	**$7,856**

Notes: $1,000s; FY23 price level

5.4. Project Performance

WOP and FWOP performance statistics help inform the risk of a flood event for a specific frequency. Three components are indicators of project performance: AEP, long-term exceedance probability (LTEP), and conditional non-exceedance probability (CNEP). AEP is the likelihood flooding occurs in any given year. LTEP is the probability that flooding occurs in a period of 10, 30, or 50 years. CNP, also called assurance, is the probability that flooding does not occur, conditional on a flood event of 0.02, 0.01 and 0.002 frequency occurring.

AEP represents the probability of any event equaling or exceeding a specified stage in any given year. For this study, the target stage is determined by the exceedance of a percentage of the mean damage associated with a specified event. The default criteria of five percent of the total damage for the 0.01 AEP event was used for this study. Table 19 and Table 20 display the project performance statistics by reach under the WOP and FWOP conditions. Project performance statistics in the WOP condition are similar to the FWOP condition as previously state.

Table 19. Tar Pamlico Watershed WOP Performance

Reach	Expected AEP	LTEP 10 Years	LTEP 30 Years	LTEP 50 Years	CNP 2%	CNP 1%	CNP 0.2%
CC	0.06	0.47	0.85	0.96	0.07	0.01	0.00
FC1	0.03	0.24	0.56	0.75	0.57	0.40	0.16
FC2	0.20	0.89	1.00	1.00	0.14	0.07	0.01
GM	0.04	0.33	0.69	0.86	0.37	0.17	0.01
STC1A	0.35	0.99	1.00	1.00	0.02	0.01	0.01
STC1B	0.21	0.91	1.00	1.00	0.10	0.07	0.03
STC1C	0.25	0.94	1.00	1.00	0.07	0.05	0.02
STC1D	0.08	0.55	0.91	0.98	0.43	0.34	0.22
STC1E	0.11	0.70	0.97	1.00	0.29	0.23	0.13
STC1F	0.08	0.55	0.91	0.98	0.43	0.34	0.22
STC2	0.09	0.62	0.94	0.99	0.26	0.16	0.06
SWC	0.07	0.53	0.90	0.98	0.43	0.30	0.12
TP10A	0.37	0.99	1.00	1.00	0.00	0.00	0.00
TP10B	0.06	0.44	0.82	0.94	0.22	0.09	0.01
TP10C	0.40	0.99	1.00	1.00	0.00	0.00	0.00
TP10D	0.13	0.75	0.98	1.00	0.03	0.01	0.00
TP11	0.03	0.27	0.61	0.79	0.53	0.36	0.13
TP12	0.14	0.77	0.99	1.00	0.00	0.00	0.00
TP13	1.00	1.00	1.00	1.00	0.00	0.00	0.00
TP14	0.03	0.24	0.56	0.74	0.43	0.17	0.05
TP15	1.00	1.00	1.00	1.00	0.00	0.00	0.00
TP3A	0.02	0.18	0.44	0.62	0.64	0.30	0.02
TP3B	0.06	0.44	0.82	0.94	0.14	0.03	0.00
TP3C	0.02	0.22	0.52	0.71	0.51	0.21	0.01
TP3D	0.07	0.54	0.90	0.98	0.07	0.01	0.00
TP3E	0.04	0.30	0.66	0.83	0.32	0.10	0.00
TP3F	0.07	0.51	0.88	0.97	0.09	0.02	0.00
TP4	0.02	0.20	0.49	0.67	0.57	0.26	0.01
TP5	0.06	0.44	0.83	0.95	0.12	0.03	0.00
TP6	0.02	0.17	0.44	0.62	0.64	0.29	0.01
TP7	0.03	0.27	0.62	0.80	0.49	0.30	0.07
TP8	0.05	0.41	0.79	0.93	0.28	0.14	0.02
TP9A	0.05	0.41	0.80	0.93	0.41	0.27	0.10
TP9B	1.00	1.00	1.00	1.00	0.00	0.00	0.00
TP9C	0.04	0.31	0.68	0.85	0.53	0.37	0.16
TP9D	0.04	0.32	0.68	0.85	0.52	0.37	0.16

Table 20. Tar Pamlico Watershed FWOP Performance

Reach	Expected AEP	LTEP 10 Years	LTEP 30 Years	LTEP 50 Years	CNP 2%	CNP 1%	CNP 0.2%
CC	0.06	0.47	0.85	0.96	0.07	0.01	0.00
FC1	0.03	0.24	0.56	0.75	0.57	0.40	0.16
FC2	0.20	0.89	1.00	1.00	0.14	0.07	0.01
GM	0.04	0.33	0.69	0.86	0.37	0.17	0.01
STC1A	0.35	0.99	1.00	1.00	0.02	0.01	0.01
STC1B	0.21	0.91	1.00	1.00	0.10	0.07	0.03
STC1C	0.25	0.94	1.00	1.00	0.07	0.05	0.02
STC1D	0.08	0.55	0.91	0.98	0.43	0.34	0.22
STC1E	0.11	0.70	0.97	1.00	0.29	0.23	0.13
STC1F	0.08	0.55	0.91	0.98	0.43	0.34	0.22
STC2	0.09	0.62	0.94	0.99	0.26	0.16	0.06
SWC	0.07	0.53	0.90	0.98	0.43	0.30	0.12
TP10A	0.37	0.99	1.00	1.00	0.00	0.00	0.00
TP10B	0.06	0.45	0.83	0.95	0.23	0.10	0.01
TP10C	0.39	0.99	1.00	1.00	0.00	0.00	0.00
TP10D	0.13	0.76	0.99	1.00	0.04	0.01	0.00
TP11	0.03	0.28	0.62	0.80	0.53	0.36	0.14
TP12	0.14	0.77	0.99	1.00	0.01	0.00	0.00
TP13	1.00	1.00	1.00	1.00	0.00	0.00	0.00
TP14	0.03	0.24	0.56	0.75	0.44	0.18	0.06
TP15	1.00	1.00	1.00	1.00	0.00	0.00	0.00
TP3A	0.02	0.18	0.44	0.62	0.63	0.30	0.02
TP3B	0.06	0.44	0.82	0.94	0.14	0.03	0.00
TP3C	0.02	0.22	0.52	0.71	0.51	0.21	0.01
TP3D	0.08	0.54	0.91	0.98	0.07	0.01	0.00
TP3E	0.04	0.30	0.66	0.84	0.31	0.10	0.00
TP3F	0.07	0.51	0.88	0.97	0.09	0.02	0.00
TP4	0.02	0.20	0.49	0.67	0.56	0.26	0.01
TP5	0.06	0.44	0.83	0.95	0.12	0.03	0.00
TP6	0.02	0.17	0.44	0.62	0.64	0.29	0.01
TP7	0.03	0.27	0.62	0.80	0.49	0.30	0.07
TP8	0.05	0.41	0.79	0.93	0.28	0.14	0.02
TP9A	0.05	0.41	0.80	0.93	0.41	0.27	0.10
TP9B	1.00	1.00	1.00	1.00	0.00	0.00	0.00
TP9C	0.04	0.31	0.68	0.85	0.53	0.37	0.16
TP9D	0.04	0.32	0.68	0.85	0.52	0.37	0.16

5.5. Without-Project Equivalent Annual Damages

This section presents equivalent annual damages for the WOP condition. To obtain equivalent annual damages, expected annual damages are interpolated between existing and future years and discounted back to present value in HEC-FDA. As previously noted, existing WOP and FWOP EAD estimates are similar, and therefore equivalent annual damages are near FWOP EAD estimates. Equivalent damages were calculated using the current federal discount rate of 2.5 percent.

Table 21. WOP Equivalent Annual Damages 2.5%

Reach	Commercial	Industrial	Public	Residential	Total
CC	$10.91	$19.83	-	$6.07	$36.81
FC1	-	-	$7.80	$1.06	$8.86
FC2	-	$0.75	$5.65	$30.88	$37.28
GM	$15.69	-	$0.01	$3.52	$19.21
STC1A	$0.25	-	-	$28.00	$28.25
STC1B	$965.66	$44.98	-	$5.73	$1,016.37
STC1C	$240.91	$80.00	-	$72.23	$393.14
STC1D	$3.90	-	-	$24.92	$28.82
STC1E	$0.02	-	-	$6.67	$6.69
STC1F	$24.10	-	-	$0.40	$24.50
STC2	-	$0.35	-	-	$0.35
SWC	$6.57	$114.45	$0.34	$42.32	$163.67
TP10A	$135.92	-	-	$19.12	$155.03
TP10B	$75.19	$47.92	-	$60.61	$183.72
TP10C	$145.23	$15.61	-	$51.87	$212.71
TP10D	$102.63	$0.37	$0.98	$0.11	$104.09
TP11	-	-	-	$1.67	$1.67
TP12	$34.17	$0.11	-	$28.34	$62.62
TP13	-	-	-	$0.18	$0.18
TP14	$25.65	-	$105.17	$19.91	$150.73
TP15	-	-	-	$0.20	$0.20
TP3A	$13.53	-	-	$14.79	$28.32
TP3B	-	-	-	$4.47	$4.47
TP3C	$11.09	$0.74	$0.03	$54.97	$66.83
TP3D	$306.54	$0.26	-	$64.24	$371.04
TP3E	-	$0.27	-	-	$0.28
TP3F	$567.39	$1,597.01	$124.90	$109.61	$2,398.92
TP4	$10.96	$20.38	$14.70	$15.98	$62.02
TP5	$937.86	$103.00	$42.44	$507.43	$1,590.73
TP6	$67.88	$0.12	$0.02	$0.15	$68.17
TP7	$87.14	$7.32	$20.57	$83.38	$198.41
TP8	$85.95	$90.34	-	$4.23	$180.52
TP9A	$65.06	-	-	$1.38	$66.44
TP9B	$5.99	$9.17	-	-	$15.16
TP9C	$0.08	$5.48	$0.24	$5.38	$11.19
TP9D	$7.93	$113.43	$2.27	$6.84	$130.46
Total	**$3,954.20**	**$2,271.89**	**$325.11**	**$1,276.68**	**$7,827.87**

Notes: $1,000s; FY23 price level

5.6. Other Social Effects Without-Project Condition

Social vulnerability under the OSE account evaluates the beneficial and adverse impacts water resource plans have on social well-being. This section discusses how the WOP condition affects residents within the study area. Social vulnerability is based on a qualitative assessment, which largely relies on general consequences of flooding caused by natural disasters. Therefore, this section is not intended to comprehensively or quantitatively describe each aspect of social

vulnerability and is limited to logic that is based on previous flood events. A more comprehensive analysis incorporating tools available to identify the socially vulnerable populations in the study area is presented in Section 9.

5.6.1. Health and Safety

The health and safety of a community can be negatively impacted by flooding, and these effects can continue for many years after the event. Elderly individuals can be the most affected by flooding, especially regarding their health, longevity, and safety. Studies have shown that older residents are more likely to experience depressive symptoms after natural disasters, especially when their community lacks cohesion because of these events. [3] However, all individuals are affected by flooding disasters and may experience major psychological trauma[4] that can include post-traumatic stress disorder, anxiety, and depression[5] and worsen existing related psychological conditions.[6]

Flooding can also present a serious hazard to residents' safety outside of psychological conditions. Flooding continues to claim many lives each year as people are unable to evacuate or climb to safety. When flood waters threaten a community, local officials disseminate a warning to their residents who must first receive such a warning, understand its implications, and act quickly. It is generally assumed residents can get out of harm's way by evacuating (on foot, car, or likewise) or by climbing to higher elevation (like ascending to the second or third level of a home). These options both carry risks. Physical evacuation can lead to overcrowded roads where fleeing residents are left trapped in their cars if flood waters arrive. Climbing to a higher elevation may provide some level of safety from floodwaters; however, residents are left stranded in their structures until the floodwaters recede. Further, elderly residents may have trouble climbing stairs/ladders that can offer protection from rising floodwaters.

5.6.2. Economic Vitality

Disruption to the economy, business losses, and loss of wages may negatively impact the local economy for some time after flooding and contribute to a gradual deterioration of the economy.[7] Many of the reaches in the study area are characterized by high poverty rates and unemployment, as shown in tables and figures in Section 2.2. Further, many of these communities do not have large employers that give residents a reason to remain in the community. These communities may not only see stagnant growth, but some may potentially experience declining growth. North Carolina's economy has maintained a strong growth rate, so residents may relocate to other areas within the state to avoid flooding. The communities they leave behind are more likely to see stagnant growth as residents choose other regions with greater housing and occupational stability.

[3] Chao, S. F. (2016). Outdoor activities and depressive symptoms in displaced older adults following natural disaster: Community cohesion as mediator and moderator. Aging & mental health, 20(9), 940-947.
[4] Fernandez A, Black J, Jones M, et al. (2015). Flooding and mental health: a systematic mapping review. PloS One.;10(4):e0119929.
[5] Goldmann E, Galea S. (2014) Mental health consequences of disasters. Ann. Rev Public Health. 35:169-183.
[6] Hetherington, E., McDonald, S., Wu, M., & Tough, S. (2018). Risk and protective factors for mental health and community cohesion after the 2013 Calgary flood. Disaster medicine and public health preparedness, 12(4), 470-477.
[7] Cavallo, E., Galiani, S., Noy, I., & Pantano, J. (2013). Catastrophic natural disasters and economic growth. Review of Economics and Statistics, 95(5), 1549-1561.

Residents who believe that they are greatly affected by a flooding disaster are more likely to have a reduced perception of their community's recovery.[8] In this case, the effects of hazards within the physical environment translate into negative perceptions about the local economy. This can lead to a downward spiral among residents who feel trapped in their communities.

5.6.3. Social Connectedness

As the community deals with a disaster, they may lose or gain social connectedness. However, this can vary depending on the existing social structure of the community. Communities with many close bonds may have higher cohesion following a flood. At the individual level, those who remain in the community to volunteer and participate are more likely to experience positive community cohesion.[9] Conversely, residents who were marginalized or did not participate prior to a flood are not likely to remain in the community and help build this community cohesion. In areas with many transient workers or impoverished residents, these effects will be especially pronounced.

Organizations such as volunteer groups, non-profits, and community outreach programs can help to mitigate the negative effects of flooding on social connectedness. This allows community members to connect as they begin the rebuilding process. Many of the impact areas within this study have a variety of these programs in place that could be a source of support following a flood. For example, the Rocky Mount area has several of these organizations including the Salvation Army, the Food Bank of Central and Eastern North Carolina. However, in areas with more persons living below the poverty level, there are fewer of these programs.

5.6.4. Identity

Residents' identity with their community can suffer from the effects of flooding. When residents are detached prior to a disaster, they are more likely to lose any identity they had with their community.[10] However, in communities that have strong bonds prior to flooding, these ties are at risk of being frayed by stress and disagreement over post-disaster decisions. While a serious flooding event may cause residents to question their identity to the community, living in a floodplain with the constant threat of flooding can cause detachment. The constant threat of flooding means community members are aware that their homes and/or places of work may be temporary, leading residents to view their positions in the community as temporary.

5.6.5. Social Vulnerability and Resiliency

Socially vulnerable populations include those who are demographically or socioeconomically at a disadvantage relative to the average population. These social groups are more susceptible to the adverse impacts of natural disasters, including experiencing disproportionate death, injury, loss, or disruption of livelihood.[11] Resiliency, or the capacity to recover quickly from a flood event, may be lower for socially vulnerable populations. As discussed above, the elderly have an increased risk of developing depressive disorders from flooding events while at the same time,

[8] Bergstrand, K., & Mayer, B. (2020). "The Community Helped Me:" Community Cohesion and Environmental Concerns in Personal Assessments of Post-Disaster Recovery. Society & Natural Resources, 33(3), 386-405.
[9] Ludin, S. M., Rohaizat, M., & Arbon, P. (2019). The association between social cohesion and community disaster resilience: A cross-sectional study. Health & social care in the community, 27(3), 621-631.
[10] Tapsell, S. M., Penning-Rowsell, E. C., Tunstall, S. M., & Wilson, T. L. (2002). Vulnerability to flooding: health and social dimensions. Philosophical transactions of the royal society of London. Series A: Mathematical, Physical and Engineering Sciences, 360(1796), 1511-1525.
[11] FEMA 2021. "Social Vulnerability". https://hazards.fema.gov/nri/social-vulnerability

the elderly are more likely to struggle with evacuation and post-flood cleanup. Young children, while not as physically limited as elderly residents, may also experience psychological hardships because of damage caused by flooding events. The tables in Section 2.2 show the percent minority and households below the federal poverty line within the study area. These populations face more hardship when rebuilding from disasters. Such communities are especially vulnerable to economic changes and social fraying.

5.6.1. Summary of Baseline Profile

These conditions create a qualitative account of the social issues at stake without any flood reduction measures. Residents in the floodplain will be impacted in nearly every aspect of their lives because of flooding events. Further, simply living in a floodplain with the constant threat of flooding can cause lasting effects personally and economically. Community and personal health are intertwined, and when flooding threatens one aspect, both suffer. There are several tools USACE uses to analyze disadvantaged communities. For this analysis, CEQ Tool and EJScreen were utilized to understand the disadvantaged populations in the study area.

5.6.2. CEQ Tool

In January of 2021, President Biden issued Executive Order 14008 directing the Council on Environmental Quality (CEQ) to develop a new tool that characterizes environmental justice considerations. This tool—the Climate and Economic Justice Screening Tool (CEJST) — provides indicators of burdens in eight categories: climate change, energy, health, housing, legacy pollution, transportation, water and wastewater, and workforce development using 2010 census tract boundaries. A community is highlighted as disadvantaged on the CEJST map if it is in a census tract that is (1) at or above the threshold for one or more environmental, climate, or other burdens, and (2) at or above the threshold for an associated socioeconomic burden. These categories and thresholds are laid out in Table 22.

Table 22. CEQ Tool Categories and Threshold Criteria

	Categories							
	Climate Change	Energy	Health	Housing	Legacy Pollution	Transportation	Water and Wastewater	Workforce Development
Total Threshold Criteria	Expected agriculture loss rate	Energy Costs	Asthma	Housing Cost	Abandoned mine land	Diesel particulate matter exposure	Underground storage tanks and releases	Linguistic isolation
	Expected building loss rate	PM 2.5 in the Air (Air Quality)	Diabetes	Lack of Green Space	Formerly Used Defense Sites	Transportation barriers	Wastewater discharge	Low median income
	Expected population loss rate	And Low Income	Heart Disease	Lack of Indoor Plumbing	Proximity to hazardous waste facilities	Traffic proximity and volume	And Low Income	Poverty
	Projected flood risk		Low Life Expectancy	Lead Paint	Proximity to Risk Management Plan facilities	And Low Income		Unemployment
	Projected wildfire risk		And Low Income	And Low Income	Proximity to Superfund sites			Less Than Highschool Education
	And Low Income				And Low Income			

The tool uses this information to identify communities that are experiencing these burdens and are thus disadvantaged because they are overburdened and underserved. In the study area there are a total of 63 census tracts of which 40 are identified as at least exceeding one threshold of the categories presented in the table above. Of these 63 census tracts in the study area only 43 have structures being inundated at the 0.002 AEP. Out of these 43 tracts 32 exceed at least one threshold in a category. The are tracts within the study area that are considered disadvantaged by one or more of the burden categories as shown in Figure 45.

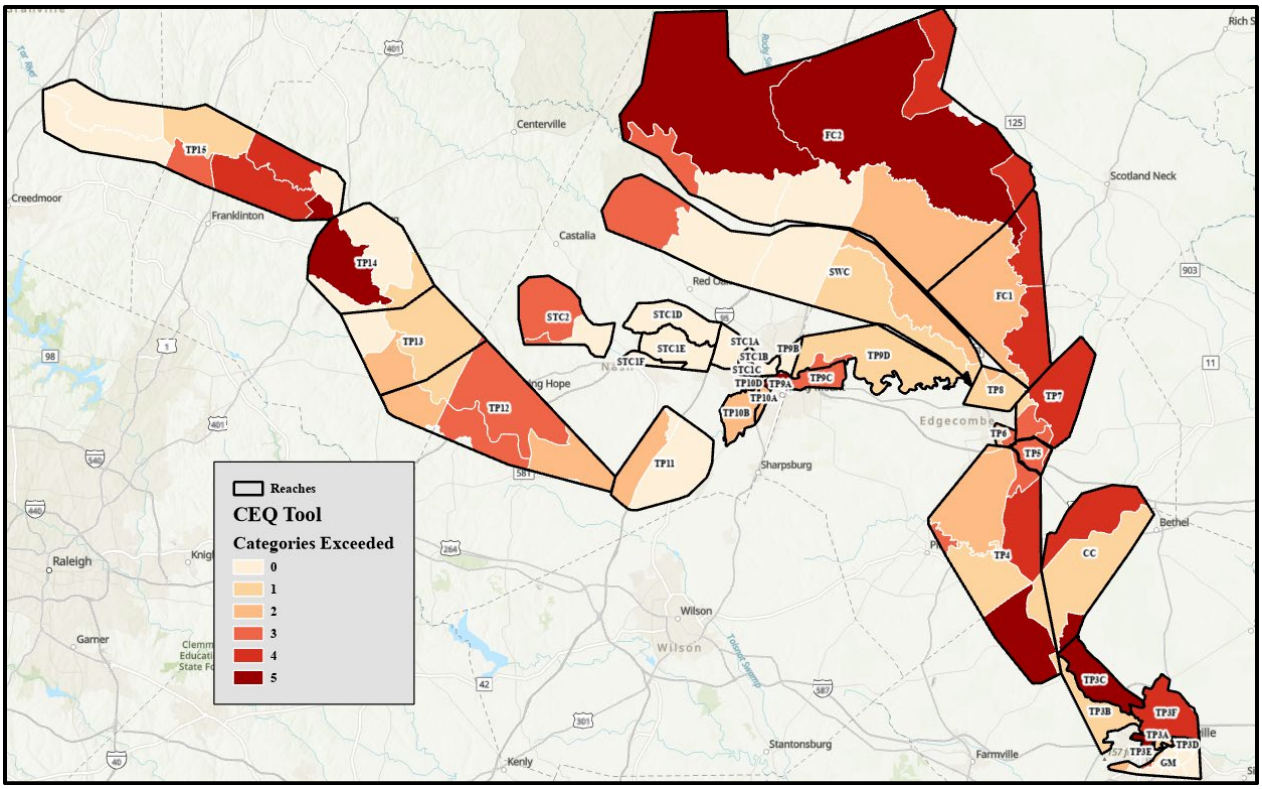

Figure 18. CEQ Tool Categories Exceeded Tar Pamlico Study Area

5.6.3. EJ Screen Tool

The Environmental Justice Screen (EJ Screen) tool, developed by the US Environmental Protection Agency, is another mapping and screening tool that provides a nationally consistent dataset and approach for combining environmental and demographic socioeconomic indicators using Census Tracts into indices that provide an assessment of environmental justice. Unlike the CEQ Tool, EJ Screen uses 2020 Census Tracts. One of these indices is the Demographic Index, which is based on the average of the percentage of people with low-income (i.e., less than or equal to twice the federal 'poverty level') and people of color (i.e., racial status other than white alone and/or ethnicity as Hispanic or Latino). The higher the Demographic Index score, the greater the combined proportion of people of color and people with low income—a group that is historically underserved. Figure 19 illustrates the Demographic Index percentile compared to the nation.

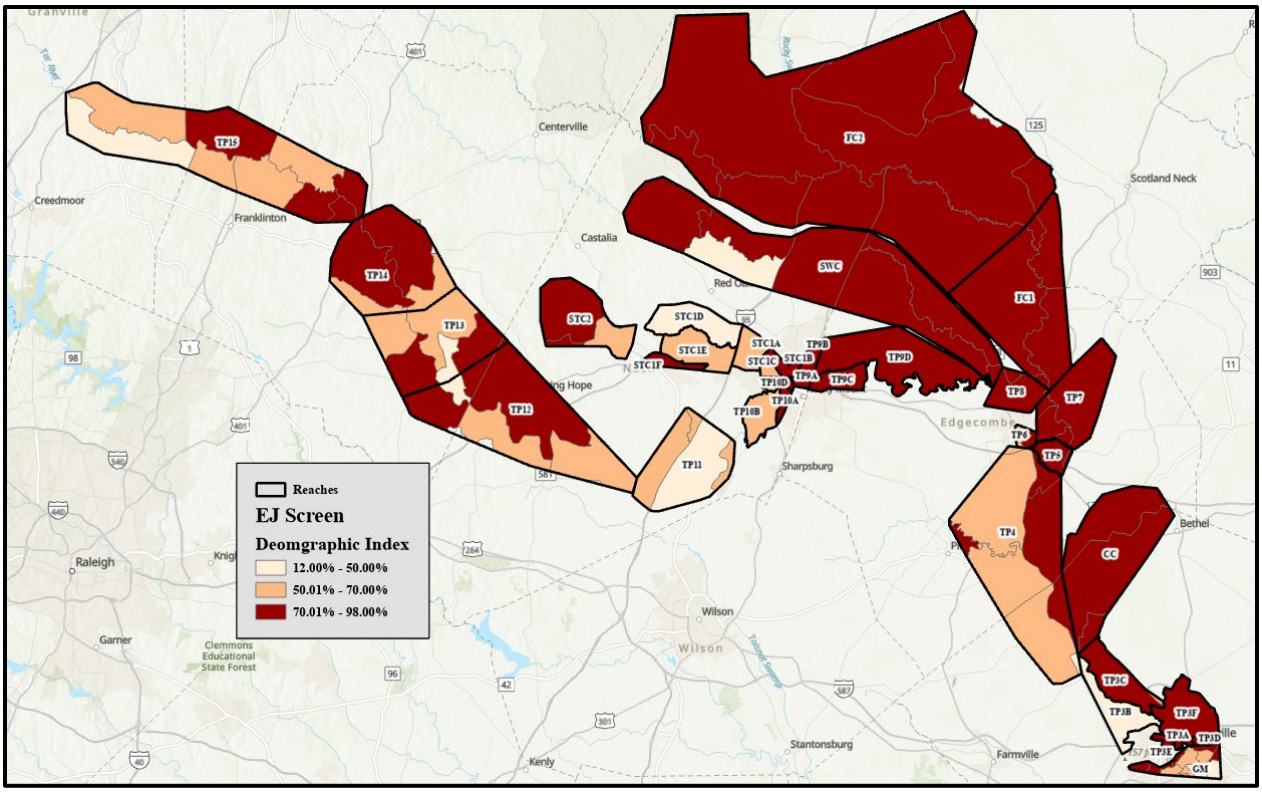

Figure 19. EJ Screen Categories Exceeded Tar Pamlico Study Area

In total the study area includes 76 census tracts with 46 tracts being identified as being in the 70th percentile in the nation. Of these 76 census tracts only 51 include structures that are being inundated at the 0.002 AEP of which 32 are identified as being in the 70th percentile of the nation for the Demographic index. Other categories included in the socioeconomic section of EJ Screen are included below in Table 23.

Table 23. Number of Census Tracts with Categories in the 70th Percentile Compared to the Nation

	Total	Demographic Index	Low Income	High Unemployment	Minority Population	Supplemental Demographic Index*
All Census Tracts	**76**	**46**	**45**	**40**	**36**	**40**
Tracts with Structures	**51**	**32**	**28**	**23**	**29**	**26**

*Supplemental Demographic Index is based on the average of five socioeconomic indicators; low-income, unemployment, limited English, less than high school education, and low life expectancy (which is a health dataset).

These tracts were used to aggregate structures in study reaches with more urban settings where the initial reach included more than 20 structures or around Rocky Mount and Greenville where a single census tract was shared with a hydraulic reach. In total 4 initial reaches were split into 20 reaches using tract data as previously explained.

5.7. Life Safety Without and Future Without Project

5.7.1. Life Safety Analysis

In accordance with ER 1105-2-101 and PB 2019-04, life loss qualifies as an Other Social Effects (OSE) damage category. A life safety analysis includes an estimation of the population at risk

and associated statistical parameters for life loss. This life loss analysis is predominantly qualitative in nature due to the low historical life loss and because the selected plan is exclusively nonstructural. Nonstructural plans do not modify the characteristics of flooding (i.e., the hazard) but modify the characteristics of structures and the population (i.e., consequences). An updated life safety analysis is presented in Section 13.3, below is the initial life safety analysis.

5.7.2. Life Safety Risk

Risk is defined as the probability of an event occurring and the consequences of the event occurring. Flood risk can be conceptualized as a function of the hazard, performance, exposure, vulnerability, and consequences as illustrated in Figure 20. Flood hazards are described in terms of frequency, stage, velocity, and depth. Performance refers to the system's reaction to the hazard. Performance can also refer to the system features and the capability to contain/manage the flood hazard. Since there are no structural measures (e.g., dams and levees) associated with the TSP, performance is not discussed in this analysis. Exposure describes the who and what may be harmed by the flood hazard. Vulnerability is the susceptibility to harm human beings, property, and the environment when exposed to the hazard. Consequence is the harm that results from the hazard. Consequences are measured in terms of harm to people, cost, time, environment, property, and other metrics; this analysis focuses on the harm to human life.

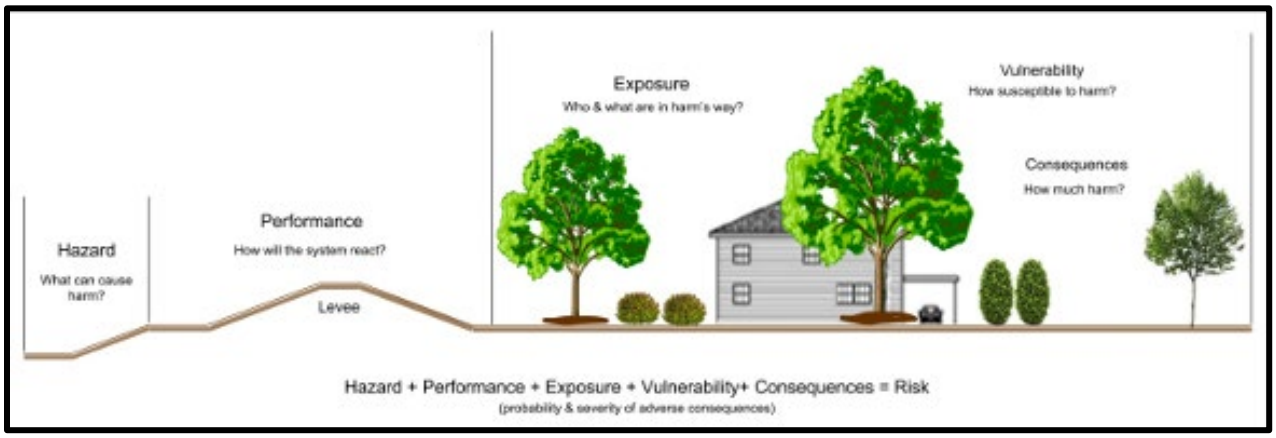

Figure 20. Risk Conceptualized

Depth is a primary factor in determining the potential life loss. To qualify as a high hazard depth, the first floor must be inundated by a depth of at least four feet. This analysis will identify the frequency of depths occurring in this high hazard category in the existing conditions and how that exposure changes with the nonstructural project. Figure 21 identifies the criteria for high hazard depths from the LifeSim model and LifeSim methodology.

	Uncertainty Type	Minimum	Most Likely	Maximum
High Hazard Depth On Roof (ft):	Triangular	3	4	5
	Uncertainty Type	Minimum	Most Likely	Maximum
High Hazard Depth From Ceiling (ft):	Triangular	0.5	1	1.5
	Uncertainty Type	Minimum	Most Likely	Maximum
High Hazard Depth From Floor (ft):	Triangular	4	5	6

Figure 21. High Hazard Depth Chart

A major component that drives life loss is the structure stability threshold. The curve in Figure 22 represents the horizon of structure stability. It is used to show the relationship that stability has with the intersection of depth and velocity. Because the plans are exclusively nonstructural, depth is the only physical characteristic being altered that will impact life safety. As the depth on the structure decreases, the ability to withstand additional velocity increases This means that a structure will have increased stability following the implementation of elevation. This analysis will focus on the extent that depth on structures is decreased.

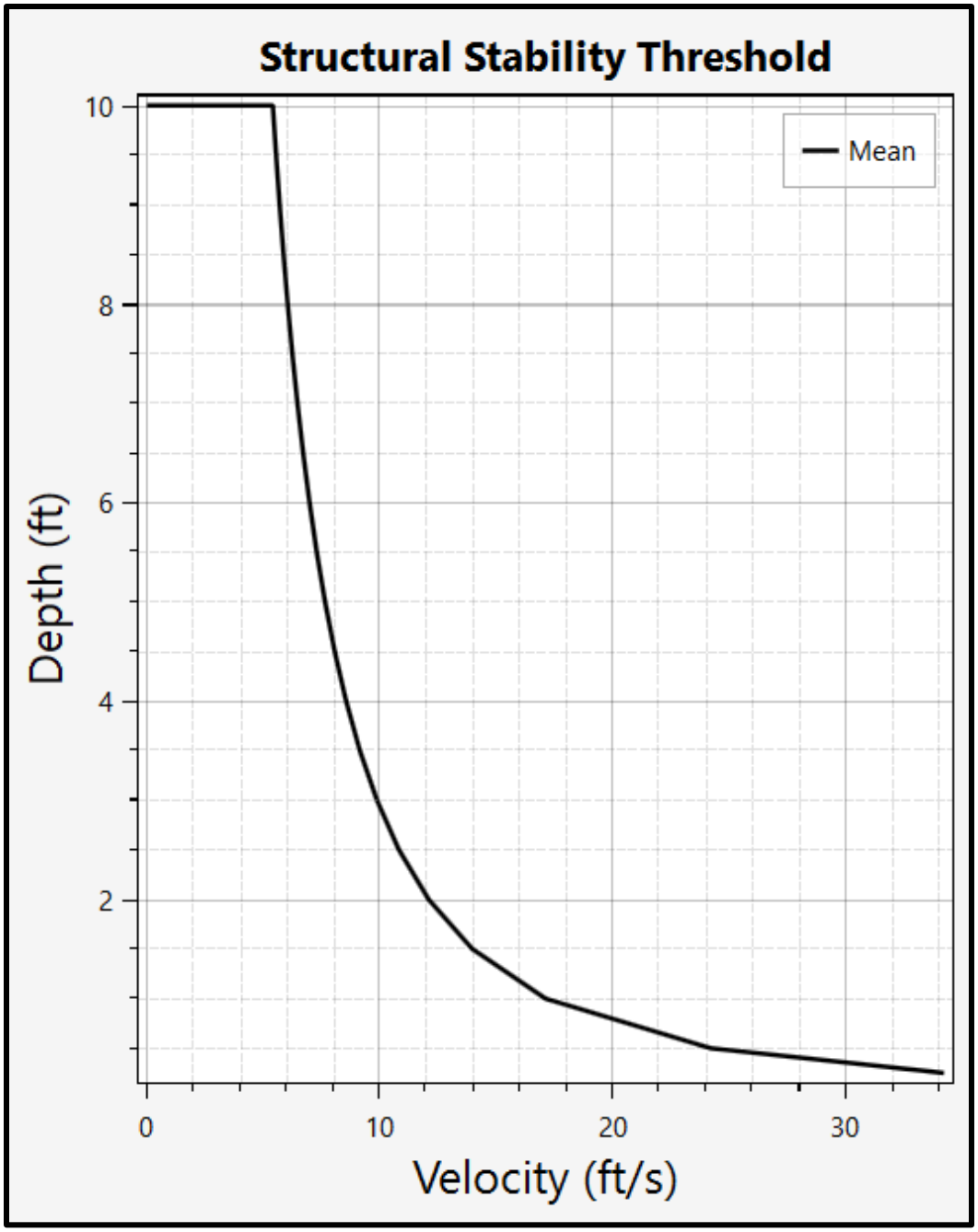

Figure 22. Structural Stability Threshold Curve (Wood-anchored)

Following the implementation of nonstructural measures, any changes in flood depths will be the main factor in potential life loss reductions (i.e., elevation); another component of life loss reduction is change in risk perception.

5.7.3. Existing and Future Without Project Conditions

No life loss modeling was completed for this study due to only having 1D steady flow modeling in most areas with limited areas having unsteady flow. Therefore, a detailed life safety analysis could not be conducted. Estimates of life loss are conducted by other agencies and will be used as a proxy to quantify existing population at risk and annual life loss.

In lieu of consequence estimates following the U.S. Army Corps of Engineers life loss estimation methodology, which would be preferable, the National Risk Index (NRI) from the Federal Emergency Management Agency (FEMA) provides an estimate of expected annual life loss (EALL) from various natural hazards. This was estimated to be the best available information to estimate existing life loss. It also provides a score for social vulnerability and community resilience. All data is available at the county and Census tract level. Since the damage reaches in this study were broken out near the tract level, this tool was used to estimate existing life safety risk in the study area.

The National Risk Index (NRI) is an online tool that illustrates the risk communities face for 18 natural hazards. It was developed by FEMA in collaboration with various partners including academia, state and federal government, and private industry. Due to the robust nature of the tool, it was determined that it would be an adequate proxy for the baseline life safety risk experienced within the Tar Pam Study area.

The National Flood Hazard Layer (NFHL) 1% annual chance floodplain from FEMA is used to identify the exposure area for riverine flooding. The historical event source is the NCEI Storm Database from NOAA which includes flooding events since January 1950. The historic flooding data is used to estimate the frequency of riverine flooding. The period of record was based on records from 1/1/1996 to 12/31/2019, so the period of record is 24 years.

Building values and population estimates are taken from HAZUS 6.0. Land use mapping is used to adjust the concentrations of building value and population at risk. The overlap percentage of land use was used to adjust the exposure of the census tract. The expected annual loss for buildings, population, and ag are estimated separately and combined into an aggregated EAL number. Each are the result of multiplying the exposure, frequency, and historic loss rate.

The total population at risk of riverine flooding is estimated to be 9,716 people with an EALL of 0.224 as shown in Table 24.

Table 24. Expected Annual Population Loss (NRI)

GEOID	Reach 1	Reach 2	Reach 3	Reach 4	County	Riverine Flooding Population Exposure	Population EAL (Fatalities)
37065020400	TP9C				Edgecombe	964	0.0424
37065020600	SWC	TP9D			Edgecombe	537	0.0236
37065020700	FC1	FC2	SWC		Edgecombe	137	0.0060
37065020800	CC	FC1	TP4	TP7	Edgecombe	302	0.0133
37065020900	TP4	TP5	TP7		Edgecombe	176	0.0077
37065021000	TP6	TP7			Edgecombe	189	0.0083
37065021100	SWC	TP7	TP8		Edgecombe	178	0.0078
37065021200	TP6				Edgecombe	72	0.0032
37065021300	TP4	TP9D			Edgecombe	21	0.0009
37065021600	TP4				Edgecombe	13	0.0006
37069060301	TP14	TP15			Franklin	56	0.0014
37069060302	TP14				Franklin	6	0.0002
37069060401	TP15				Franklin	9	0.0002
37069060703	TP12				Franklin	51	0.0013
37069060801	TP12	TP13			Franklin	23	0.0006
37083930800	FC2				Halifax	64	0.0029
37083930902	FC2				Halifax	40	0.0018

GEOID	Reach 1	Reach 2	Reach 3	Reach 4	County	Riverine Flooding Population Exposure	Population EAL (Fatalities)
37127010200	TP10B				Nash	383	0.0138
37127010301	TP10A				Nash	87	0.0031
37127010302	TP10B				Nash	380	0.0137
37127010400	TP10C	TP9A			Nash	169	0.0061
37127010503	STC1A				Nash	74	0.0027
37127010505	STC1B	TP10D			Nash	164	0.0059
37127010506	STC1C	TP10D			Nash	360	0.0129
37127010604	TP9B				Nash	193	0.0069
37127010700	FC2	SWC			Nash	15	0.0005
37127010801	FC2	SWC			Nash	6	0.0002
37127010802	STC1D	SWC			Nash	161	0.0058
37127010900	SWC				Nash	21	0.0007
37127011000	TP12				Nash	12	0.0004
37127011101	STC1E				Nash	143	0.0051
37127011103	STC1F				Nash	30	0.0011
37127011104	STC2				Nash	2	0.0001
37127011201	TP10B	TP11			Nash	52	0.0019
37127011202	TP11				Nash	80	0.0029
37127011300	TP11				Nash	8	0.0003
37127011502	TP12				Nash	8	0.0003
37147000101	TP3A				Pitt	90	0.0003
37147000102	GM				Pitt	312	0.0012
37147000201	GM	TP3D			Pitt	964	0.0037
37147000400	GM				Pitt	227	0.0009
37147000604	GM				Pitt	213	0.0008
37147000701	TP3E				Pitt	52	0.0002
37147000800	TP3F				Pitt	849	0.0032
37147000901	TP3F				Pitt	608	0.0023
37147001700	TP3B	TP4			Pitt	42	0.0002
37147001900	TP4				Pitt	36	0.0001
37147002002	CC	TP4			Pitt	147	0.0006
37147002003	CC	TP3C			Pitt	919	0.0035
37147002004	TP3C				Pitt	70	0.0003
					Total	**9,716**	**0.2240**

Source: https://www.fema.gov/flood-maps/products-tools/national-risk-index

Overall, the existing life loss risk is low. The largest EALL is in tract 37065020400 with an EALL of 0.042. This tract is only in reach TP9C.

Following the identification of the NED and Comprehensive Benefits plans, additional analysis was conducted on the existing conditions and FWOP conditions for life safety. The table below shows the depths at the 0.04, 0.01, and 0.002 AEP events for the 53 structures that are recommended to be elevated in the comprehensive benefits plan. There are hundreds of other structures impacted by the analyzed hydraulic scenarios, but the life loss analysis focuses on how the NED and Comprehensive Benefits plans impact the specific structures' life safety risk identified for elevation. The data is from the structure detail output from the HEC-FDA model. Negative depth values indicate the structure is flooded, but the water surface elevations are below the first-floor elevation of the structure.

Table 25. FWOP - Depth by Structure

Structure	Occ Type	SID Reach	Elevation (ft)	FWOP Depth at 0.04 AEP	FWOP Depth at 0.01 AEP	FWOP Depth at 0.002 AEP
5367	R06	STC1B	2.72	-0.16	0.72	1.76
5114	R04	STC1C	3.01	-0.68	1.01	2.8
5117	R06	STC1C	2.86	-0.6	0.86	2.38
5265	R04	STC1C	0.52	-2.56	-1.48	-0.35
5269	R04	STC1C	0.55	-2.54	-1.45	-0.3
5306	R04	STC1C	0.88	-2.28	-1.12	0.11
5322	R06	STC1C	2.02	-1.44	0.02	1.55
5327	R04	STC1C	2.88	-0.58	0.88	2.41
5354	R06	STC1C	3.78	0.21	1.78	3.43
5097	R04	TP10A	3.42	-0.97	1.42	3.3
1232	R07	TP10B	4.05	0.33	2.05	4.04
5193	R04	TP10C	0.77	-1.99	-1.23	-0.02
5211	R06	TP10C	6.58	3.28	4.58	6.08
5236	R04	TP10C	1.61	-1.73	-0.39	1.09
1412	R07	TP3C	1.18	-9.02	-0.82	2.73
1497	R07	TP3C	1.21	-8.72	-0.79	2.76
1519	R07	TP3C	1.02	-9.32	-0.98	2.58
1818	R07	TP3C	0.96	-10.53	-1.04	2.52
1898	R07	TP3C	2.09	-9	0.09	3.65
1899	R07	TP3C	3.01	-1.99	1.01	4.57
1909	R07	TP3C	2.31	-9.42	0.31	3.86
1910	R07	TP3C	2.64	-9.19	0.64	4.2
1912	R07	TP3C	2.13	-9.7	0.13	3.69
1916	R07	TP3C	0.7	-9.4	-1.3	2.26
1917	R07	TP3C	1.45	-3.54	-0.55	3.01
1918	R07	TP3C	2.19	-9.8	0.19	3.74
2049	R07	TP3C	1.19	-9.17	-0.81	2.73
2162	R07	TP3C	0.55	-9.63	-1.45	2.09
3206	R04	TP3C	1.48	-7.66	-0.52	2.93
3320	R07	TP3C	1.04	-9.31	-0.96	2.56
3378	R04	TP3C	2.16	-2.81	0.16	3.66
3385	R07	TP3C	0.54	-9.31	-1.46	2.06
3400	R07	TP3C	0.62	-8.73	-1.38	2.16
3401	R07	TP3C	0.9	-9.6	-1.1	2.43
3404	R07	TP3C	0.66	-8.9	-1.34	2.19
3410	R07	TP3C	0.7	-9.12	-1.3	2.15
1440	R04	TP3F	2.52	-9	0.52	3.73
1505	R04	TP3F	2.3	-7.26	0.3	3.54
1585	R04	TP3F	1.26	-9	-0.74	2.49
1588	R04	TP3F	2.88	-8	0.88	4.11

Structure	Occ Type	SID Reach	Elevation (ft)	FWOP Depth at 0.04 AEP	FWOP Depth at 0.01 AEP	FWOP Depth at 0.002 AEP
1597	R04	TP3F	5.2	0.4	3.2	6.44
1606	R07	TP3F	0.8	-10.93	-1.2	2.03
1757	R04	TP3F	1.01	-8	-0.99	2.16
1936	R04	TP3F	1.06	-8	-0.94	2.29
1952	R07	TP3F	1.03	-9.4	-0.97	2.18
2247	R07	TP3F	1.16	-9.4	-0.84	2.4
2419	R07	TP3F	0.98	-9.4	-1.02	2.23
2637	R04	TP3F	3.07	-1.72	1.07	4.31
2671	R04	TP3F	2.04	-8	0.04	3.28
2907	R07	TP3F	1.32	-8.43	-0.68	2.52
3125	R07	TP3F	1.04	-9.4	-0.96	2.29
5902	R06	TP8	1.86	-9.4	-0.14	3.08
5367	R06	STC1B	2.72	-0.16	0.72	1.76

Flood characteristics throughout the Tar River basin vary depending on location within the watershed. Smaller tributaries and the headwaters of the major tributaries experience quicker flooding that is characterized by a rapid rise of flood waters, which persist for a relatively short time (i.e., hours). Flooding further downstream along the Tar River and its major tributaries, as well as along the backwater areas of smaller adjoining tributaries, is characterized by a much slower rise of flood waters that persist for longer periods of time (i.e., several days). Although major tributaries experience a rapid rise of floodwaters, the historical flood records indicate inundation pools and is slow moving.

6. WITHOUT AND FWOP REGIONAL ECONOMIC DEVELOPMENT (RED)

The regional economic development (RED) account measures change in the distribution of regional economic activity that would result from an alternative plan. Evaluations of regional effects are measured using nationally consistent projection of income, employment, output, and population.

6.1. RED Effects under Without-Project Conditions

There would also be negative impacts if no action was taken to reduce flood risk. This lack of action would loom in the area's business climate. RED effects resulting from this and other factors would include the following:

6.1.1. Threats to Existing Local/Regional Businesses

(Probable adverse income and jobs impacts) - Businesses in and around the Tar Pamlico study area would be threatened by multiple factors related to flood risk, including (a) periodic flood damage; (b) frequent business closures; (c) employee safety during flood events; (d) the cost of flood insurance requirements; and (e) stiff building codes, that would work against firms needing to expand. In large flood events, business shutdowns can last for weeks, causing sizable and even ruinous production losses. Some production losses with potential to represent unquantified NED losses could occur with local municipal utilities.

6.1.2. Threats to Economic Development Prospects

(Probable adverse income and jobs impacts) - If no project is completed in the region, this could discourage new development and growth in the form of businesses migrating into the city or region or the development of new areas. Businesses may leave the Tar Pamlico study area, be reluctant to expand, or refuse to locate in the area due to concerns over potential flood damages. Large companies considering moving into the study area, bringing job concentrations with them, may be less inclined to do so in a flood-prone area.

6.1.3. Residential Flood Insurance Premium Costs

(Probable adverse income impact) – If no action is taken, residents would continue to face onerous flood insurance requirements.

7. ALTERNATIVES SCREENING

7.1. Initial Array of Alternatives

As illustrated in Table 26, the initial measure screening numerous measures were screened out and only two were carried forward to the initial array, dry dams, and nonstructural measures. More information is presented in the main report.

Table 26. Measures Screened

Measure (# Evaluated)	# Screened Out	Reason Screened
Dry Dams (21)	19	Acceptability, Environmental, Efficiency
Floodwalls / Levees (10)	10	Effectiveness, Completeness, Efficiency
Bridge Modifications (10)	10	Effectiveness, Completeness
Modify existing projects (2)	2	Effectiveness, Efficiency
Debris management (10)	10	Effectiveness, Efficiency
Auxiliary Channels (12)	12	Completeness, Technical Feasibility, Efficiency
Channel Modifications (10)	10	Effectiveness
Dam Removal (1)	1	Effectiveness, Acceptability
Offline detention (5)	5	Effectiveness
Green Infrastructure (1)	1	Effectiveness
Nonstructural (Watershed-wide)	NA	NA

The initial array of alternatives consisted of three alternatives that were further refined and evaluated. Descriptions of these alternatives is presented below. Only Alternative 1 and Alternative 3 were carried on the final array.

7.2. Alternative 1- No Action

USACE planning policy (Engineering Regulation 1105-2-100) and the National Environmental Policy Act (NEPA) require consideration of 'No Action'. The No Action alternative is synonymous with the 'Future without Project Condition' and assumes no measures would be implemented by the federal government to achieve the planning objectives. Any activities to be pursued by local, state, and/or other federal agencies (e.g., modification of Princeville levee system) are assumed to be undertaken, therefore TP5 was removed from consideration.

The no action plan would not reduce ongoing flood risk within the watershed, including economic damages associated with inundation of structures and impacts to industry and commerce, as well as risks to life safety. There would be no change in regional economic development as a result of the no action plan. Environmental resources would continue to be degraded due to flooding, including impacts to water quality.

7.3. Alternative 2- Dry Dams

Alternative 2 consisted of two dry dams located along Stoney Creek and the upper Tar River as described in the main report. The proposed dry dams would work together to detain floodwaters and decrease flood risk to downstream rural and urban areas, including Rocky Mount, Tarboro, and Greenville. Dry dams would be effective at reducing downstream flood risk, including economic damages associated with inundation of structures and impacts to industry and commerce, including in agricultural areas and many areas identified as socially vulnerable.

However, preliminary costs and benefits analysis indicated the alternative would not result in positive net benefits. Essentially the eliminating damages at all events to structures in the existing conditions would still result in a Benefit Cost Ratio (BCR) of around 0.3 with the total cost being $642 million (average annual costs of around $24 million) and potential average annual benefits of around $7.8 million.

In addition, dry dams would have significant, permanent impacts to environmental resources, including threatened and endangered species and their designated critical habitats—impacts that were of major concern to partnering state and federal resource agencies. Due to the lack of efficiency and significant environmental impacts, dry dams were screened from further consideration.

7.4. Alternative 3- Nonstructural

Alternative 3 consists of physical nonstructural measures, including elevation and acquisition/relocation of residential structures and wet and dry floodproofing of commercial structures within both major population centers and adjacent rural areas. Non-physical nonstructural measures (i.e., flood warning) would be incorporated to the extent practicable. Nonstructural measures were considered for all reaches in the Tar Pamlico study area except for TP5 in Princeville based on the ongoing modifications to their levee system.

Nonstructural measures would be effective at reducing downstream flood risk by reducing the consequences of flooding, including reducing economic damages and life safety risk associated with inundation of structures. Nonstructural measures could be implemented in commercial areas, resulting in reductions in risk to commerce; however, there would be minimal benefit to the agricultural industry. Participation in elevation and floodproofing would not be mandatory and, thus, participation rates could affect the overall efficiency and completeness of the plan. Alternative 3 was the only alternative besides no action to move onto the final array.

8. WITH-PROJECT ALTERNATIVES ANALYSIS

8.1. With-Project Analysis Overview

To determine the economic justification of the final array of alternatives, Alternative 3 was entered into the HEC-FDA risk analysis model. The Monte Carlo analysis in HEC-FDA was then employed to determine residual damages – i.e., damages that would continue to occur even with implementation of an alternative. The difference between the without project condition EAD and the residual EAD for each alternative represents the damages reduced or benefits for the alternative. Benefits calculated in the HEC-FDA model are based on physical inundation reduction to homes, businesses, and public facilities. Although the final array of alternatives is nonstructural, it should be noted that extensive modeling was undertaken to evaluate structural alternatives until it was evident that these plans were not viable.

8.2. Nonstructural Formulation

A refinement of the original structure inventory was conducted after the reaches with coastal influences (Tar Pam 1, Tar Pam 2, and Jacks Creek) were removed from the study area and all the structural alternatives were screened out as described in Section 7. During this refinement an initial nonstructural was developed ran for the watershed which identified 716 of the 4,423 remaining structures getting damaged at the .01 AEP event (100-year). These 716 structures were then individually surveyed for nonstructural measures already implemented, structure value, first floor height, and occupancy type. A significant number of structures in the initial nonstructural plan were identified as already having nonstructural solutions implemented, and beginning damages were edited within the FDA modeling to reflect the measures. Examples of these structures are illustrated in Figure 23-Figure 26.

Figure 23. Residential Elevated Greenville TP3D

Figure 24. Residential Raised with Flood Vents Greenville TP3D

Figure 25. Elevated and Vented Residential Structure Greenville TP3F

Figure 26. Apartments Rocky Mount Front and Back TP10D

After refining the supporting attributes of the structures recommended in the initial nonstructural plan, 582 structures were identified to be carried forward in the nonstructural analysis.

8.3. Nonstructural Methodology

The intent of nonstructural assessment is to identify the nonstructural measure most appropriate for the specific structure. Within the Tar Pamlico study area, a total of 4,423 structures were identified in or near the 0.002 annual exceedance probability (AEP) floodplain (500-year). Of those, 582 incur damages at the 0.01 AEP flood event (100-year) based on the HEC-FDA model and were assessed for nonstructural measures. Figure 27 shows a map of all structures identified for nonstructural measures.

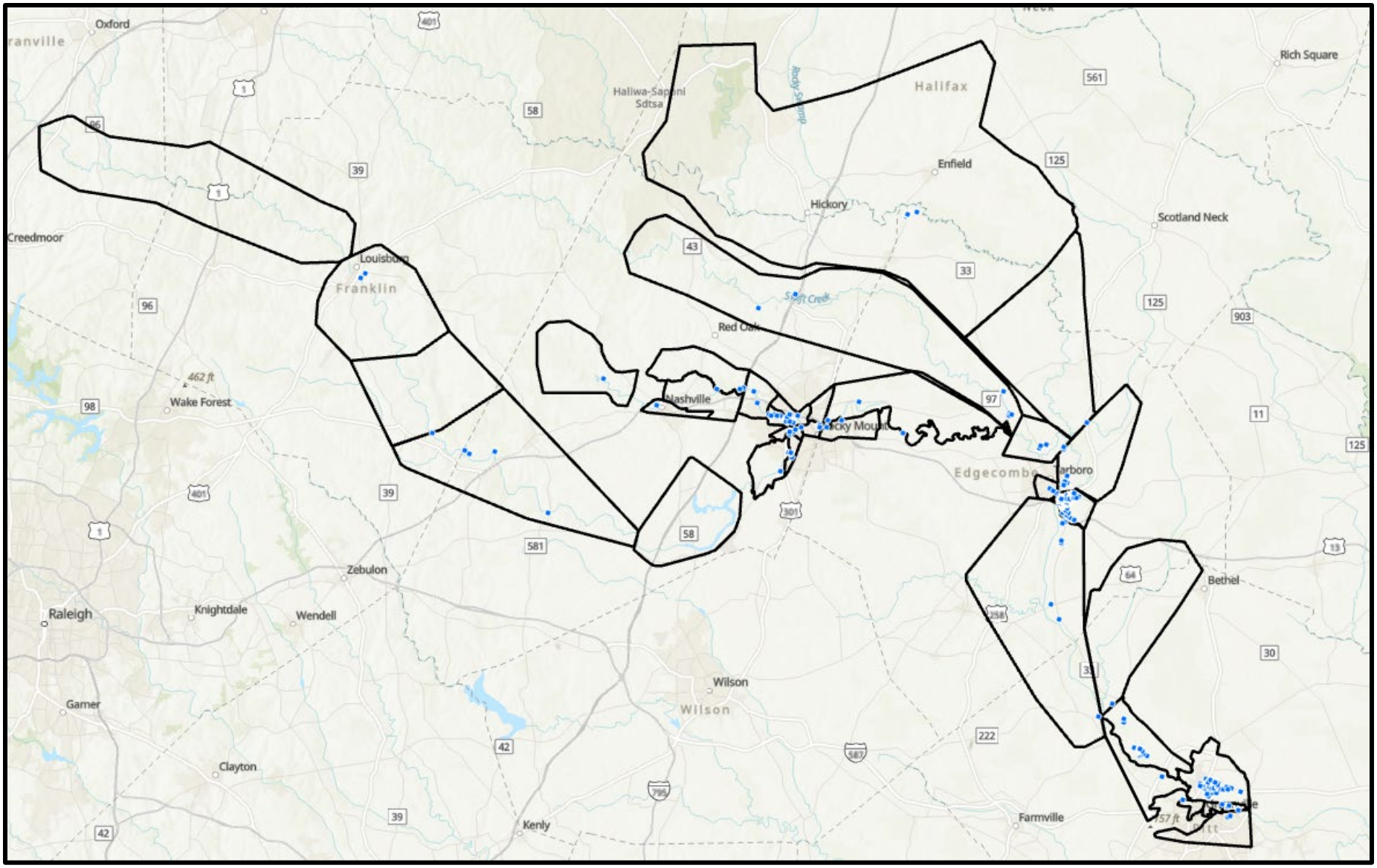

Figure 27. Structures Identified for Nonstructural Analysis

Nonstructural measures reduce flood risk by modifying the characteristics of structures and people. These measures do not modify the characteristics of floods (stage, velocity, duration) and do not induce development in a floodplain. There are four broad categories of nonstructural measures that modify the characteristics of structures: elevation, wet floodproofing, dry floodproofing, and acquisitions/removal. In addition to those measures which modify structures, flood preparedness measures can modify the vulnerability of people in the floodplain. These measures can include evacuation procedures, flood alert systems, and educational outreach programs.

Nonstructural measures are applied to individual structures based on specific criteria. Those structures are then aggregated together in a logical way to form nonstructural alternatives. Flood damages are estimated using the HEC-FDA model. The change in flood damages from the existing condition to the alternative are described as the benefits. Costs are estimated by cost engineers based on the measure identified.

The BCR is calculated the same way as with structural alternatives by finding the ratio of benefits to costs in annualized terms.

8.4. Assumptions

No limiting factors were found in the study area that would result in specific measures being unusable. The assumptions used were:

- No rapid moving water in inundated areas.
- Adequate notifications systems to implement nonstructural measures ahead of flood events. Streams in the upper watershed are characterized as flashy hydrographs in stream, however there would be notifications before flooding impact and the areas would be impacted. In addition, based off of
- No debris/ice flow
- Impermeable soil
- All structures excellent to fair condition

Flood characteristics throughout the Tar River basin vary depending on location within the watershed. As previously stated major tributaries experience a rapid rise of floodwaters, the historical flood records indicate inundation pools and is slow moving.

In addition, the state of North Carolina actively works to mitigate flood risk for residents. Several tools and warning systems exist to help residents access flood mitigation preparedness / warning services. Resources available include the NC Flood Risk Information System, which provides a simple mapping interface to help residents identify their flood risk; the Flood Inundation Mapping and Alert Network, that provides rain and stage gage data, flood inundation maps, and alerts in real-time; and the NC Emergency Management Advisory Flood Mitigation Application to provide non-regulatory flood hazard mapping for previously unmapped portions of the state. It is assumed that owner or employees of a dry flood proofed structure would be notified before through the Flood Inundation Mapping and Alert Network real-time monitoring of gage data enabling them to implement the dry floodproof measures constructed.

Specific structures may be deemed ineligible for the recommended nonstructural measure when additional scrutiny is applied. A participation rate sensitivity analysis is conducted to provide adequate context to decision makers in the event of less than 100% participation.

8.5. Measures

The array of nonstructural measures considered in the analysis included elevation/basement fill, wet floodproofing, dry floodproofing, and acquisitions/relocations. Each of those measures is explained in more detail below.

The target stage for each measure was set to the 0.01 AEP (100-year) event with an additional 2 feet per after a sensitivity analysis was conducted.

8.5.1. Elevation/Basement Fill

This nonstructural measure elevates the existing building from its original foundation to the design flood elevation (DFE) and is illustrated in Figure 28. This measure is recommended for residential buildings, with or without basements. The DFE for this analysis is the 0.01 AEP event plus two feet. To calculate the necessary amount each building should be elevated, the elevation of the first floor was subtracted from the base flood elevation then two feet were added. The maximum final height considered for any residential building is 12 feet. Since flood depths did not exceed 6 feet, all residential buildings were evaluated.

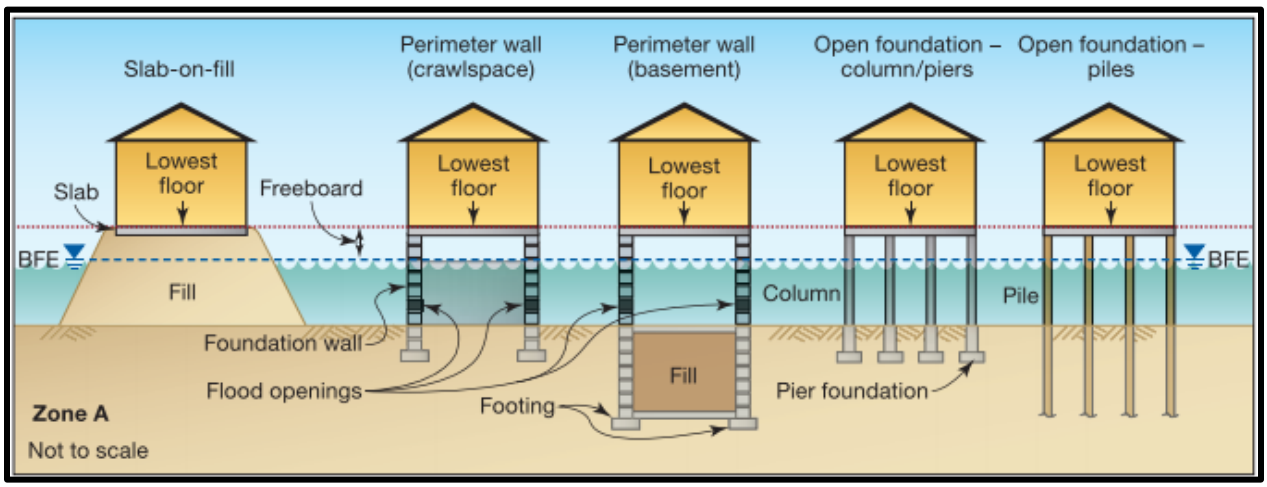

Figure 28. Elevation

Elevation costs in the initial screening were estimated by cost engineering using a 2,000 sq ft structure being raised 6 feet. To estimate the costs of structures more accurately, the matrix in Table 27 below was used as the base cost for elevating structures based on the closest square footage of the structure and the height of recommended elevation. The distribution of this matrix was based on work performed by the USACE National Nonstructural Committee. After the nonstructural plans were selected, costs were developed based on each structure's attributes and the elevation height as described below in Section 13.1.4.

Table 27. Elevation Cost Matrix

Height Raised	1,000 sqft	2,000 sqft	3,000 sqft
2ft Raise	$234,580	$269,307	$331,346

4ft Raise	$252,824	$305,048	$366,715
6ft Raise	$271,183	**$328,598**	$402,005
8ft Raise	$289,427	$352,034	$437,374
10ft Raise	$307,786	$375,583	$472,629
12ft Raise	$326,030	$399,019	$507,886

Basement fill consists of filling in the existing basement with sand or gravel and the top of the fill is covered with a vapor barrier. This measure could occur without elevating the structure if the first floor is located above the base flood elevation. Filling in the basement is required when elevating residential buildings which have basements or dry floodproofing commercial buildings that have basements. The filled basement resists damage to the building foundation from hydrostatic forces and raises the threshold of flood damages to the main floor elevation, whether existing or elevated. To compensate for a portion of the lost basement area and provide a location for relocation of the utilities (i.e. electrical panel, furnace, water heater, water softener, washer and dryer) which may be located in the basement, an above ground addition may be constructed onto the building at the DFE. Relocation of the furnace and water heater provides the property owner an opportunity at their expense to replace those items with new units that are more efficient. In that situation, the estimated cost of relocating the existing furnace and water heater would be applied to the cost of installing the replacement units. For purposes of this analysis an addition size of 64 square feet was used as shown in Table 28.

Table 28. Basement Fill Costs

Item	Unit of Measure	Unit Cost
Sand Fill	$/Cu.ft.	$5.25
Addition	$/SF	$642.00
Utility Addition	Ft	64

8.5.2. Wet Floodproofing

Wet floodproofing is applicable as either a standalone measure or as a measure combined with other measures such as elevation. Application of wet floodproofing techniques may require a variance from local floodplain management regulations (see FEMA Technical Bulletin 7-93 for more information). As a standalone measure, floodwaters are allowed to enter a structure, thereby requiring that all construction materials be water resistant, and all utilities must be elevated above the DFE. Flood vents are installed in the walls to allow floodwaters into the building and equalize the hydrostatic forces. It is required that there be a minimum of two vents with a minimum one square inch of flood vent area for each square foot of the wet floodproofing area, as specified in 44 CFR Section 60.3(c)(5). All utilities, such as heating, lighting, electrical panels, and outlets must be elevated above the DFE or be located inside flood-resistant closures.

Since wet floodproofing allows floodwaters into a building, it is not recommended for finished floors of residential buildings. Wet floodproofing may be applicable to residential buildings with crawlspaces and commercial buildings when combined with a flood warning, preparedness, and response plan. This measure is not applicable in areas with large flood depths and high velocity flows. A wet floodproofing proposal should be discussed with the local floodplain manager prior to implementation as it may require a variance from floodplain management regulations.

For this analysis, a residential structure being damaged would be recommended for wet floodproofing if the existing foundation had a crawlspace or if the structure was being raised. The amount of clearance necessary for the flood venting was set at 0.5 feet.

Wet floodproofing nonresidential structures is a complicated measure that has structure specific determining factors that were not readily available in the underlying data. Specifics such as internal layout, location of utilities and contents, and executability of wet floodproofing plans are not available in the underlying data. However, if a specific structure was identified for dry floodproofing in the analysis but was later determined to be a good candidate for wet floodproofing in the design phase, the cost difference would be in favor of wet floodproofing in most instances. Therefore, nonresidential structures were not considered for wet floodproofing in this analysis but could be the best measure as determined in the design phase when additional details are available. An example of wet floodproofing for a residential structure is illustrated in Figure 29.

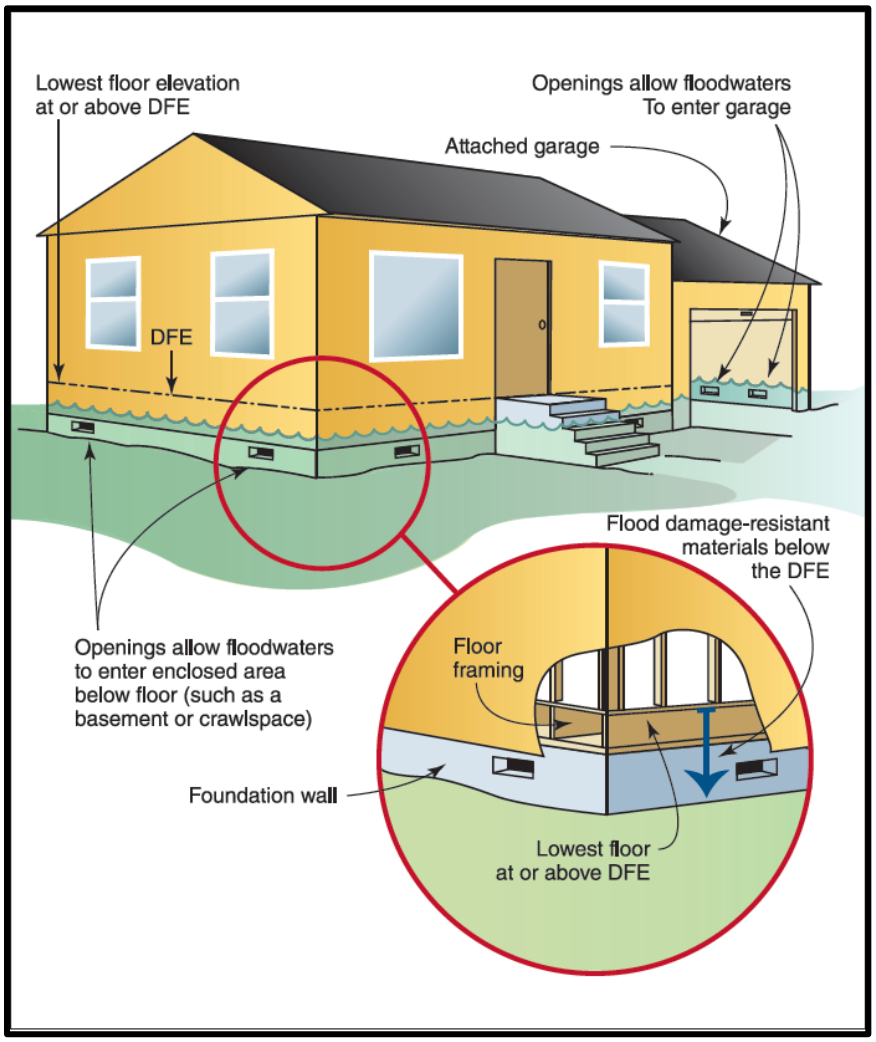

Figure 29. Wet Floodproofing

Wet floodproofing for residential structures costs are represented in measures that include flood vents. Cost estimates were provided by cost engineering with the costs applied on a per structure basis based on the specific structure attributes. Flood vent costs are estimated by dividing the

structure sq footage by 100 to determine the number of flood vents needed. Then, that number is multiplied by the flood vent cost estimated. For structures with unfinished basements, the estimation for raising the electric utilities and demoing interior walls was estimated for full basements. A sewer backflow valve was added to each structure as well.

The costs associated with this measure can vary based on the specific configuration of the structure it is being applied. The costs associated with this measure is purely for estimation purposes and are presented in Table 29 below.

Table 29. Cost Parameters for Wet Floodproofing

Item	Unit of Measure	Unit Cost
Demo Interior Wall	$/SF	$24.00
Insulation and Wains Coat	$/SF	$56.43
Raise Electric Utilities	$/LF	$266.00
Flood Vents	1 Unit	$687.00
Sewer Backflow Valve	1 Unit	$11,184.00

8.5.3. Dry Floodproofing

Dry floodproofing of commercial and other nonresidential buildings involves applying a water-resistant sealant around the building to prevent flood water from entering. The sealant layer is then protected with a brick veneer or similar material. Closure panels are used at building openings, and backflow prevention devices are installed on sanitary sewer lines. A sump pump and drain system should be installed as part of the measure.

Masonry or concrete commercial building can generally be dry floodproofed up to design depth of 4 feet (USACE, 1988). A structural analysis of the wall strength is required if it is desired to achieve higher protection. Buildings constructed of poured concrete, concrete masonry, or brick are most suitable for dry floodproofing. All nonresidential structures were evaluated with a maximum floodproofing height of 4 feet considered.

A structure was selected for this measure if it was showing damages and the structure is nonresidential. An example of dry floodproofing is given in Figure 30.

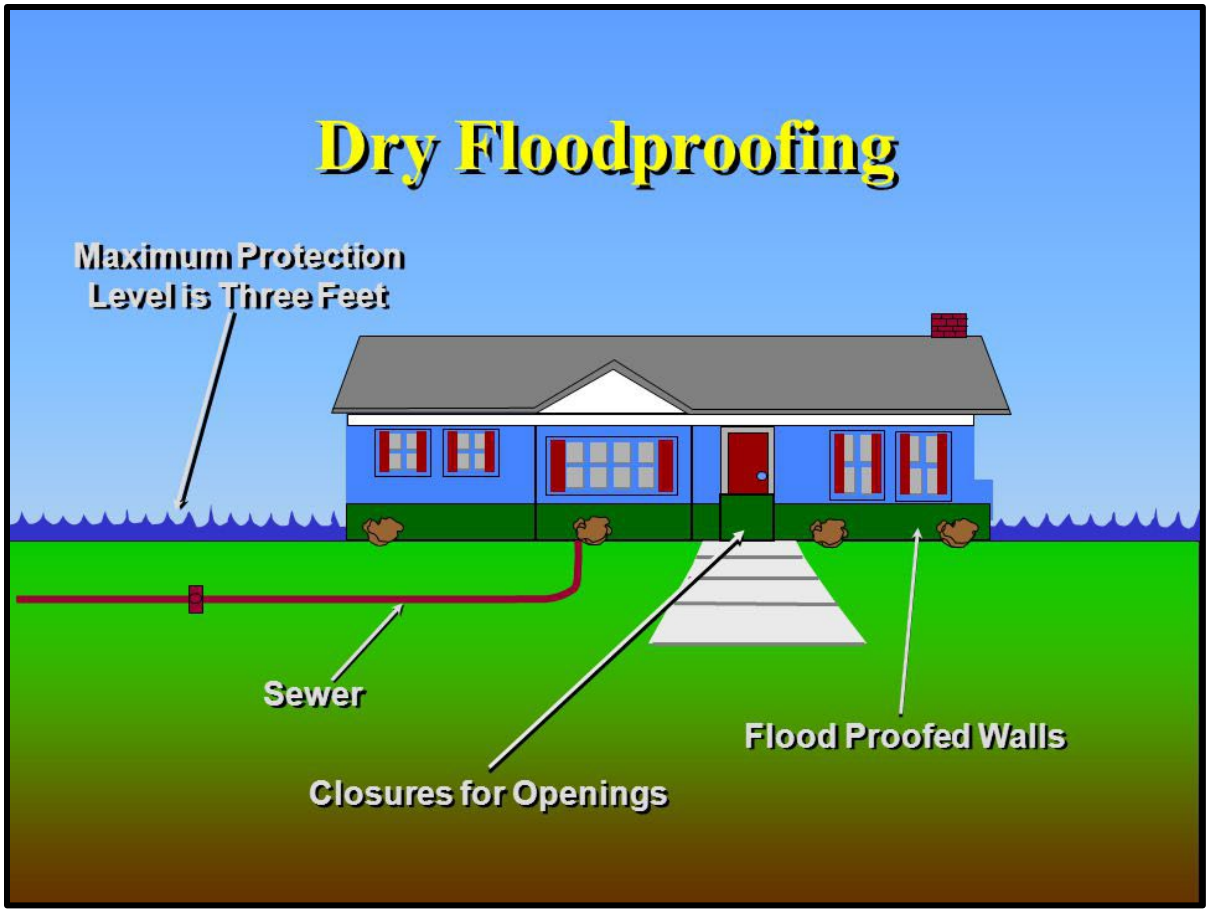

Figure 30. Dry Floodproofing

Cost estimates were developed for commercial buildings with design flood depths up to 4 feet and removal of basement if necessary. A structural engineer will be required to thoroughly review the adequacy of the building to withstand hydrostatic and dynamic floodwater loading on the walls and uplift forces on the foundation prior to implementation. The perimeter was estimated by taking the square root of the area and then multiplying by four. The number and size of closure panels needed were estimated from the Google Earth Street View map application. The floodproofing height was calculated by subtracting the foundation elevation from the design flood elevation. Dry floodproofing achieves flood insurance premium reduction for commercial structures but is not recognized by the NFIP for flood insurance premium reduction if applied to a residential structure. Residential buildings cannot be removed from insurance or floodplain management requirements by dry floodproofing. An individual homeowner may choose to floodproof their home (provided not a substantial improvement), but the lowest floor will not change for insurance or permitting. Costs for dry floodproofing are illustrated in Table 30.

Table 30. Cost Parameters of Dry Floodproofing

Item	Unit of Measure	Unit Cost
Waterproofing Sealant	$/SF	$7.65
Masonry Veneer	$/SF	$66.97
3 ft Floodproof Door	1 Unit	$5,564.00
6 ft Floodproof Door	1 Unit	$10,040.00
Closure Panels	1 Panel	$22,000.00
CMU Wall	$/SF	$65.00
Wall Foundation	$/LF	$192.00
Skimmer Pumps	1 Unit	$4,945.00
Sewer Backflow Valve	1 Unit	$11,184.00

8.5.4. Acquisitions/Relocations

This nonstructural technique consists of buying the structure and the associated land. The building is either demolished or sold to others and relocated outside of the floodplain. Land acquisition can be in the form of fee title or permanent easement with fee title. After acquisition, the land must be maintained as open space through deed restriction that prohibits any type of development that can sustain flood damages or restrict flood flows. Land acquired as part of a nonstructural project can be converted to a new use such as ecosystem restoration and/or recreation that is consistent with open space restrictions. Examples of this include trails, shoreline access, and interpretive markers.

Relocation requires moving the at-risk structure out of the floodplain and buying the associated land. This measure achieves a high level of flood risk reduction when structures can be relocated from a high flood hazard area to an area outside of the floodplain. Relocation projects may include the development of sites where structures could be moved to achieve the planning objectives and retain such aspects as community tax base, neighborhood cohesion, and cultural and historic significance.

Acquisitions and relocations were not considered in the initial nonstructural measure array due to existing data from the sister Neuse study being completed concurrently. It was determined to analyze acquisitions and relocations among the identified aggregation.

8.6. Total Measure Selection

The final array of nonstructural measures is shown in table 1 below. The nonstructural measure with the most identified structures is elevate and flood vent followed by dry floodproof.

Table 31. Nonstructural Measures Identified

Nonstructural Measure	Count
Elevate Only	73
Flood Vent Only	42
Elevate & Flood Vent	255
Fill Basement & Flood Vent	3
Elevate & Fill Basement & Flood Vent	18
Dry Floodproof	191
Total	**582**

8.7. Nonstructural Economic Evaluation

Following the identification of the appropriate nonstructural measure(s), an economic evaluation is performed to find the appropriate aggregation of structures to make up the nonstructural alternative. For this analysis, structures were aggregated based on their geographic location (damage reach) and their flooding characteristics (floodplains). These aggregations were then run through the HEC-FDA model to determine the change in EAD by reach.

8.7.1. Aggregation

Structure aggregation was done based on similar geographic location and community as well as similar flooding characteristics. This approach has been identified as the recommended method and gives a comprehensive logical approach to structure aggregation because it allows for optimization within geographic boundaries and ensuring that structures with similar flooding frequencies and depths are all addressed instead of at a structure-by-structure basis.

8.7.2. Damage Reaches

Damage reaches were broken out by census tracts to incorporate environmental justice considerations into a comprehensive benefit analysis. While these reaches maintain the same hydraulic characteristics and hydromorphology, these political divisions were introduced to more finely address communities that have environmental justice concerns because the data available for that analysis was available at the census tract level. It is an appropriate level of detail as part of an aggregation because recommendations come at a more community level.

8.7.3. Floodplains

Floodplain aggregation groups all structures that have first floor elevation less than or equal to the stages associated with that AEP event. For this analysis, the 0.1, 0.04, 0.02, and 0.01 AEP events were analyzed to find the appropriate floodplain aggregation that reasonably maximizes National Economic Development (NED). These aggregations group structures experiencing similar flooding frequencies, depths, and velocities because they are broken down by damage reach as described in Section 3.1.3. Analyzing aggregations based on floodplains allow for optimizing the damage reaches total aggregation based on maximization of NED considerations. The aggregations for each AEP event are presented in Table 32 below.

Table 32. Floodproofed Structures by Floodplain

Reach	0.1 AEP Floodproofed Structures	0.04 AEP Floodproofed Structures	0.02 AEP Floodproofed Structures	0.01 AEP Floodproofed Structures
CC	0	0	2	2
FC1	0	0	0	1
FC2	0	3	9	14
GM	0	0	2	3
STC1A	1	1	1	2
STC1B	2	5	9	15
STC1C	5	5	9	19
STC1D	0	0	0	4
STC1E	0	0	0	0
STC1F	0	0	0	1
STC2	0	1	1	1
SWC	0	2	7	14
TP10A	2	3	3	4
TP10B	0	1	1	2
TP10C	2	4	4	5
TP10D	0	1	1	1
TP11	0	0	0	0
TP12	3	4	5	5
TP13	0	0	0	0
TP14	1	4	4	6
TP15	0	0	0	0
TP3A	0	0	0	0
TP3B	0	0	1	1
TP3C	0	0	2	22
TP3D	0	27	35	39
TP3E	0	0	1	1
TP3F	4	17	34	69
TP4	0	0	1	9
TP5	0	103	157	310
TP6	0	0	0	4
TP7	0	0	0	9
TP8	0	1	4	10
TP9A	0	0	1	4
TP9B	0	0	0	0
TP9C	0	0	0	1
TP9D	1	2	2	4
Total	**21**	**184**	**296**	**582**

8.8. Alternatives

Structure inventories were created for the four floodplains with the structure attributes of the specific structures altered to reflect the changes that the nonstructural measure would have on the structure. For elevations, the first-floor elevation was raised the appropriate height. If the structure was identified as receiving flood vents, the beginning damages were set to 0, indicating that damages only begin if the depth of flooding exceeds the first-floor stage. If a structure had a basement filled, the occupancy type was changed to reflect the new damage curve. If a structure was dry floodproofed, the beginning damage was set to the height identified for dry floodproofing. No changes were made to the hydraulic data from the existing condition

modeling. The following sections will break down the results of this HEC-FDA modeling for each floodplain.

8.8.1. 0.1 AEP Floodplain

The 0.1 AEP floodplain (10-year) represents the structures seeing damages at very frequent events. Only 21 total structures were identified in this floodplain as illustrated in Table 33 with the greatest number of structures being in STC1C. No reach had greater than 5 structures in this floodplain. Reaches that are not included in the table below did not have any structure identified in the 0.1 AEP aggregation.

Table 33. 0.1 AEP Floodproofing by Reach

Reach	Elevate	Flood Vent	Elevate & Flood Vent	Fill Bsmt & Flood Vent	Elevate Fill Bsmt Flood Vent	Dry Floodproof	Total Floodproofed Structures
STC1A	0	0	1	0	0	0	**1**
STC1B	0	0	0	0	0	2	**2**
STC1C	0	0	4	0	0	1	**5**
TP10A	0	0	0	0	0	2	**2**
TP10C	0	0	1	0	0	1	**2**
TP12	2	0	1	0	0	0	**3**
TP14	0	0	1	0	0	0	**1**
TP3F	0	0	0	0	0	4	**4**
TP9D	0	0	1	0	0	0	**1**
Total	**2**	**0**	**9**	**0**	**0**	**10**	**21**

Due to the limited nature of this floodplain, there is not a lot of variation in EAD between the without and with-project condition. The largest benefit pool occurs in TP3F with annual benefits estimated at about $146,000. Total annual benefits are estimated at just above $630,000 as shown in Table 34.

Table 34. 0.1 AEP Benefits (In $1,000)

Reach	Without Project EAD	10% AEP Floodplain EAD	Expected Annual Benefits
STC1A	$28.25	$16.65	$11.60
STC1B	$1,016.37	$880.25	$136.12
STC1C	$393.14	$325.95	$67.19
TP10A	$155.03	$60.47	$94.56
TP10C	$212.71	$69.40	$143.31
TP12	$62.62	$36.14	$26.48
TP14	$150.73	$147.54	$3.19
TP3F	$2,398.92	$2,252.78	$146.14
TP9D	$130.46	$128.88	$1.58
Total	**$4,548.23**	**$3,918.06**	**$630.17**

Note: Reaches not included have $0 expected annual benefits and have not been included in the without project condition

The total construction costs estimated for the 0.1 AEP floodplain is estimated at just above $5.5 million and shown in Table 35. These costs do not include contingencies, planning, engineering, and design (PED), construction management, or real estate costs.

Table 35. 0.1 AEP Construction Costs by Reach

Reach	Elevation Cost	Fill Basement Cost	Flood Vent Cost	Dry Floodproofing Cost	Total Construction Costs
STC1A	$337,266	$0	$16,488	$0	$353,754
STC1B	$0	$0	$0	$647,429	$647,429
STC1C	$1,035,086	$0	$56,334	$155,813	$1,247,234
TP10A	$0	$0	$0	$418,047	$418,047
TP10C	$632,781	$0	$29,541	$124,874	$787,196
TP12	$747,916	$0	$19,923	$0	$767,839
TP14	$92,301	$0	$4,809	$0	$97,110
TP3F	$0	$0	$0	$1,090,945	$1,090,945
TP9D	$166,795	$0	$8,244	$0	$175,039
Total	**$3,012,146**	**$0**	**$135,339**	**$2,437,109**	**$5,584,593**

Note: Reaches not included were not in the 10% AEP aggregation

In addition to the construction costs, PED, Construction Management, and Real Estate costs were included. PED is estimated at 11.9% of construction costs, construction management is estimated at 6.3% of construction costs, and real estate is estimated at $36,528.66 per structure based on input from real estate, which includes a 25% contingency markup. A contingency of 43% is added to construction, PED, and construction management. The interest during construction is estimated on the total of the costs plus contingencies. 3 months were used for the IDC time period because it is the length of time funds are committed to a structure for dry floodproofing consistent with PB 2019-03. The total investment cost is estimated at just over $10.2 million. Average annual costs are calculated by using the FY23 rate of 2.5% with a period of 50 years. The average annual costs are estimated at about $361,000. With benefits just above $630,000,

the net benefits are estimated at just below $270,000. This is a benefit cost ratio of 1.75. Total costs for the 0.1 AEP plan are shown in Table 36.

Table 36. 0.1 AEP Cost Benefit Summary

0.1 AEP Costs	Contract Cost ($)	Contingency (%)	Contingency ($)	Total Cost
Construction Cost	$5,584,593	43%	$2,401,375	**$7,985,968**
Planning, Engineering, and Design	$664,567	43%	$285,764	**$950,330**
Construction Management	$351,829	43%	$151,287	**$503,116**
Real Estate	$767,102	0%	$0	**$767,102**
Total	**$7,368,091**		**$2,838,425**	**$10,206,516**
Interest During Construction (3 Months)				$31,572
Total Investment Cost				**$10,238,089**
Average Annual Costs				**$360,975**
Average Annual Benefits				**$630,170**
Net Benefits				**$269,195**
BCR				**1.75**

8.8.2. 0.04 AEP Floodplain

The 0.04 AEP floodplain includes 184 structures identified for nonstructural measures as shown in Table 37. A total of 17 reaches are included in the floodplain. The most structures are identified in TP5 with 103 structures. Most of the structures are identified as receiving flood vents. This indicates residential structures are seeing low depth flooding but are seeing damages. TP3D and TP3F are the reaches with the next the greatest number of structures with 27 and 17 respectively. While the split is almost even in TP3D, TP3F is almost exclusively dry floodproofing. This indicates nonresidential areas are seeing inundation at a relatively frequent event.

Table 37. 0.04 AEP Floodproofing by Reach

Reach	Elevate	Flood Vent	Elevate & Flood Vent	Fill Bsmt & Flood Vent	Elevate Fill Bsmt Flood Vent	Dry Floodproof	Total Floodproofed Structures
FC2	0	0	3	0	0	0	**3**
STC1A	0	0	1	0	0	0	**1**
STC1B	0	0	0	0	0	5	**5**
STC1C	0	0	4	0	0	1	**5**
STC2	0	0	0	0	0	1	**1**
SWC	2	0	0	0	0	0	**2**
TP10A	0	0	1	0	0	2	**3**
TP10B	1	0	0	0	0	0	**1**
TP10C	0	0	3	0	0	1	**4**
TP10D	0	0	0	0	0	1	**1**
TP12	2	0	1	0	0	1	**4**
TP14	1	0	3	0	0	0	**4**
TP3D	0	0	0	0	15	12	**27**

TP3F	1	0	0	0	0	16	**17**
TP5*	4	0	78	0	0	21	**103**
TP8	0	0	0	0	0	1	**1**
TP9D	0	0	1	0	0	1	**2**
Total	**11**	**0**	**95**	**0**	**15**	**63**	**184**

Note: Reaches not included were not in the 0.04 AEP aggregation
* Included in analysis but not carried forward based on current levee improvement projects

The expected annual benefits are just over $2.4 million. TP3F is the reach with the largest benefit pool with just over $720,000. This reach is almost exclusively nonresidential structures being dry floodproofed. STC1B and TP5 also have large benefit pools. STC1B is another reach that is exclusively nonresidential structures being dry floodproofed. Table 38give a breakout of the expected annual benefits by reach.

Table 38. 0.04 AEP Benefits (In $1,000)

Reach	Without Project EAD	0.04 AEP Floodplain EAD	Expected Annual Benefits
FC2	$37.28	$26.53	$10.75
STC1A	$28.25	$16.65	$11.60
STC1B	$1,016.37	$390.25	$626.12
STC1C	$393.14	$325.95	$67.19
STC2	$0.35	$0.07	$0.28
SWC	$163.67	$159.13	$4.54
TP10A	$155.03	$49.79	$105.24
TP10B	$183.72	$179.45	$4.27
TP10C	$212.71	$66.22	$146.49
TP10D	$104.09	$70.18	$33.91
TP12	$62.62	$15.90	$46.72
TP14	$150.73	$139.77	$10.96
TP3D	$371.04	$250.87	$120.17
TP3F	$2,398.92	$1,678.63	$720.29
TP5*	$1,590.73	$1,083.72	$507.01
TP8	$180.52	$169.52	$11.00
TP9D	$130.46	$127.48	$2.98
Total	**$7,179.63**	**$4,750.11**	**$2,429.52**

Note: Reaches not included were not in the 0.04 AEP aggregation
* Included in analysis but not carried forward based on current levee improvement projects and have not been included in the without project condition

The total construction costs estimated for the 0.04 AEP floodplain is estimated at just above $41 million and shown in Table 39. These costs do not include contingencies, planning, engineering, and design (PED), construction management, or real estate costs.

Table 39. 0.04 AEP Construction Costs by Reach

Reach	Elevation Cost	Fill Basement Cost	Flood Vent Cost	Dry Floodproofing Cost	Total Construction Costs
FC2	$577,929	$0	$28,854	$0	$606,783
STC1A	$337,266	$0	$16,488	$0	$353,754
STC1B	$0	$0	$0	$1,612,042	$1,612,042
STC1C	$1,035,086	$0	$56,334	$155,813	$1,247,234
STC2	$0	$0	$0	$73,986	$73,986

SWC	$414,330	$0	$0	$0	$414,330
TP10A	$488,138	$0	$23,358	$418,047	$929,543
TP10B	$252,824	$0	$0	$0	$252,824
TP10C	$1,005,791	$0	$48,090	$124,874	$1,178,755
TP10D	$0	$0	$0	$247,247	$247,247
TP12	$747,916	$0	$19,923	$286,670	$1,054,509
TP14	$420,369	$0	$15,114	$0	$435,483
TP3D	$4,175,425	$1,107,878	$205,413	$1,379,699	$6,868,416
TP3F	$252,824	$0	$0	$5,386,553	$5,639,377
*TP5**	*$15,522,205*	*$0*	*$713,106*	*$3,576,211*	*$19,811,522*
TP8	$0	$0	$0	$176,148	$176,148
TP9D	$166,795	$0	$8,244	$139,520	$314,559
Total	**$25,396,900**	**$1,107,878**	**$1,134,924**	**$13,576,812**	**$41,216,514**

Note: Reaches not included were not in the 0.04 AEP aggregation
* Included in analysis but not carried forward based on current levee improvement projects

In addition to the construction costs, PED, Construction Management, and Real Estate costs were included. PED is estimated at 11.9% of construction costs, construction management is estimated at 6.3% of construction costs, and real estate is estimated at $36,528.66 per structure based on input from real estate, which includes a 25% contingency markup. A contingency of 43% is added to construction, PED, and construction management. The interest during construction is estimated on the total of the costs plus contingencies. 3 months were used for the IDC time period because it is the length of time funds are committed to a structure for dry floodproofing consistent with PB 2019-03. The total investment cost is estimated at just over $76 million. Average annual costs are calculated by using the FY23 rate of 2.5% with a period of 50 years. The average annual costs are estimated at about $2.7 million. With benefits just above $2.4 million, the net benefits are estimated at around -$272,000. The is a benefit cost ratio for the 0.04 AEP aggregation is 0.90 as illustrated in Table 40 .

Table 40. 0.04 AEP Floodplain BCR

0.04 AEP Costs	Contract Cost ($)	Contingency (%)	Contingency ($)	Total Cost
Construction Cost	$41,216,514	43%	$17,723,101	**$58,939,615**
Planning, Engineering, and Design	$4,904,765	43%	$2,109,049	**$7,013,814**
Construction Management	$2,596,640	43%	$1,116,555	**$3,713,196**
Real Estate	$6,721,273	0%	$0	**$6,721,273**
Total	**$55,439,193**		**$20,948,705**	**$76,387,898**
Interest During Construction (3 Months)				$236,293
Total Investment Cost				**$76,624,191**
Average Annual Costs				**$2,701,620**
Average Annual Benefits				**$2,429,520**
Net Benefits				**-$272,100**
BCR				**0.90**

8.8.3. 0.02 AEP Floodplain

The 0.02 AEP floodplain includes 296 structures identified for nonstructural measures as shown in Table 41. A total of 24 reaches are included in the floodplain. The most structures are identified in TP5 with 157 structures. Most of the structures are identified as receiving flood

vents. This indicates residential structures are seeing low depth flooding but are seeing damages. TP3D and TP3F are the reaches with the next the greatest number of structures with 35 and 34 respectively. While the split is almost even in TP3D, TP3F is almost exclusively dry floodproofing.

Table 41. 0.02 AEP Floodproofing by Reach

Reach	Elevate	Flood Vent	Elevate & Flood Vent	Fill Bsmt & Flood Vent	Elevate Fill Bsmt Flood Vent	Dry Floodproof	Total Floodproofed Structures
CC	0	0	0	0	0	2	**2**
FC2	0	0	9	0	0	0	**9**
GM	0	0	1	0	0	1	**2**
STC1A	0	0	1	0	0	0	**1**
STC1B	1	0	0	0	0	8	**9**
STC1C	0	0	7	0	0	2	**9**
STC2	0	0	0	0	0	1	**1**
SWC	2	0	4	0	0	1	**7**
TP10A	0	0	1	0	0	2	**3**
TP10B	1	0	0	0	0	0	**1**
TP10C	0	0	3	0	0	1	**4**
TP10D	0	0	0	0	0	1	**1**
TP12	3	0	1	0	0	1	**5**
TP14	1	0	3	0	0	0	**4**
TP3B	1	0	0	0	0	0	**1**
TP3C	2	0	0	0	0	0	**2**
TP3D	0	0	1	0	15	19	**35**
TP3E	0	0	0	0	0	1	**1**
TP3F	3	0	1	0	0	30	**34**
TP4	1	0	0	0	0	0	**1**
TP5*	6	0	112	0	3	36	**157**
TP8	0	0	0	0	0	4	**4**
TP9A	0	0	0	0	0	1	**1**
TP9D	0	0	1	0	0	1	**2**
Total	**21**	**0**	**145**	**0**	**18**	**112**	**296**

Note: Reaches not included were not in the 0.04 AEP aggregation
* Included in analysis but not carried forward based on current levee improvement projects

The expected average annual benefits of applying nonstructural measures to all structures in the 0.02 AEP floodplain is estimated at just below $3 million as shown in Table 42. TP3F and STC1B are the reaches with the largest benefit pools. Both are overwhelmingly performing dry floodproofing to nonresidential structures.

Table 42. 0.02 AEP Benefits (In $1,000)

Reach	Without Project EAD	0.02 AEP Floodplain EAD	Expected Annual Benefits
CC	$36.81	$32.42	$4.39
FC2	$37.28	$17.75	$19.53
GM	$19.21	$17.96	$1.25
STC1A	$28.25	$16.65	$11.60
STC1B	$1,016.37	$306.91	$709.46
STC1C	$393.14	$294.29	$98.85
STC2	$0.35	$0.07	$0.28
SWC	$163.67	$146.23	$17.44
TP10A	$155.03	$49.79	$105.24
TP10B	$183.72	$179.45	$4.27
TP10C	$212.71	$66.22	$146.49
TP10D	$104.09	$70.18	$33.91
TP12	$62.62	$15.79	$46.83
TP14	$150.73	$139.77	$10.96
TP3B	$4.47	$1.63	$2.84
TP3C	$66.83	$66.41	$0.42
TP3D	$371.04	$219.49	$151.55
TP3E	$0.28	$0.12	$0.16
TP3F	$2,398.92	$1,520.06	$878.86
TP4	$62.02	$61.85	$0.17
TP5*	$1,590.73	$931.84	$658.89
TP8	$180.52	$126.44	$54.08
TP9A	$66.44	$44.71	$21.73
TP9D	$130.46	$127.48	$2.98
Total	**$7,435.69**	**$4,453.51**	**$2,982.18**

Note: Reaches not included were not in the 0.02 AEP aggregation and have not been included in the without project condition

* Included in analysis but not carried forward based on current levee improvement projects

The total construction costs estimated for the 0.02 AEP floodplain is estimated at just above $64 million and shown in Table 43. These costs do not include contingencies, planning, engineering, and design (PED), construction management, or real estate costs.

Table 43. 0.02 AEP Floodplain Construction Costs by Reach

Reach	Elevation Cost	Fill Basement Cost	Flood Vent Cost	Dry Floodproofing Cost	Total Construction Costs
CC	$0	$0	$0	$319,284	$319,284
FC2	$1,678,330	$0	$83,814	$0	$1,762,144
GM	$222,258	$0	$10,992	$76,823	$310,074
STC1A	$337,266	$0	$16,488	$0	$353,754
STC1B	$234,580	$0	$0	$2,314,082	$2,548,662
STC1C	$1,773,553	$0	$91,371	$671,931	$2,536,855
STC2	$0	$0	$0	$73,986	$73,986
SWC	$1,369,927	$0	$46,716	$245,337	$1,661,980
TP10A	$488,138	$0	$23,358	$418,047	$929,543
TP10B	$252,824	$0	$0	$0	$252,824
TP10C	$1,005,791	$0	$48,090	$124,874	$1,178,755
TP10D	$0	$0	$0	$247,247	$247,247
TP12	$892,935	$0	$19,923	$286,670	$1,199,529
TP14	$420,369	$0	$15,114	$0	$435,483
TP3B	$295,218	$0	$0	$0	$295,218
TP3C	$469,160	$0	$0	$0	$469,160
TP3D	$4,359,717	$1,107,878	$214,344	$2,032,097	$7,714,035
TP3E	$0	$0	$0	$73,710	$73,710
TP3F	$991,291	$0	$11,679	$8,103,517	$9,106,486
TP4	$217,100	$0	$0	$0	$217,100
*TP5**	*$23,471,703*	*$168,395*	*$1,092,330*	*$6,447,680*	*$31,180,107*
TP8	$0	$0	$0	$756,263	$756,263
TP9A	$0	$0	$0	$207,224	$207,224
TP9D	$166,795	$0	$8,244	$139,520	$314,559
Total	**$38,646,954**	**$1,276,273**	**$1,682,463**	**$22,538,291**	**$64,143,982**

Note: Reaches not included were not in the 0.02 AEP aggregation
* Included in analysis but not carried forward based on current levee improvement projects

In addition to the construction costs, PED, Construction Management, and Real Estate costs were included. PED is estimated at 11.9% of construction costs, construction management is estimated at 6.3% of construction costs, and real estate is estimated at $36,528.66 per structure based on input from real estate, which includes a 25% contingency markup. A contingency of 43% is added to construction, PED, and construction management. The interest during construction is estimated on the total of the costs plus contingencies. The total investment cost is estimated at just over $119 million. Average annual costs are calculated by using the FY23 rate of 2.5% with a period of 50 years. The average annual costs are estimated at about $4.2 million. With benefits just below $3 million, the net benefits are estimated at just above -$1.2 million. This is a benefit cost ratio of 0.71 as illustrated in Table 44.

Table 44. 0.02 AEP Floodplain BCR

0.02 AEP Costs	Contract Cost ($)	Contingency (%)	Contingency ($)	Total Cost
Construction Cost	$64,143,982	43%	$27,581,912	**$91,725,894**
Planning, Engineering, and Design	$7,633,134	43%	$3,282,248	**$10,915,381**
Construction Management	$4,041,071	43%	$1,737,660	**$5,778,731**
Real Estate	$10,812,483	0%	$0	**$10,812,483**
Total	**$86,630,670**		**$32,601,820**	**$119,232,490**
Interest During Construction (3 Months)				$368,826
Total Investment Cost				**$119,601,316**
Average Annual Costs				**$4,216,910**
Average Annual Benefits				**$2,982,180**
Net Benefits				**-$1,234,730**
BCR				**0.71**

8.8.4. 0.01 AEP Floodplain

The 0.01 AEP floodplain includes 582 structures identified for nonstructural measures as shown in Table 45. A total of 30 reaches are included in the floodplain. The most structures are identified in TP5 with 310 structures. Most of the structures are identified as receiving flood vents. This indicates residential structures are seeing low depth flooding but are seeing damages. TP3F and TP3D are the reaches with the next the greatest number of structures with 69 and 39 respectively. While the split is almost even in TP3D, TP3F is almost exclusively dry floodproofing.

Table 45. 0.01 AEP Floodproofing by Reach

Reach	Elevate	Flood Vent	Elevate & Flood Vent	Fill Bsmt & Flood Vent	Elevate Fill Bsmt Flood Vent	Dry Floodproof	Total Floodproofed Structures
CC	0	0	0	0	0	2	**2**
FC1	0	0	0	0	0	1	**1**
FC2	0	2	12	0	0	0	**14**
GM	0	0	1	0	0	2	**3**
STC1A	0	1	1	0	0	0	**2**
STC1B	1	0	0	0	0	14	**15**
STC1C	1	4	7	0	0	7	**19**
STC1D	2	0	0	2	0	0	**4**
STC1F	0	0	0	0	0	1	**1**
STC2	0	0	0	0	0	1	**1**
SWC	2	1	9	0	0	2	**14**
TP10A	0	1	1	0	0	2	**4**
TP10B	1	0	0	0	0	1	**2**
TP10C	0	1	3	0	0	1	**5**
TP10D	0	0	0	0	0	1	**1**
TP12	3	0	1	0	0	1	**5**
TP14	1	0	5	0	0	0	**6**
TP3B	1	0	0	0	0	0	**1**
TP3C	22	0	0	0	0	0	**22**
TP3D	4	0	1	0	15	19	**39**
TP3E	0	0	0	0	0	1	**1**
TP3F	10	0	5	0	0	54	**69**
TP4	5	0	0	0	0	4	**9**
TP5*	14	29	206	1	3	57	**310**
TP6	0	0	0	0	0	4	**4**
TP7	6	1	1	0	0	1	**9**
TP8	0	0	1	0	0	9	**10**
TP9A	0	2	0	0	0	2	**4**
TP9C	0	0	0	0	0	1	**1**
TP9D	0	0	1	0	0	3	**4**
Total	73	42	255	3	18	191	**582**

Note: Reaches not included were not in the 0.01 AEP aggregation
* Included in analysis but not carried forward based on current levee improvement projects

The expected annual benefits of applying nonstructural measures to all structures in the 0.01 AEP floodplain is estimated at just above $3.6 million as illustrated in Table 46. TP3F and STC1B are the reaches with the largest benefit pools. Both are overwhelmingly performing dry floodproofing to nonresidential structures.

Table 46. 0.01 AEP Benefits (In $1,000)

Reach	Without Project EAD	0.01 AEP Floodplain EAD	Expected Annual Benefits
CC	$36.81	$32.42	$4.39
FC1	$8.86	$6.85	$2.01
FC2	$37.28	$13.74	$23.54
GM	$19.21	$16.85	$2.36
STC1A	$28.25	$14.34	$13.91
STC1B	$1,016.37	$228.08	$788.29
STC1C	$393.14	$156.13	$237.01
STC1D	$28.82	$18.67	$10.15
STC1E	$6.69	$6.69	$0.00
STC1F	$24.50	$9.36	$15.14
STC2	$0.35	$0.07	$0.28
SWC	$163.67	$140.09	$23.58
TP10A	$155.03	$49.56	$105.47
TP10B	$183.72	$174.56	$9.16
TP10C	$212.71	$64.72	$147.99
TP10D	$104.09	$70.18	$33.91
TP11	$1.67	$1.67	$0.00
TP12	$62.62	$15.79	$46.83
TP13	$0.18	$0.18	$0.00
TP14	$150.73	$138.48	$12.25
TP15	$0.20	$0.20	$0.00
TP3A	$28.32	$28.32	$0.00
TP3B	$4.47	$1.63	$2.84
TP3C	$66.83	$59.40	$7.43
TP3D	$371.04	$215.99	$155.05
TP3E	$0.28	$0.12	$0.16
TP3F	$2,398.92	$1,307.48	$1,091.44
TP4	$62.02	$53.64	$8.38
*TP5**	*$1,590.73*	*$840.10*	*$750.63*
TP6	$68.17	$55.51	$12.66
TP7	$198.41	$186.90	$11.51
TP8	$180.52	$109.00	$71.52
TP9A	$66.44	$28.78	$37.66
TP9B	$15.16	$15.16	$0.00
TP9C	$11.19	$10.65	$0.54
TP9D	$130.46	$84.47	$45.99
Total	**$7,827.86**	**$4,155.78**	**$3,672.08**

* Included in analysis but not carried forward based on current levee improvement projects and have not been included in the without project condition

Total construction costs for the 0.01 AEP floodplain are estimated at just above $116 million as illustrated in Table 47. These costs do not include contingencies, PED, construction management, or real estate.

Table 47. 0.01 AEP Floodplain Construction Costs by Reach

Reach	Elevation Cost	Fill Basement Cost	Flood Vent Cost	Dry Floodproofing Cost	Total Construction Costs
CC	$0	$0	$0	$319,284	$319,284
FC1	$0	$0	$0	$165,895	$165,895
FC2	$2,458,455	$0	$138,774	$0	$2,597,229
GM	$222,258	$0	$10,992	$146,834	$380,084
STC1A	$337,266	$0	$48,777	$0	$386,043
STC1B	$234,580	$0	$0	$3,567,546	$3,802,126
STC1C	$2,104,899	$0	$142,209	$1,662,319	$3,909,427
STC1D	$429,184	$128,738	$19,236	$0	$577,158
STC1E	$0	$0	$0	$0	$0
STC1F	$0	$0	$0	$389,790	$389,790
STC2	$0	$0	$0	$73,986	$73,986
SWC	$2,472,907	$0	$109,233	$447,363	$3,029,503
TP10A	$488,138	$0	$27,480	$418,047	$933,665
TP10B	$252,824	$0	$0	$124,378	$377,202
TP10C	$1,005,791	$0	$85,188	$124,874	$1,215,853
TP10D	$0	$0	$0	$247,247	$247,247
TP11	$0	$0	$0	$0	$0
TP12	$892,935	$0	$19,923	$286,670	$1,199,529
TP13	$0	$0	$0	$0	$0
TP14	$763,860	$0	$32,289	$0	$796,149
TP15	$0	$0	$0	$0	$0
TP3A	$0	$0	$0	$0	$0
TP3B	$295,218	$0	$0	$0	$295,218
TP3C	$5,195,486	$0	$0	$0	$5,195,486
TP3D	$5,371,263	$1,107,878	$214,344	$2,032,097	$8,725,582
TP3E	$0	$0	$0	$73,710	$73,710
TP3F	$3,675,851	$0	$62,517	$12,293,214	$16,031,582
TP4	$1,135,351	$0	$0	$674,012	$1,809,363
*TP5**	*$46,212,730*	*$236,355*	*$2,449,155*	*$9,517,570*	*$58,415,810*
TP6	$0	$0	$0	$748,118	$748,118
TP7	$1,118,027	$0	$19,923	$255,416	$1,393,366
TP8	$56,604	$0	$2,748	$1,505,734	$1,565,086
TP9A	$0	$0	$18,549	$615,280	$633,829
TP9B	$0	$0	$0	$0	$0
TP9C	$0	$0	$0	$91,430	$91,430
TP9D	$166,795	$0	$8,244	$1,142,326	$1,317,365
Total	**$74,890,421**	**$1,472,971**	**$3,409,581**	**$36,923,137**	**$116,696,110**

* Included in analysis but not carried forward based on current levee improvement projects

In addition to the construction costs, PED, Construction Management, and Real Estate costs were included. PED is estimated at 11.9% of construction costs, construction management is estimated at 6.3% of construction costs and real estate is estimated at $36,528.66 per structure based on input from real estate, which includes a 25% contingency markup. A contingency of 43% is added to construction, PED, and construction management. The interest during construction is estimated on the total of the costs plus contingencies. The total investment cost is estimated at just over $219 million. Average annual costs are calculated by using the FY23 rate of 2.5% with a period of 50 years. The average annual costs are estimated at about $7.7 million. With benefits just above $3.6 million, the net benefits are estimated at just above -$4 million. This is a benefit cost ratio of 0.48 as illustrated in Table 48. Some reaches were not carried forward based on

economic viability or proximity to economically viable reaches if they were identified as EJ communities.

Table 48. 0.01 AEP Floodplain BCR

0.01 AEP Costs	Contract Cost ($)	Contingency (%)	Contingency ($)	Total Cost
Construction Cost	$116,696,110	43%	$50,179,327	**$166,875,438**
Planning, Engineering, and Design	$13,886,837	43%	$5,971,340	**$19,858,177**
Construction Management	$7,351,855	43%	$3,161,298	**$10,513,153**
Real Estate	$21,259,680	0%	$0	**$21,259,680**
Total	**$159,194,482**		**$59,311,965**	**$218,506,447**
Interest During Construction (3 Months)				$675,913
Total Investment Cost				**$219,182,361**
Average Annual Costs				**$7,727,944**
Average Annual Benefits				**$3,672,080**
Net Benefits				**-$4,055,864**
BCR				**0.48**

8.9. Alternative 3A: NED Plan Analysis

Following the determination of average annual benefits and average annual costs by reach for each of the four floodplains, an analysis was done to optimize the aggregation to select the floodplain that maximized net benefits. If a reach did not have a floodplain aggregation with positive net benefits, that reach was removed from the NED plan.

The aggregation for the nonstructural analysis which reasonably maximizes net NED benefits includes 7 reaches and 42 total structures as illustrated in Table 49. The NED plan is almost exclusively dry floodproofing with 39 of the structures identified for that measure. The remaining three are elevations of residential structures with one structure having flood vents added as well.

Table 49. NED Plan Measures by Reach

Reach	Aggregation	Elevate	Elevate Flood Vent	Dry Floodproof	Total
STC1B	0.01 AEP Floodplain	1	0	14	15
TP10A	0.10 AEP Floodplain	0	0	2	2
TP10C	0.10 AEP Floodplain	0	1	1	2
TP10D	0.01 AEP Floodplain	0	0	1	1
TP3F	0.04 AEP Floodplain	1	0	16	17
TP8	0.02 AEP Floodplain	0	0	4	4
TP9A	0.02 AEP Floodplain	0	0	1	1
	NED Plan	**2**	**1**	**39**	**42**

The total construction costs of the identified 42 structures is estimated at just under $12 million. In addition to the construction costs, PED, Construction Management, and Real Estate costs were included. PED is estimated at 11.9% of construction costs, construction management is estimated

at 6.3% of construction costs, and real estate is estimated at $36,528.66 per structure based on input from real estate, which includes a 25% contingency markup. A contingency of 43% is added to construction, PED, and construction management. The interest during construction is estimated on the total of the costs plus contingencies and is over a 3-month construction period.

The total investment cost is estimated at just over $21 million as shown in Table 50 and costs for the NED plan by reach and aggregation are shown in Table 51 . Average annual costs are calculated by using the FY23 rate of 2.5% with a period of 50 years. The average annual costs are estimated at about $763,000. With benefits just above $1.8 million, the net benefits are estimated at just under $1.1 million. The NED plan has a benefit cost ratio of 2.43.

Table 50. NED Nonstructural Plan BCR

NED Nonstructural Plan Costs	Contract Cost ($)	Contingency (%)	Contingency ($)	Total Cost
Construction Cost	$11,857,479	43%	$5,098,716	**$16,956,195**
Planning, Engineering, and Design	$1,411,040	43%	$606,747	**$2,017,787**
Construction Management	$747,021	43%	$321,219	**$1,068,240**
Real Estate	$1,534,204	0%	$0	**$1,534,204**
Total	**$15,549,744**		**$6,026,682**	**$21,576,426**
Interest During Construction (3 Months)				$66,743
Total Investment Cost				**$21,643,169**
Average Annual Costs				**$763,096**
Average Annual Benefits				**$1,856,170**
Net Benefits				**$1,093,074**
BCR				**2.43**

Table 51. NED Plan Costs

NED Plan							
Reach	**Aggregation**	**Total**	**Construction Costs**	**Contingencies**	**IDC**	**Total Cost**	**Average Annual Costs**
STC1B	0.01 AEP Floodplain	15	$5,042,043	$1,932,468	$21,574	$6,996,086	$246,668
TP10A	10% AEP Floodplain	2	$567,189	$212,476	$2,412	$782,077	$27,575
TP10C	10% AEP Floodplain	2	$1,003,523	$400,100	$4,342	$1,407,965	$49,642
TP10D	0.01 AEP Floodplain	1	$328,774	$125,666	$1,406	$455,846	$16,072
TP3F	0.04 AEP Floodplain	17	$7,286,731	$2,866,270	$31,407	$10,184,408	$359,082
TP8	0.02 AEP Floodplain	4	$1,040,017	$384,378	$4,406	$1,428,801	$50,377
TP9A	0.02 AEP Floodplain	1	$281,467	$105,323	$1,196	$387,987	$13,680
Total		**42**	**$15,549,744**	**$6,026,682**	**$66,743**	**$21,643,169**	**$763,096**

The reaches and aggregations that made up the NED plan are listed in Table 52 along with the average annual benefits and costs for each reach.

Table 52. NED Plan Average Annual Costs and Benefit Summary (In $1,000)

NED Plan								
Reach	**Aggregation**	**Total**	**EAD Without**	**With EAD**	**Average Annual Benefits**	**Average Annual Costs**	**BCR**	**Net Benefits**
STC1B	0.01 AEP Floodplain	15	$1,016.37	$228.08	$788.29	$246.67	3.20	$541.62
TP10A	10% AEP Floodplain	2	$155.03	$60.47	$94.56	$27.57	3.43	$66.99
TP10C	10% AEP Floodplain	2	$212.71	$69.40	$143.31	$49.64	2.89	$93.67
TP10D	0.01 AEP Floodplain	1	$104.09	$70.18	$33.91	$16.07	2.11	$17.84
TP3F	0.04 AEP Floodplain	17	$2,398.92	$1,678.63	$720.29	$359.08	2.01	$361.21
TP8	0.02 AEP Floodplain	4	$180.52	$126.44	$54.08	$50.38	1.07	$3.70
TP9A	0.02 AEP Floodplain	1	$66.44	$44.71	$21.73	$13.68	1.59	$8.05
Total		**42**	**$4,134.08**	**$2,277.91**	**$1,856.17**	**$763.10**	**2.43**	**$1,093.07**

Following the identification of the reaches and structures that would comprise the NED plan, an analysis of relocations by reach was performed to ensure that all measures were considered in the analysis. The analysis assumed a $40,000 relocation assistance package per structure, as well as utilizing the total costs including land value for the acquisition of the property as estimated by the real estate assessment. Finally, a contingency of 43% was added to account for uncertainties in these cost estimates. This analysis revealed only one reach which showed a positive net benefit, but the overall net benefits were significantly less. From this analysis, it was determined that buyouts and relocations were not economically justified in this study. Table 53 below gives a complete overview of the analysis.

Table 53. NED Plan Relocation and Buy-Out Analysis Net Benefits by Reach

Reach	Aggregation	Number of Structures	Total Relocation Cost	Average Annual Costs	Average Annual Benefits (100 yr Nonstruc)	Net Benefits	BCR
STC1B	0.01 AEP Floodplain	15	$28,859	$1,018	$509	-$508	0.50
TP10A	10% AEP Floodplain	2	$2,221	$79	$125	$47	1.59
TP10C	10% AEP Floodplain	2	$1,393	$49	$171	$122	3.48
TP10D	0.01 AEP Floodplain	1	$1,191	$42	$35	-$7	0.83
TP3F	0.04 AEP Floodplain	17	$54,307	$1,921	$939	-$982	0.49
TP8	0.02 AEP Floodplain	4	$3,237	$114	$69	-$45	0.60
TP9A	0.02 AEP Floodplain	1	$850	$30	$15	-$15	0.51
Total		**42**	**$92,058**	**$3,253**	**$1,864**	**-$1,389**	**0.57**

8.10. Alternative 3B: Comprehensive Benefits Plan

Per the 5 January 2021 SACW POLICY DIRECTIVE – Comprehensive Documentation of Benefits in Decision Document, all USACE planning study project delivery teams (PDTs) must evaluate and provide a complete accounting, consideration, and documentation of the total benefits of alternative plans across all benefit categories. Total benefits involve a summation of monetized and/or quantified benefits, along with a complete accounting of qualitative benefits, for project alternatives across national and regional economic, environmental, and social benefit

categories. Therefore, the PDT formulated a comprehensive benefits plan which reasonably maximized benefits across all categories.

As a result of that analysis, 13 damage reaches with all structures in the 0.01 AEP floodplain were included. The 13 damage reaches total includes all 7 reaches in the NED plan at the 0.01 AEP aggregation as well as 6 additional reaches in the surrounding areas of the NED reaches. The 6 additional reaches were determined to have environmental justice and social vulnerability concerns that would warrant inclusion in a comprehensive benefit analysis and is discussed in detail below Section 9 in comparison to the NED Plan. All reaches used the 0.01 AEP floodplain aggregation to minimize the impacts on community cohesion.

The formulated comprehensive benefits plan includes a total of 157 structures. Of these. 96 are recommended for dry floodproofing, 35 for elevation alone, 18 for elevation and flood vents, and 8 with only flood vents as presented in Table 54.

Table 54. Comprehensive Benefit Measures by Reach

Reach	Aggregation	Elevate	Elevate Flood Vent	Flood Vent	Dry Floodproof	Total
STC1B	0.01 AEP Floodplain	1	0	0	14	15
STC1C	0.01 AEP Floodplain	1	7	4	7	19
STC1F	0.01 AEP Floodplain	0	0	0	1	1
TP10A	0.01 AEP Floodplain	0	1	1	2	4
TP10B	0.01 AEP Floodplain	1	0	0	1	2
TP10C	0.01 AEP Floodplain	0	3	1	1	5
TP10D	0.01 AEP Floodplain	0	0	0	1	1
TP3C	0.01 AEP Floodplain	22	0	0	0	22
TP3F	0.01 AEP Floodplain	10	5	0	54	69
TP8	0.01 AEP Floodplain	0	1	0	9	10
TP9A	0.01 AEP Floodplain	0	0	2	2	4
TP9C	0.01 AEP Floodplain	0	0	0	1	1
TP9D	0.01 AEP Floodplain	0	1	0	3	4
Total	**Comp Benefits**	**35**	**18**	**8**	**96**	**157**

The total construction costs of the identified 157 structures are estimated at just under $48 million. Construction costs includes first building costs, PED, Construction Management, and Real Estate costs. PED is estimated at 11.9% of construction costs, construction management is estimated at 6.3% of construction costs, and real estate is estimated at $5,000 per residential structure and $15,000 per nonresidential structure. A contingency of 43% is added to construction, PED, and construction management. The interest during construction is estimated on the total of the costs plus contingencies and is over a 3-month construction period. The total investment cost is estimated at just over $66 million. Average annual costs are calculated by using the FY23 rate of 2.5% with a period of 50 years. The average annual costs are estimated at about $2.3 million. With benefits just under $2.6 million, the net benefits are estimated at just above $250,000. This is a benefit cost ratio of 1.11. Table 55 through Table 57 illustrate the costs and benefits in each of reaches for the comprehensive benefits plan.

Table 55. Comprehensive Benefits Plan

Alternative 3B: Comprehensive Benefits Plan							
Reach	**Aggregation**	**Total**	**Construction Costs**	**Contingencies**	**IDC**	**Total Cost**	**Average Annual Costs**
STC1B	0.01 AEP Floodplain	15	$5,042,043	$1,932,468	$21,574	$6,996,086	$246,668
STC1C	0.01 AEP Floodplain	19	$5,314,987	$1,987,005	$22,587	$7,324,580	$258,250
STC1F	0.01 AEP Floodplain	1	$497,260	$198,114	$2,151	$697,525	$24,593
TP10A	0.01 AEP Floodplain	4	$1,249,707	$474,545	$5,334	$1,729,585	$60,982
TP10B	0.01 AEP Floodplain	2	$518,910	$191,717	$2,198	$712,825	$25,133
TP10C	0.01 AEP Floodplain	5	$1,619,781	$617,969	$6,922	$2,244,673	$79,143
TP10D	0.01 AEP Floodplain	1	$328,774	$125,666	$1,406	$455,846	$16,072
TP3C	0.01 AEP Floodplain	22	$6,944,696	$2,640,658	$29,651	$9,615,004	$339,006
TP3F	0.01 AEP Floodplain	69	$21,469,807	$8,148,212	$91,618	$29,709,637	$1,047,504
TP8	0.01 AEP Floodplain	10	$2,215,218	$795,470	$9,313	$3,020,001	$106,479
TP9A	0.01 AEP Floodplain	4	$895,300	$322,150	$3,766	$1,221,216	$43,058
TP9C	0.01 AEP Floodplain	1	$144,598	$46,470	$591	$191,659	$6,758
TP9D	0.01 AEP Floodplain	4	$1,703,240	$669,564	$7,340	$2,380,144	$83,919
Total		**157**	**$47,944,321**	**$18,150,008**	**$204,452**	**$66,298,781**	**$2,337,566**

Table 56. Comprehensive Benefits Plan Average Annual Costs and Benefits (In $1,000)

Alternative 3B: Comprehensive Benefits Plan								
Reach	**Aggregation**	**Total**	**EAD Without**	**With EAD**	**Average Annual Benefits**	**Average Annual Costs**	**BCR**	**Net Benefits**
STC1B	0.01 AEP Floodplain	15	$1,016.37	$228.08	$788.29	$246.67	3.20	$541.62
STC1C	0.01 AEP Floodplain	19	$393.14	$156.13	$237.01	$258.25	0.92	-$21.24
STC1F	0.01 AEP Floodplain	1	$24.50	$9.36	$15.14	$24.59	0.62	-$9.45
TP10A	0.01 AEP Floodplain	4	$155.03	$49.56	$105.47	$60.98	1.73	$44.49
TP10B	0.01 AEP Floodplain	2	$183.72	$174.56	$9.16	$25.13	0.36	-$15.97
TP10C	0.01 AEP Floodplain	5	$212.71	$64.72	$147.99	$79.14	1.87	$68.85
TP10D	0.01 AEP Floodplain	1	$104.09	$70.18	$33.91	$16.07	2.11	$17.84
TP3C	0.01 AEP Floodplain	22	$66.83	$59.40	$7.43	$339.01	0.02	-$331.58
TP3F	0.01 AEP Floodplain	69	$2,398.92	$1,307.48	$1,091.44	$1,047.50	1.04	$43.94
TP8	0.01 AEP Floodplain	10	$180.52	$109.00	$71.52	$106.48	0.67	-$34.96
TP9A	0.01 AEP Floodplain	4	$66.44	$28.78	$37.66	$43.06	0.87	-$5.40
TP9C	0.01 AEP Floodplain	1	$11.19	$10.65	$0.54	$6.76	0.08	-$6.22
TP9D	0.01 AEP Floodplain	4	$130.46	$84.47	$45.99	$83.92	0.55	-$37.93
Total		**157**	**$4,943.92**	**$2,352.37**	**$2,591.55**	**$2,337.57**	**1.11**	**$253.98**

Table 57. Alternative 3B Comprehensive Benefit BCR

Comprehensive Benefits Costs	Contract Cost ($)	Contingency (%)	Contingency ($)	Total Cost
Construction Cost	$35,710,086	43%	$15,355,337	**$51,065,423**
Planning, Engineering, and Design	$4,249,500	43%	$1,827,285	**$6,076,785**
Construction Management	$2,249,735	43%	$967,386	**$3,217,122**
Real Estate	$5,735,000	0%	$0	**$5,735,000**
Total	**$47,944,321**		**$18,150,008**	**$66,094,329**
Interest During Construction (3 Months)				$204,452
Total Investment Cost				**$66,298,781**
Average Annual Costs				**$2,337,566**
Average Annual Benefits				**$2,591,550**
Net Benefits				**$253,984**
BCR				**1.11**

Following the identification of the reaches and structures that would comprise the comprehensive benefits plan, an analysis of relocations by reach was performed to ensure that all measures were considered in the analysis. The analysis assumed a $40,000 relocation assistance package per structure, as well as utilizing the total costs including land value for the acquisition of the property as estimated by the real estate assessment. Finally, a contingency of 43% was added to account for uncertainties in these cost estimates. This analysis revealed only one reach which showed a positive net benefit, but those benefits were less than the net benefits of the previously identified measures. From this analysis, it was determined that buyouts and relocations were not economically justified in this study. Table 58 below gives a complete overview of the analysis.

Table 58. Relocation and Buy-Out Analysis Net Benefits by Reach

Reach	Number of Structures	Total Relocation Cost	Average Annual Costs	Average Annual Benefits (100 yr Nonstruc)	Net Benefits	BCR
STC1B	15	$28,858,972	$1,017.51	$788.29	-$229.22	0.77
STC1C	19	$23,718,835	$836.28	$237.01	-$599.27	0.28
STC1F	1	$5,551,011	$195.72	$15.14	-$180.58	0.08
TP10A	4	$3,465,148	$122.17	$105.47	-$16.70	0.86
TP10B	2	$715,149	$25.21	$9.16	-$16.05	0.36
TP10C	5	$3,639,816	$128.33	$147.99	$19.66	1.15
TP10D	1	$1,191,478	$42.01	$33.91	-$8.10	0.81
TP3C	22	$6,844,784	$241.33	$7.43	-$233.90	0.03
TP3F	69	$137,910,980	$4,862.47	$1,091.44	-$3,771.03	0.22
TP8	10	$6,289,620	$221.76	$71.52	-$150.24	0.32
TP9A	4	$4,267,226	$150.45	$37.66	-$112.79	0.25
TP9C	1	$151,632	$5.35	$0.54	-$4.81	0.10
TP9D	4	$15,497,514	$546.41	$45.99	-$500.42	0.08
Total	**157**	**$238,102,164**	**$8,395**	**$2,592**	**-$5,803**	**0.31**

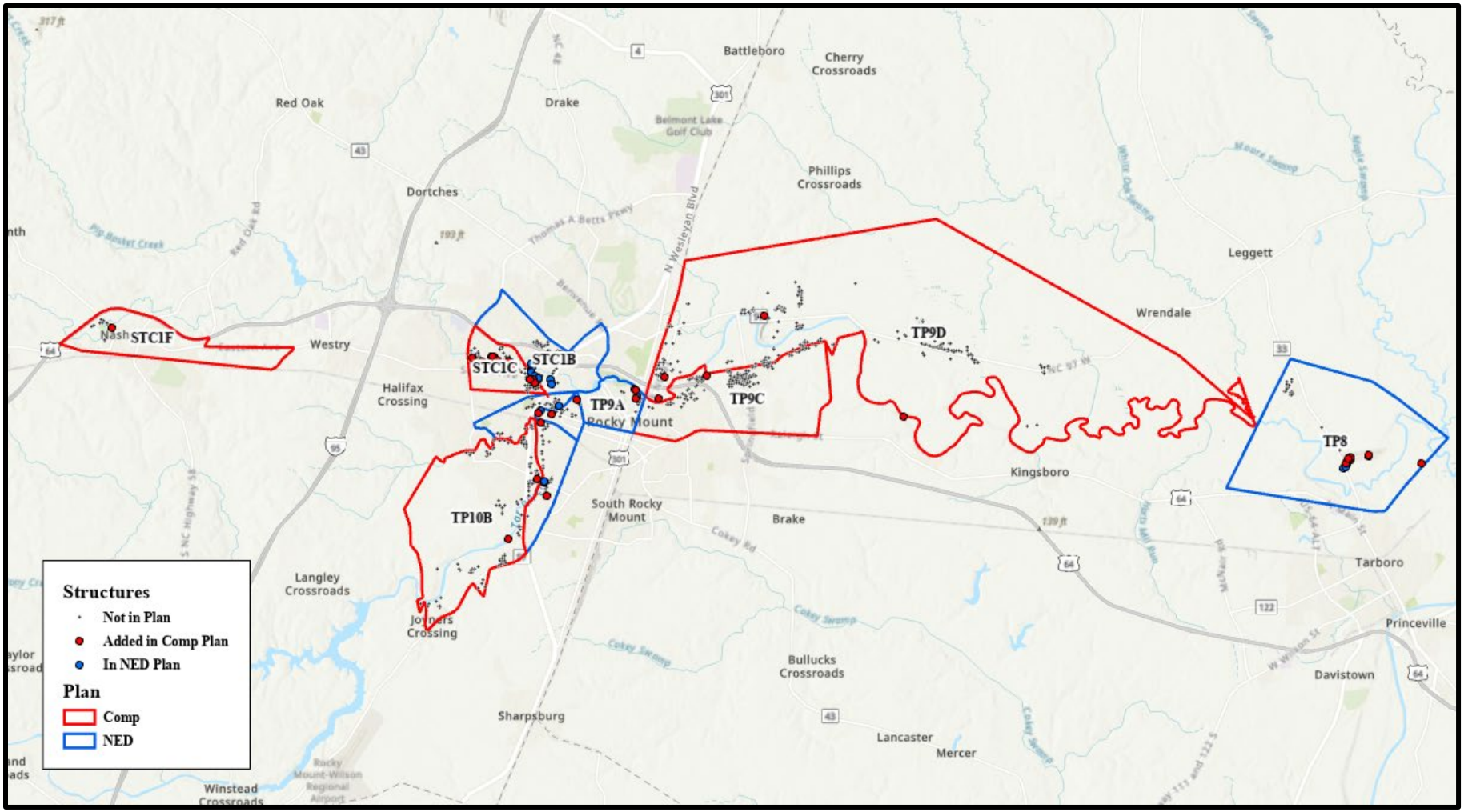
Structures
Not in Plan
Added in Comp Plan
In NED Plan
Plan
Comp
NED
STC1F
STC1C
STC1B
TP9A
TP9C
TP9D
TP8
TP10B
Battleboro
Cherry Crossroads
Red Oak
Drake
Dortches
Phillips Crossroads
Leggett
Wrendale
Westry
Halifax Crossing
Rocky Mount
South Rocky Mount
Brake
Kingsboro
Tarboro
Princeville
Davistown
Langley Crossroads
Joyners Crossing
Bullucks Crossroads
Sharpsburg
Lancaster
Mercer
Winstead Crossroads

Figure 31. Structures in Rocky Mount Area in Alternative 3A NED Plan and 3B Comp Benefits Plan

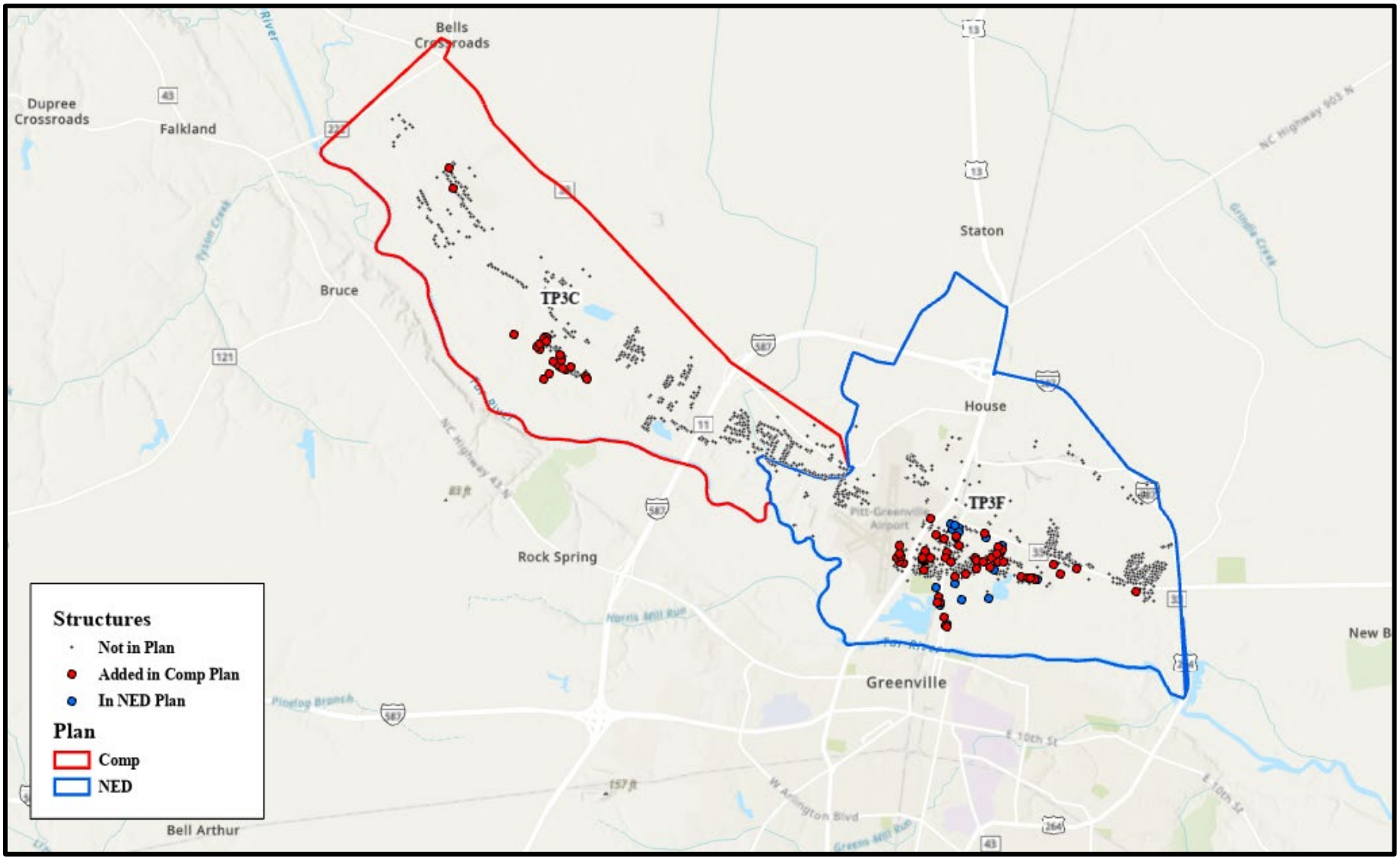

Figure 32. Structures in Greenville Area in Alternative 3A NED Plan and 3B Comp Benefits Plan

9. COMPREHENSIVE BENEFITS PLAN DEVELOPMENT

As previously described in Section 5.6, natural disasters such as flooding have significant impacts on vulnerable populations and impact the vitality of the community. The study area as a whole endured numerous natural disasters which include flooding from hurricanes and rain fall events which hampers the community's resiliency. Implementing a more comprehensive plan compared to the existing conditions and NED Plan would greatly impact community cohesion, allowing a community to recover more effectively individually and economically based on the damage reduction of from an event.

9.1. Selection Criteria

9.1.1. Repetitive Flooding

It is widely recognized that natural disasters effect the livelihoods of people living in the impacted community, but being exposed to numerous inundation events hamper the community as a whole to recover. As previously stated, the Tar Pamlico study area has witnessed numerous floods. Specifically, the communities around Rock Mount and Greenville have been impacted by high water events numerous times in the past ten years hindering the economic viability of the community and creates an ongoing cycle of recovery. Several events are listed below in Table 59. In addition, Figure 33 through Figure 43 illustrated numerous flood events occurring in Rocky Mount and Greenville directly impacted by Alternative 3B.

Table 59. Flood History

Hurricane	Rain Event
Bertha (1996)	Rocky Mount Area (April 25, 2017)
Fran (1996)	Rocky Mount Area (June 16,2020)
Bonnie (1998)	Rocky Mount Area (July 14, 2023)
Dennis (1999)	Greenville Area (June 2019)
Floyd (1999),	
Isabel (2003)	
Irene (2011)	
Matthew (2016)	

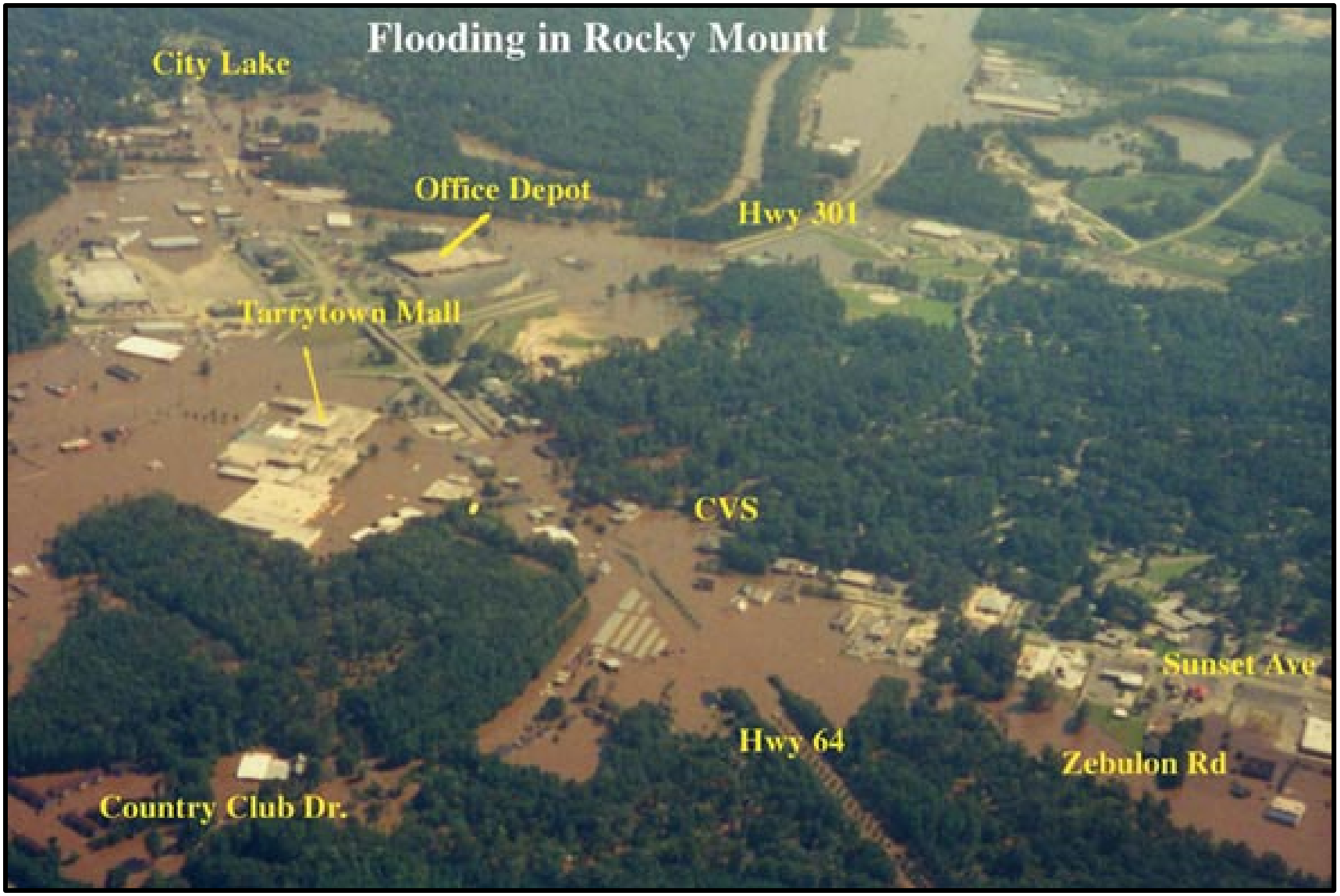

Figure 33. Rocky Mount 1999 Hurricane Floyd

Figure 34. Rocky Mount 2016 Hurricane Matthew

Figure 35. Rocky Mount 2016 Hurricane Matthew

Figure 36. Rocky Mount Flooding April 2017

Figure 37. Rocky Mount Flooding June 2020

Figure 38. Rocky Mount Flooding June 2020

Figure 39. Rocky Mount Flooding June 2020

Figure 40. Rocky Mount Flooding June 2020

Figure 41. Rocky Mount Flooding July 2023

Figure 42. Greenville Airport Flooding 2016 Hurricane Matthew

Figure 43. Greenville Flooding 2016 Hurricane Matthew

Figure 44. Greenville Flooding June 2019

9.1.2. Disadvantaged Populations

The repetitive flooding illustrated above impacts a number of disadvantaged peoples. Generally, vulnerable low-income populations are more exposed to devastating costs of flooding whether it be from not having adequate flood insurance or lack of available resources. Losses by income and ethnic groups partly depend on whether flood management programs have reached the vulnerable population. The Comprehensive Benefits Policy Directive allows for social benefit categories to be considered when formulating a tentatively selected plan. Below are two of the tools available for use in USACE studies and were utilized to identify disadvantaged populations in the Tar Pamlico watershed which were used to formulate Alternative 3B the comprehensive benefits plan.

9.1.3. CEQ Tool

In January of 2021, President Biden issued Executive Order 14008 directing the Council on Environmental Quality (CEQ) to develop a new tool that characterizes environmental justice considerations. This tool—the Climate and Economic Justice Screening Tool (CEJST) —provides indicators of burdens in eight categories: climate change, energy, health, housing, legacy pollution, transportation, water and wastewater, and workforce development. A community is highlighted as disadvantaged on the CEJST map if it is in a census tract that is (1) at or above the threshold for one or more environmental, climate, or other burdens, and (2) at or above the threshold for an associated socioeconomic burden. These categories and thresholds are laid out in Table 60.

Table 60. CEQ Tool Categories and Threshold Criteria

	Categories							
	Climate Change	**Energy**	**Health**	**Housing**	**Legacy Pollution**	**Transportation**	**Water and Wastewater**	**Workforce Development**
Total Threshold Criteria	Expected agriculture loss rate	Energy Costs	Asthma	Housing Cost	Abandoned mine land	Diesel particulate matter exposure	Underground storage tanks and releases	Linguistic isolation
	Expected building loss rate	PM 2.5 in the Air (Air Quality)	Diabetes	Lack of Green Space	Formerly Used Defense Sites	Transportation barriers	Wastewater discharge	Low median income
	Expected population loss rate	**And Low Income**	Heart Disease	Lack of Indoor Plumbing	Proximity to hazardous waste facilities	Traffic proximity and volume	**And Low Income**	Poverty
	Projected flood risk		Low Life Expectancy	Lead Paint	Proximity to Risk Management Plan facilities	**And Low Income**		Unemployment
	Projected wildfire risk		**And Low Income**	**And Low Income**	Proximity to Superfund sites			Less Than Highschool Education
	And Low Income				**And Low Income**			

The tool uses this information to identify communities that are experiencing these burdens and are thus disadvantaged because they are overburdened and underserved. There are numerous tracts within the study area that are considered disadvantaged by one or more of the burden categories as shown in Figure 45. This information along with the data for EJ screen was used to formulate Alternative 3B the comprehensive benefits plan by bringing in reaches within the vicinity of reaches included in the NED plan.

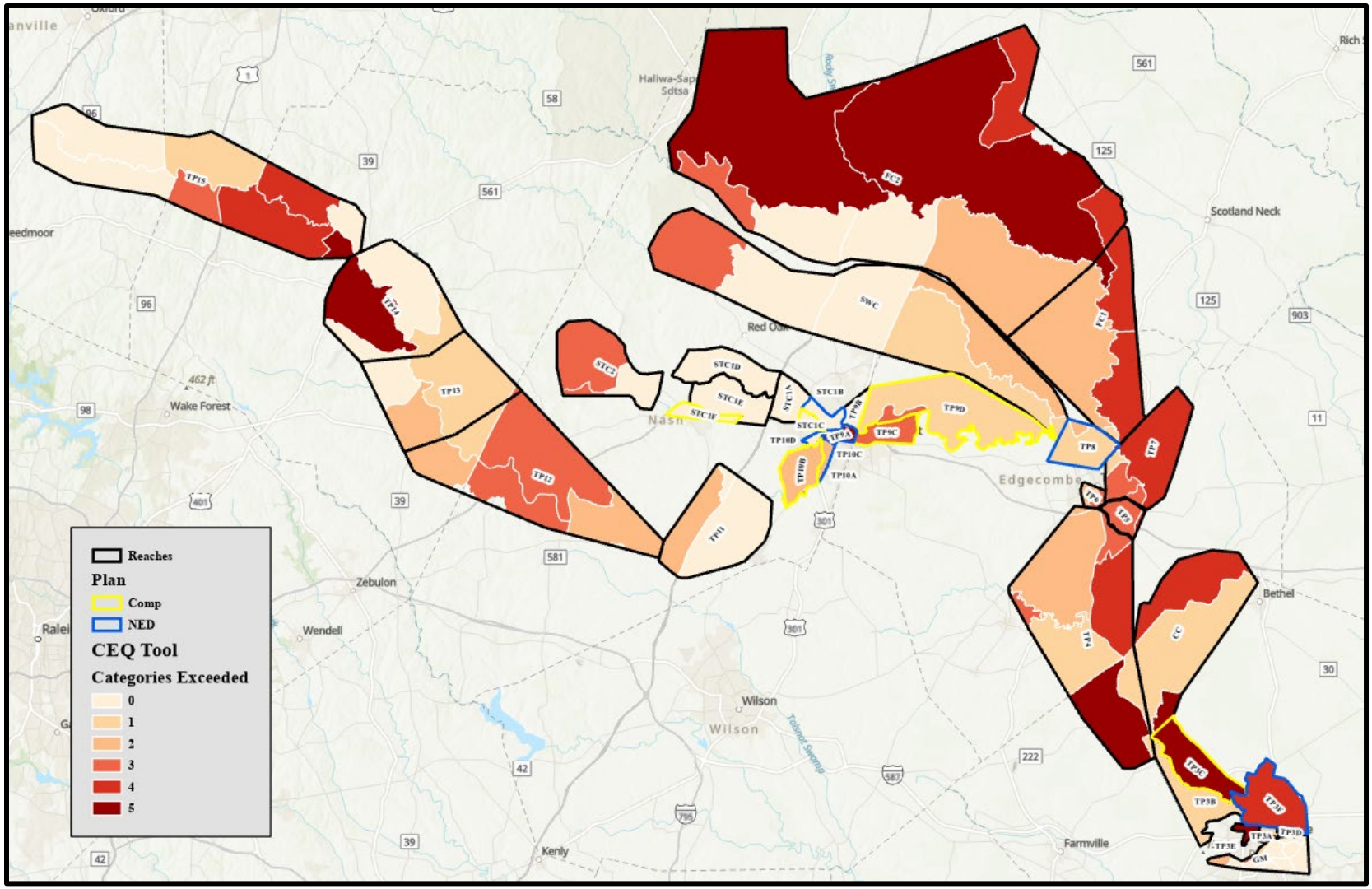

Figure 45. CEQ Tool Categories Exceeded Tar Pamlico Study Area

Table 61 illustrates if a reach within the comprehensive benefits plan exceeds any of the categories in the CEQ tool and which category it is. In addition, Figure 46 through Figure 47Figure 48 illustrate the reaches added onto the Comprehensive benefits plan in proximity to the reaches in the NED plan.

Table 61. CEQ Study Area Alternatives Categories Exceeded

Reach	Climate Threshold Exceeded	Energy Threshold Exceeded	Traffic Threshold Exceeded	Housing Threshold Exceeded	Pollution Threshold Exceeded	Water Threshold Exceeded	Health Threshold Exceeded	Workforce Threshold Exceeded	Identified As Disadvantaged	Total Categories Exceeded
Rocky Mount										
TP9A	X	X				X	X	X	X	5
TP9C	X	X					X		X	3
TP9D*								X	X	1
TP10A	X			X					X	2
TP10B	X			X					X	2
TP10C*	X	X				X	X	X	X	5
TP10D*										0
STC1B*										0
STC1C										0
STC1F										0
TP8*	X								X	1
Greenville										
TP3C	X	X	X				X	X	X	5
TP3F*	X	X					X	X	X	4

Note: X represents if a category was exceeded for the specific reach. *Reach is in NED plan

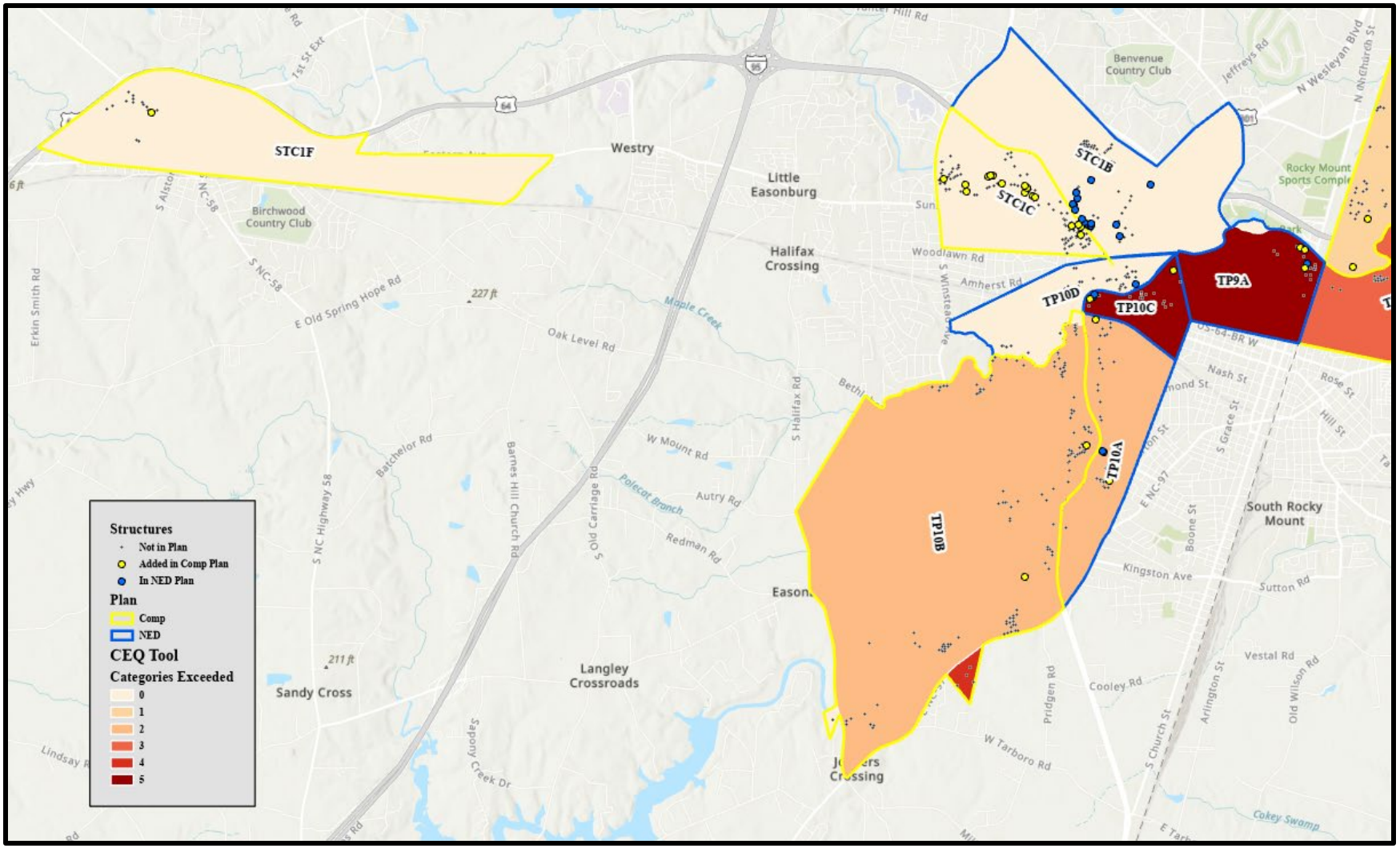

Figure 46. CEQ Tool Categories Exceeded Alternatives West of Rocky Mount

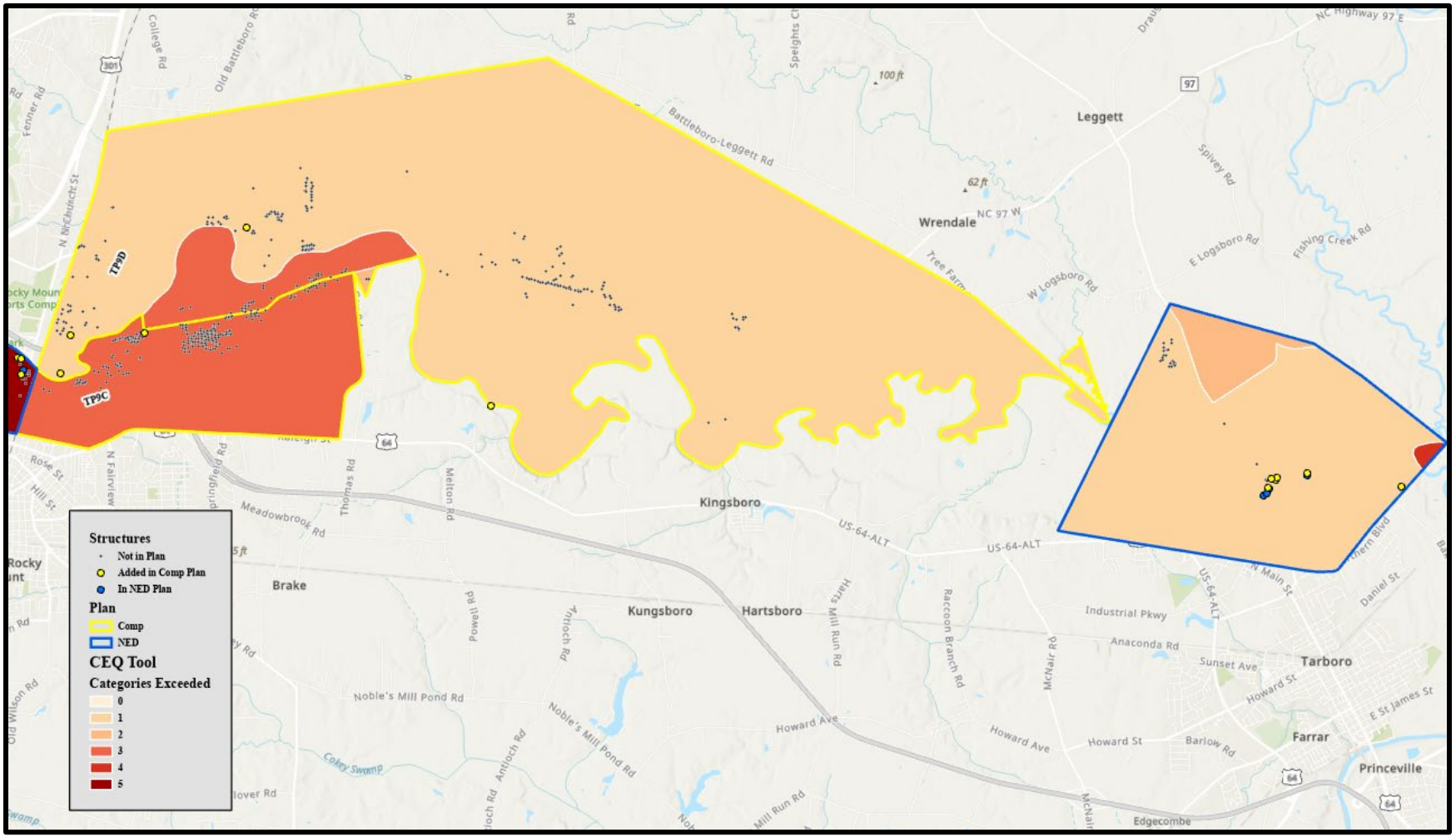

Figure 47. CEQ Tool Categories Exceeded Alternatives East of Rocky Mount

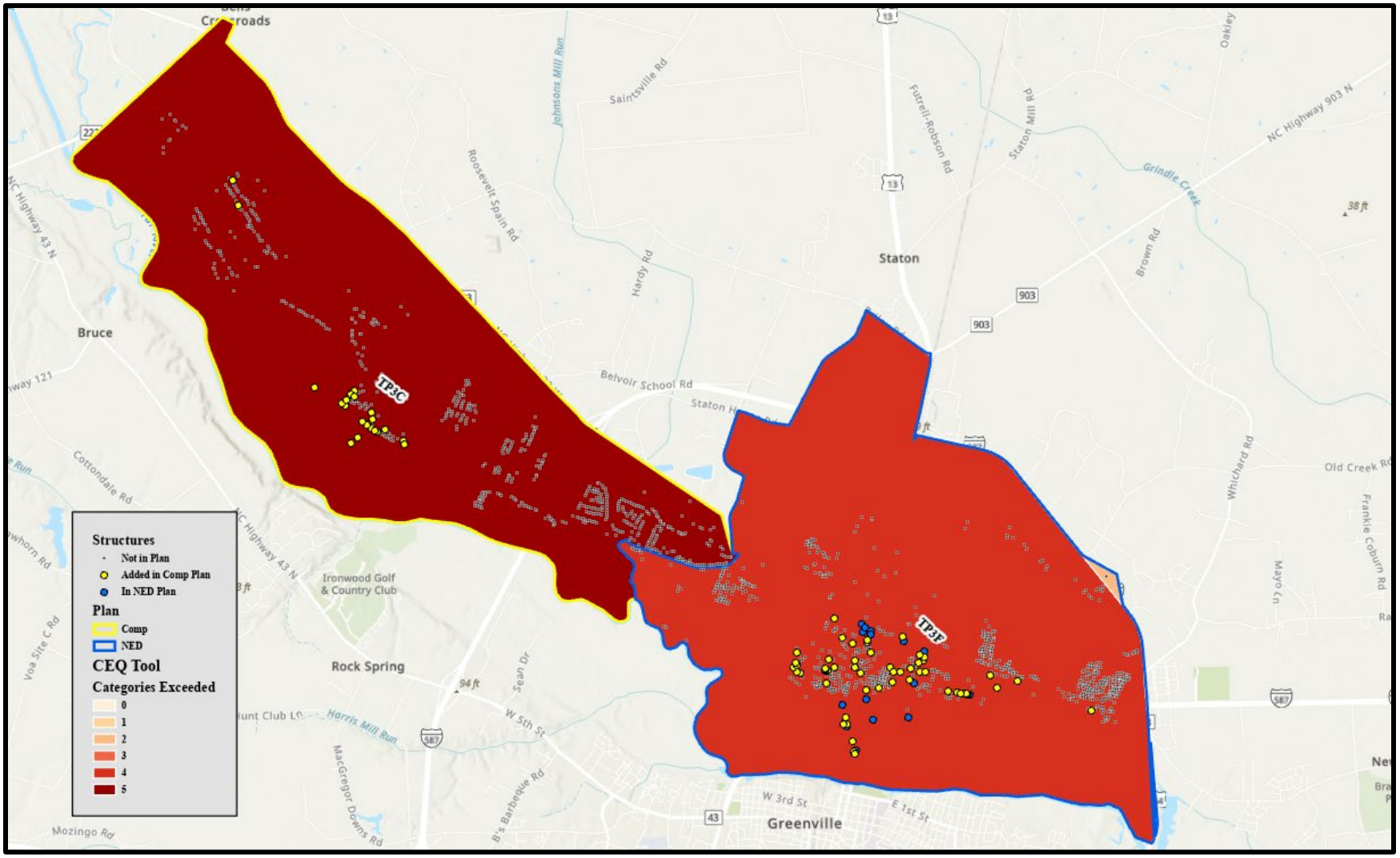

Figure 48. CEQ Tool Categories Exceeded Alternatives Greenville

9.1.4. EJ Screen Tool

The Environmental Justice Screen (EJ Screen) tool, developed by the US Environmental Protection Agency, is another mapping and screening tool that provides a nationally consistent dataset and approach for combining environmental and demographic socioeconomic indicators using Census Tracts into indices that provide an assessment of environmental justice. One of these indices is the Demographic Index, which is based on the average of the percentage of people with low-income (i.e., less than or equal to twice the federal 'poverty level') and people of color (i.e., racial status other than white alone and/or ethnicity as Hispanic or Latino). The higher the Demographic Index score, the greater the combined proportion of people of color and people with low income—a group that is historically underserved. Figure 49 illustrates the Demographic Index percentile compared to the nation. This was used in combination with the CEQ tool to determine disadvantaged reaches in proximity to reaches in the NED plan for incorporation into the comprehensive benefits plan or Alternative 3B as shown in Figure 49 through Figure 53.

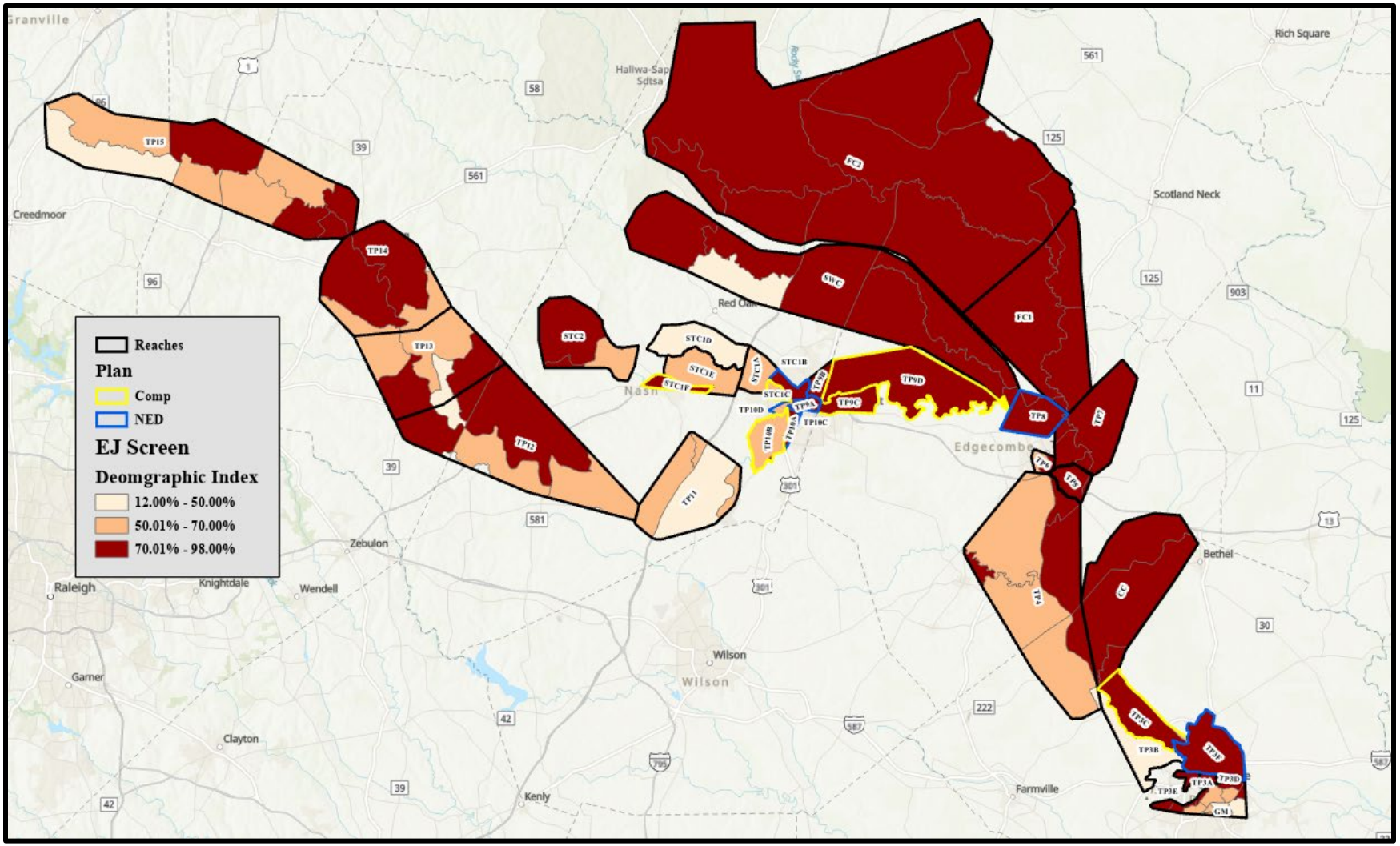

Figure 49. EJ Screen Demographic Index Tar Pam Watershed

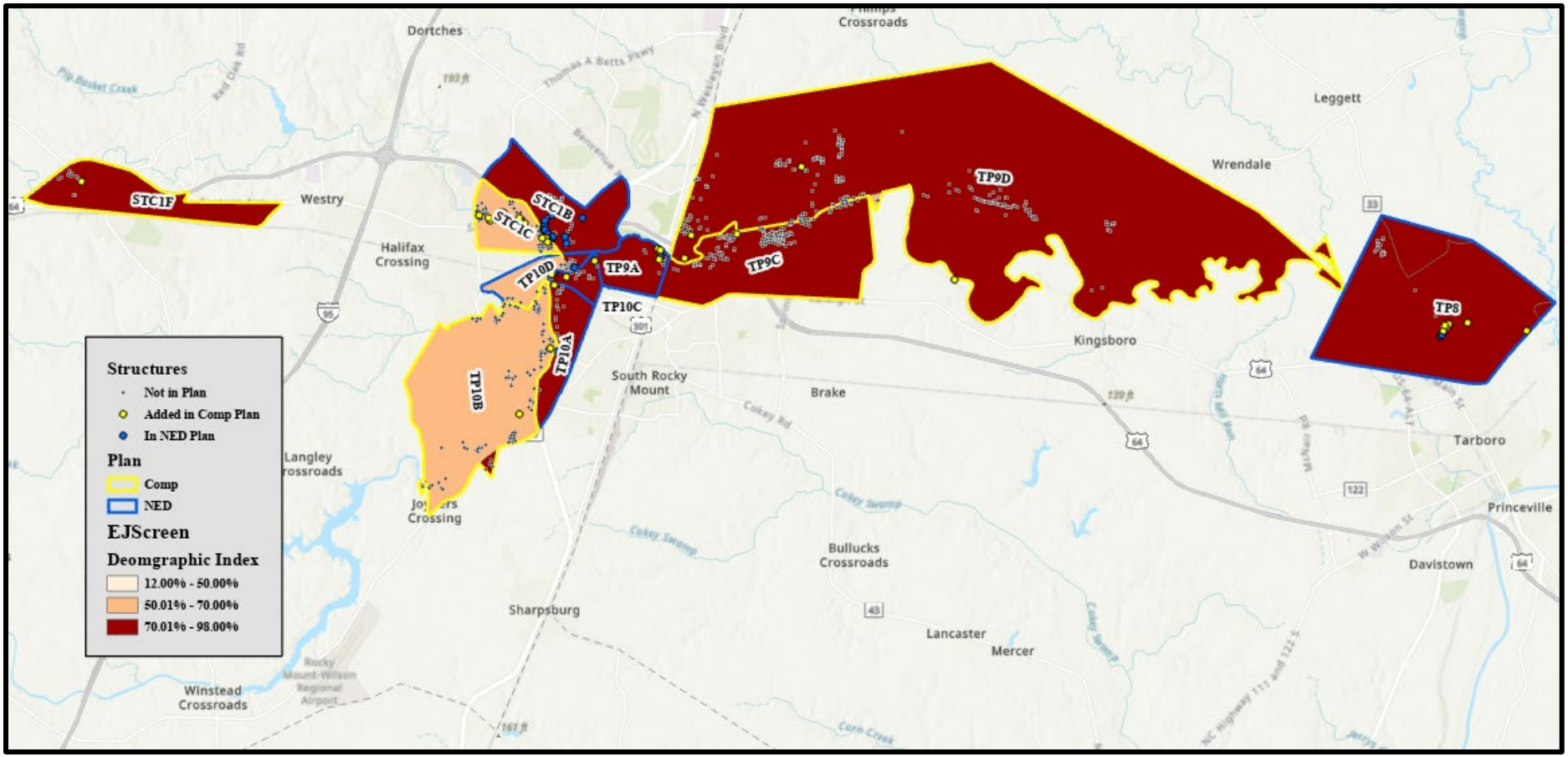

Figure 50. EJ Screen Demographic Index with Alternatives in Rocky Mount Area

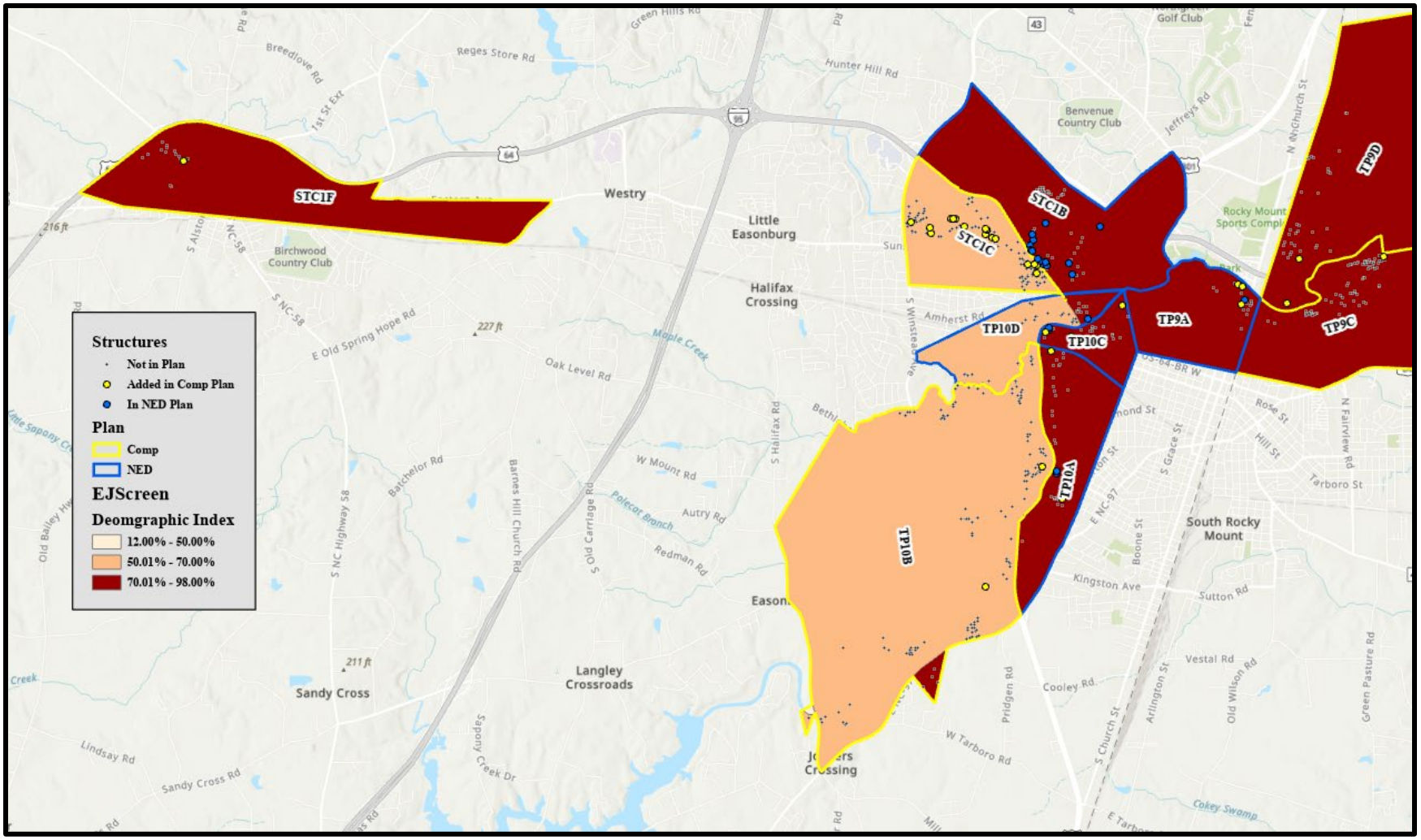

Figure 51. EJ Screen Demographic Index with Alternatives in Rocky Mount Area Zoomed In

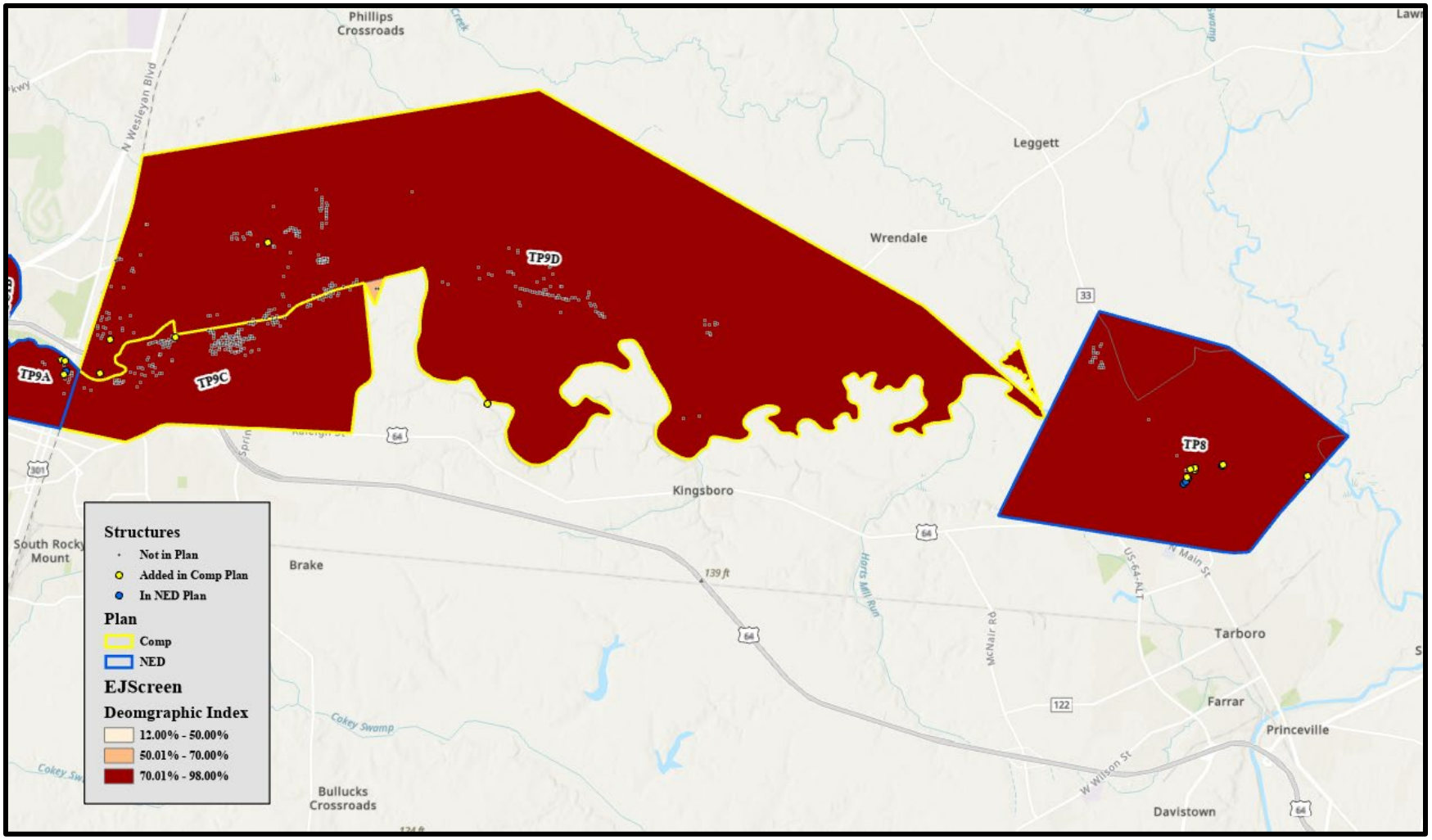
Phillips Crossroads
N Wesleyan Blvd
Leggett
Wrendale
TP9D
TP9A
TP9C
TP8
Kingsboro
South Rocky Mount
Brake
139 ft
Horns Mill Run
McNair Rd
US-64-ALT
N Main St
Tarboro
Farrar
Princeville
W Wilson St
Davistown
Cokey Swamp
Bullucks Crossroads
Structures
Not in Plan
Added in Comp Plan
In NED Plan
Plan
Comp
NED
EJScreen
Deomgraphic Index
12.00% - 50.00%
50.01% - 70.00%
70.01% - 98.00%

Figure 52. EJ Screen Demographic Index with Alternatives in Rocky Mount Area Zoomed In

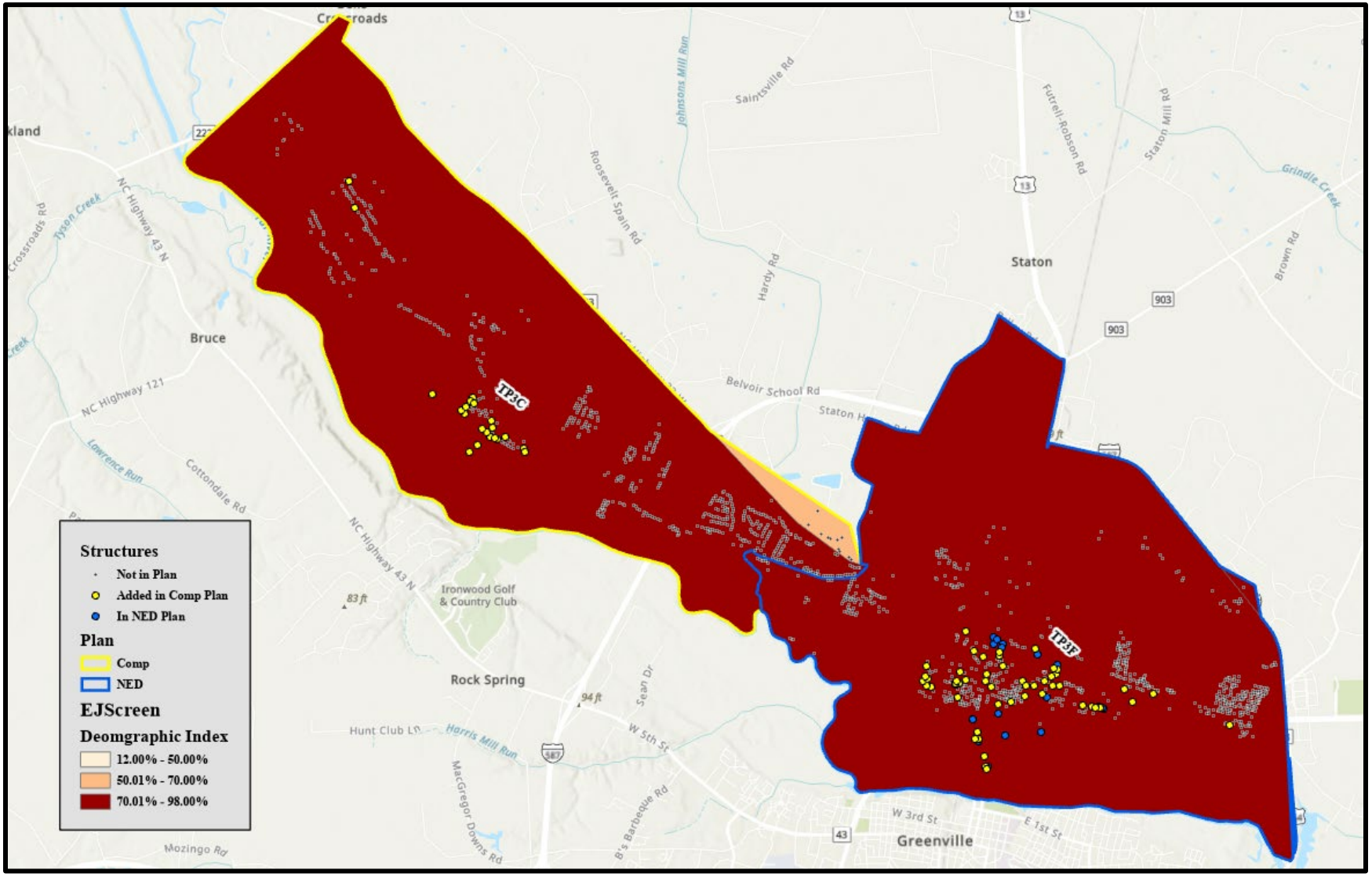

Figure 53. EJ Screen Demographic Index with Alternatives in Greenville

In addition, socioeconomic information by Census Tract is included in the dataset with the percentiles based on the national average using the most up to date US Census American Community Survey Data (2017-2022). Table 62 provides the percentages of each category while Table 63 provides the percentile for each Census Tract compared to the nation. After discussions with the PDT, it was determined that if a tract was above the 75th percentile, then it was considered a vulnerable or disadvantaged population. As illustrated in Table 62, there are significant numbers of minority, low income, and dependent populations in specific reaches along with five reached with an unemployment rate in double digits. The percentages demonstrate the presence of vulnerable population in the study area but seeing the percentiles in comparison to the nation in Table 63 exemplifies this.

Table 62. EJ Screen Percentages

Reach	Population	Census FIPS code	Demographic Index	People of Color	Low Income	Unemployment Rate	Less Than Highschool Education	Under Age 5	Over Age 64
Rocky Mount									
TP9A*	4,096	37065020400	72.4%	96.1%	48.8%	6.8%	11.5%	8.5%	19.9%
TP9C	2,202	37065020600	63.1%	72.2%	54.1%	10.9%	8.6%	5.7%	21.0%
TP9D	3,582	37127010400	61.0%	78.4%	43.5%	8.8%	16.2%	2.9%	12.8%
TP10A*	3,215	37127010301	63.2%	75.2%	51.3%	10.5%	13.3%	3.2%	17.1%
TP10B	2,568	37127010302	38.2%	43.3%	33.1%	3.7%	11.8%	1.5%	24.9%
TP10C*	3,582	37127010400	61.0%	78.4%	43.5%	8.8%	16.2%	2.9%	12.8%
TP10D*	4,827	37127010506	42.5%	65.7%	19.2%	15.9%	4.5%	6.4%	15.6%
STC1B*	3,217	37127010505	47.8%	73.7%	21.9%	8.2%	5.2%	1.7%	20.6%
STC1C	4,827	37127010506	42.5%	65.7%	19.2%	15.9%	4.5%	6.4%	15.6%
STC1F	5,462	37127011103	46.8%	61.2%	32.5%	8.1%	3.1%	5.6%	15.6%
TP8*	3,891	37065021100	56.9%	67.7%	46.1%	8.5%	17.9%	5.5%	16.1%
Greenville									
TP3C	2,929	37147000800	71.5%	84.1%	59.0%	12.0%	23.6%	3.8%	16.7%
TP3F*	4,014	37147002003	77.5%	84.1%	70.9%	3.7%	26.6%	11.6%	14.1%

* Reach is in NED Plan

Table 63. EJ Screen Percentiles in Comparison National Data

Reach	Population	Census FIPS code	Demographic Index Percentile	People of Color Percentile	Low Income Percentile	Unemployment Rate Percentile	Less than Highschool Education Percentile	Under Age 5 Percentile	Over Age 64 Percentile
Rocky Mount									
TP9A*	4,096	37065020400	92%	94%	82%	69%	61%	84%	70%
TP9C	2,202	37065020600	86%	79%	87%	88%	49%	54%	75%
TP9D	3,582	37127010400	84%	83%	76%	81%	75%	16%	33%
TP10A*	3,215	37127010301	86%	81%	85%	87%	67%	19%	57%
TP10B	2,568	37127010302	62%	60%	59%	37%	62%	6%	87%
TP10C*	3,582	37127010400	84%	83%	76%	81%	75%	16%	33%
TP10D*	4,827	37127010506	67%	76%	31%	95%	25%	64%	49%
STC1B*	3,217	37127010505	72%	80%	37%	78%	30%	7%	74%
STC1C	4,827	37127010506	67%	76%	31%	95%	25%	64%	49%
STC1F	5,462	37127011103	71%	73%	58%	77%	17%	53%	48%
TP8*	3,891	37065021100	81%	77%	79%	79%	79%	51%	51%
Greenville									
TP3C	2,929	37147000800	92%	86%	91%	90%	88%	27%	55%
TP3F*	4,014	37147002003	95%	86%	96%	37%	91%	96%	40%

*** Reach is in NED Plan**

9.1.5. Summary of Comprehensive Benefit Plan Development

Although the Alternative 3A, the NED plan, does provide assistance to 39 commercial structures and 3 residential structures in communities identified as disadvantaged in some aspect, there are still structures in those reaches where vulnerable peoples live and work. With the repetitive flooding disrupting the daily life of these individuals and the stress put on the community, Alternative 3B, the comprehensive benefits plan, better addresses the problems the community. These areas have faced several floods in the past decade, and the comprehensive benefits plan allows for less disruption in the daily life for people in these vulnerable and disadvantaged areas by elevating 61 homes out of the floodplain and floodproofing 96 commercial businesses where the members of the community work and shop. Table 64 below summarizes if the reach in the plan has a BCR over 1 and the findings in the CEQ and EJ screen tools.

Table 64. EJ Screen and CEQ Tool Summary for Alternative 3B Comprehensive Benefits Plan

Reach	BCR Over 1 in Comp Benefits Plan	EJ Screen	CEQ Tool
Rocky Mount			
TP9A*		X- Demographic Index	X
TP9C		X- Demographic Index	X
TP9D		X- Demographic Index	X
TP10A*	X	X- Demographic Index	X
TP10B		X- Over 64	X
TP10C*	X	X- Demographic Index	X
TP10D*		X- Unemployment	
STC1B*	X	X- Minority	
STC1C		X- Unemployment	
STC1F		X- Unemployment	
TP8*		X- Demographic Index	X
Greenville			
TP3C		X- Demographic Index	X
TP3F*	X	X- Demographic Index	X

Note: X represents if a category was exceeded for the specific reach. * If in NED Plan

9.2. Life Safety NED Plan

The NED Plan was identified as the aggregation that reasonably maximized net benefits that accrued to the NED account. NED was measured by the decreased expected annual damages from the without-project to the with-project condition. This analysis looks at the changes in depths of the structures that were identified for elevation in this aggregation.

9.2.1. Flood Depth

A total of 42 structures across 7 damage reaches have been identified for nonstructural measures in the NED plan. A total of 3 structures are recommended to be elevated and will see a decrease in depths at the structure level as illustrated in Table 65.

Table 65. Recommended Nonstructural Measure Breakdown by Reach

Reach	Aggregation	Elevate	Elevate Flood Vent	Dry Floodproof	Total
STC1B	0.01 AEP Floodplain	1	0	14	15
TP10A	10% AEP Floodplain	0	0	2	2
TP10C	10% AEP Floodplain	0	1	1	2
TP10D	0.01 AEP Floodplain	0	0	1	1
TP3F	0.04 AEP Floodplain	1	0	16	17
TP8	0.02 AEP Floodplain	0	0	4	4
TP9A	0.02 AEP Floodplain	0	0	1	1
Total		**2**	**1**	**39**	**42**

Structures are recommended to be elevated to 2 feet above the 0.01 AEP flood stage. The average elevation across these structures is 1.84 feet which would translate to 1.84 less depth at the first floor on average. The implication is that these structures see a decrease in overall life loss risk because water is not expected to reach the living area of these structures as illustrate in Table 66.

Table 66. Depth Change by Structure

Structure	Occ Type	SID Reach	Elevation (ft)	FWOP Depth at 0.04 AEP	NED Depth at 0.04 AEP	FWOP Depth at 0.01 AEP	NED Depth at 0.01 AEP	FWOP Depth at 0.002 AEP	NED Depth at 0.002 AEP
5367	R06	STC1B	2.72	-0.16	-2.89	0.72	-2.00	1.76	-0.97
5236	R04	TP10C	1.61	-1.73	-3.34	-0.39	-2.00	1.09	-0.52
2049	R07	TP3C	1.19	-9.17	-10.36	-0.81	-2.00	2.73	1.54

9.2.2. Risk Perception

While the proposed nonstructural measure for nonresidential structures does not change depth of water in the structure, it does provide an additional level of awareness to the employees at these structures. Dry floodproofing requires the closure of openings such as doors and windows. These additional requirements will lead to training and awareness of how to act in a flooding situation. As previously stated, the state has an extensive notification system to inform residents of flood risk in real time using gage data (https://fiman.nc.gov/#/) and there are numerous resources provided by the local and county governments outlining the flood risk for prone areas, but the

nonstructural measures heavily rely on implementation of the temporary measures on a structure such as blocking off openings.

Similarly, houses that have been floodproofed increases the awareness of the risk to not only the residents in that home, but throughout the community. Because nonstructural plans are formulated at the community level for structures experiencing similar flood risks, the awareness throughout the community is high even if individuals opt out of participating.

9.3. Life Safety Comprehensive Benefits Plan

The comprehensive benefits aggregation reasonably maximized the net benefits across all benefit categories.

9.3.1. Flood Depth

A total of 157 structures across 13 damage reaches have been identified for nonstructural measures as illustrated in Table 67. A total of 53 structures are recommended to be elevated and will see a decrease in depths at the structure level. All reaches were aggregated to the 0.01 AEP floodplain.

Table 67. Recommended Nonstructural Measure Breakdown by Reach

Reach	Elevate	Elevate Flood Vent	Flood Vent	Dry Floodproof	Total
STC1B	1	0	0	14	15
STC1C	1	7	4	7	19
STC1F	0	0	0	1	1
TP10A	0	1	1	2	4
TP10B	1	0	0	1	2
TP10C	0	3	1	1	5
TP10D	0	0	0	1	1
TP3C	22	0	0	0	22
TP3F	10	5	0	54	69
TP8	0	1	0	9	10
TP9A	0	0	2	2	4
TP9C	0	0	0	1	1
TP9D	0	1	0	3	4
Total	**35**	**18**	**8**	**96**	**157**

The average elevation across these structures is 1.86 feet. The implication is that these structures see a decrease in overall life loss risk because water is not expected to reach the living area of these structures.

Table 68 provides the change in flood depth exposure for the identified structures at three different AEP events. A negative depth indicates that water is not inundating that structure at that depth. The change in depth from the FWOP and Comp Depth represent the elevation of the structure. The elevation is in addition to existing foundation height of the structure.

A total of five structures show depth at the FWOP 0.04 AEP event. The maximum depth at this event is 3.28 feet but the average depth is -5.96 feet. This means that no structures fall into the

high hazard zone as defined in LifeSim. In the Comp Benefit 0.04 AEP event, zero structures remain with depths. The max depth is -2.68 feet, and the average is -7.83 feet.

A total of twenty-three structures show depth at the FWOP 0.01 AEP event. The maximum depth is 4.58 feet, and the average depth is -0.14 feet. There is one structure in the high hazard zone as defined by LifeSim. In the Comp Benefit 0.01 AEP event, zero structures remain with depths. Because the 0.01 AEP event is the target stage plus 2 feet, all structures experience -2 feet of depth during this event. No structures remain in the high hazard zone.

A total of fifty-one structures show depth at the FWOP 0.0.02 AEP event. The maximum depth is 6.44 feet with an average depth of 2.68 feet. A total of seven structures have depth greater than 4 feet which indicates high hazard as defined in LifeSim. In the Comp benefit 0.0.02 AEP event, thirty-eight structures remain with depth with the maximum depth still at 1.56 feet. The average depth decreases to 0.82 feet. No structures remain in the high hazard zone.

Table 68. Depth Change by Structure

Structure	Occ Type	SID Reach	Elevation (ft)	FWOP Depth at 0.04 AEP	Comp Depth at 0.04 AEP	FWOP Depth at 0.01 AEP	Comp Depth at 0.01 AEP	FWOP Depth at 0.002 AEP	Comp Depth at 0.002 AEP
1232	R07	TP10B	4.05	0.33	-3.73	2.05	-2.00	4.04	-0.01
1412	R07	TP3C	1.18	-9.02	-10.20	-0.82	-2.00	2.73	1.55
1440	R04	TP3F	2.52	-9.00	-11.52	0.52	-2.00	3.73	1.21
1497	R07	TP3C	1.21	-8.72	-9.92	-0.79	-2.00	2.76	1.56
1505	R04	TP3F	2.30	-7.26	-9.55	0.30	-2.00	3.54	1.24
1519	R07	TP3C	1.02	-9.32	-10.35	-0.98	-2.00	2.58	1.56
1585	R04	TP3F	1.26	-9.00	-10.27	-0.74	-2.00	2.49	1.23
1588	R04	TP3F	2.88	-8.00	-10.87	0.88	-2.00	4.11	1.23
1597	R04	TP3F	5.20	0.40	-4.80	3.20	-2.00	6.44	1.24
1606	R07	TP3F	0.80	-10.93	-11.73	-1.20	-2.00	2.03	1.24
1757	R04	TP3F	1.01	-8.00	-9.01	-0.99	-2.00	2.16	1.16
1818	R07	TP3C	0.96	-10.53	-11.50	-1.04	-2.00	2.52	1.56
1898	R07	TP3C	2.09	-9.00	-11.09	0.09	-2.00	3.65	1.56
1899	R07	TP3C	3.01	-1.99	-5.00	1.01	-2.00	4.57	1.56
1909	R07	TP3C	2.31	-9.42	-11.72	0.31	-2.00	3.86	1.56
1910	R07	TP3C	2.64	-9.19	-11.83	0.64	-2.00	4.20	1.56
1912	R07	TP3C	2.13	-9.70	-11.83	0.13	-2.00	3.69	1.56
1916	R07	TP3C	0.70	-9.40	-10.10	-1.30	-2.00	2.26	1.56
1917	R07	TP3C	1.45	-3.54	-5.00	-0.55	-2.00	3.01	1.56
1918	R07	TP3C	2.19	-9.80	-11.99	0.19	-2.00	3.74	1.55
1936	R04	TP3F	1.06	-8.00	-9.06	-0.94	-2.00	2.29	1.23
1952	R07	TP3F	1.03	-9.40	-10.43	-0.97	-2.00	2.18	1.16
2049	R07	TP3C	1.19	-9.17	-10.36	-0.81	-2.00	2.73	1.54
2162	R07	TP3C	0.55	-9.63	-10.18	-1.45	-2.00	2.09	1.54
2247	R07	TP3F	1.16	-9.40	-10.55	-0.84	-2.00	2.40	1.24
2419	R07	TP3F	0.98	-9.40	-10.38	-1.02	-2.00	2.23	1.25
2637	R04	TP3F	3.07	-1.72	-4.79	1.07	-2.00	4.31	1.24
2671	R04	TP3F	2.04	-8.00	-10.04	0.04	-2.00	3.28	1.24
2907	R07	TP3F	1.32	-8.43	-9.76	-0.68	-2.00	2.52	1.20
3125	R07	TP3F	1.04	-9.40	-10.44	-0.96	-2.00	2.29	1.25
3206	R04	TP3C	1.48	-7.66	-9.13	-0.52	-2.00	2.93	1.45
3320	R07	TP3C	1.04	-9.31	-10.35	-0.96	-2.00	2.56	1.52
3378	R04	TP3C	2.16	-2.81	-4.98	0.16	-2.00	3.66	1.50
3385	R07	TP3C	0.54	-9.31	-9.85	-1.46	-2.00	2.06	1.52
3400	R07	TP3C	0.62	-8.73	-9.35	-1.38	-2.00	2.16	1.53
3401	R07	TP3C	0.90	-9.60	-10.50	-1.10	-2.00	2.43	1.52
3404	R07	TP3C	0.66	-8.90	-9.56	-1.34	-2.00	2.19	1.53
3410	R07	TP3C	0.70	-9.12	-9.82	-1.30	-2.00	2.15	1.45
5097	R04	TP10A	3.42	-0.97	-4.40	1.42	-2.00	3.30	-0.12
5114	R04	STC1C	3.01	-0.68	-3.69	1.01	-2.00	2.80	-0.21
5117	R06	STC1C	2.86	-0.60	-3.46	0.86	-2.00	2.38	-0.47
5193	R04	TP10C	0.77	-1.99	-2.77	-1.23	-2.00	-0.02	-0.80
5211	R06	TP10C	6.58	3.28	-3.30	4.58	-2.00	6.08	-0.50
5236	R04	TP10C	1.61	-1.73	-3.34	-0.39	-2.00	1.09	-0.52
5265	R04	STC1C	0.52	-2.56	-3.08	-1.48	-2.00	-0.35	-0.86
5269	R04	STC1C	0.55	-2.54	-3.08	-1.45	-2.00	-0.30	-0.85
5306	R04	STC1C	0.88	-2.28	-3.16	-1.12	-2.00	0.11	-0.77
5322	R06	STC1C	2.02	-1.44	-3.46	0.02	-2.00	1.55	-0.47
5327	R04	STC1C	2.88	-0.58	-3.46	0.88	-2.00	2.41	-0.47
5354	R06	STC1C	3.78	0.21	-3.57	1.78	-2.00	3.43	-0.35
5367	R06	STC1B	2.72	-0.16	-2.89	0.72	-2.00	1.76	-0.97
5375	R01	STC1C	1.72	-1.71	-3.43	-0.28	-2.00	1.23	-0.49
5718	R06	TP9D	3.08	0.40	-2.68	1.08	-2.00	1.77	-1.31
5902	R06	TP8	1.86	-9.40	-11.26	-0.14	-2.00	3.08	1.21

Table 69 below provides the summary of the structures in the comprehensive benefits plan. Overall, depths are significantly decreased across the range of events in the Comprehensive Benefits project condition.

Table 69. Comprehensive Benefits Plan Summary

Depth	FWOP Depth at 0.04 AEP	Comp Depth at 0.04 AEP	FWOP Depth at 0.01 AEP	Comp Depth at 0.01 AEP	FWOP Depth at 0.002 AEP	Comp Depth at 0.002 AEP
Min	-10.93	-11.99	-1.48	-2.00	-0.35	-1.31
Max	3.28	-2.68	4.58	-2.00	6.44	1.56
Average	-5.96	-7.83	-0.14	-2.00	2.68	0.82
Have depth	5	0	23	0	51	38
Depth > 4ft	0	0	1	0	7	0

9.3.2. Risk Perception

While the proposed nonstructural measure for nonresidential structures does not change depth of water in the structure, it does provide an additional level of awareness to the employees at these structures. Dry floodproofing requires the closure of openings such as doors and windows. These additional requirements will lead to training and awareness of how to act in a flooding situation. It is very difficult to quantify these impacts, but it is important to acknowledge that they occur.

10. WITH PROJECT REGIONAL ECONOMIC DEVELOPMENT

The RED account registers changes in the distribution of regional economic activity that results from each alternative plan. Evaluations of regional effects are carried out using nationally consistent projections of income, employment, output, and population.

To evaluate RED, the USACE Regional Economic System (RECONS) model was used. RECONS is a USACE-certified regional economic model designed to provide accurate and defensible estimates of regional economic impacts and contributions associated with USACE projects, programs, and infrastructure. Regional economic impacts and contributions are measured as economic output, jobs, income, and value added. Estimates are provided simultaneously for three levels of geographic impact area: local, state, and national. RECONS is an input/output (IO) model that uses IMPLAN data, which is comprehensive economic data gathered from government agencies and the private sector. Within RECONS, the Civil Works Spending Module was used to estimate local, state, and national impacts. For this study, the generic area used was Nash County, the business line selected was Flood Risk Management, and the work activity selected was Flood Risk Management Construction. Since RECONS is an IO model, construction dollars must be spent for an impact to occur. IO models assume that there is a relationship between the volume of output of an industry and the volume of various inputs used to produce that output. The impact of construction dollars on the economy more broadly is based on the multiplier effect, or the proportional amount of increase in final income that results from project spending. Therefore, only WP conditions are analyzed. In the absence of the project, it is likely that RED would be negatively impacted by flood events.

The economic impacts presented below exclude IDC since this portion of project costs are not spent within the region. Purchases of land are similarly excluded since this cost is considered a

transfer from one individual to another. Results are presented for each alternative in this section in FY23 price levels.

10.1. RED Alternative 3A NED Plan

The expenditures associated with Alternative 3A - are estimated to be $21,576,216. Of this total expenditure, $14,826,483 will be captured within the local impact area. The remainder of the expenditures will be captured within the state impact area and the nation. 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 the following tables. The regional economic effects are shown for the local, state, and national impact areas. In summary, the Civil Works expenditures $21,576,216 support a total of 222.6 full-time equivalent jobs, $13,401,734 in labor income, $14,606,935 in the gross regional product, and $24,336,499 in economic output in the local impact area. More broadly, these expenditures support 370.7 full-time equivalent jobs, $25,879,295 in labor income, $33,977,231 in the gross regional product, and $58,619,856 in economic output in the nation as illustrated in Table 70.

Table 70. RED Alternative 3A NED Plan

Area	Jobs*	Labor Income	Value Added
Local			
Direct Impact	163.3	$10,522,730	$9,351,303
Secondary Impact	59.2	$2,879,003	$5,255,633
Total Impact	222.6	$13,401,734	$14,606,935
State			
Direct Impact	184.3	$12,197,793	$11,194,211
Secondary Impact	96.4	$5,848,202	$10,056,524
Total Impact	280.8	$18,045,995	$21,250,736
US			
Direct Impact	200.9	$13,764,881	$13,241,303
Secondary Impact	169.9	$12,114,413	$20,735,927
Total Impact	**370.7**	**$25,879,295**	**$33,977,231**

* Jobs are presented in full-time equivalence (FTE)

10.2. RED Alternative 3B Comprehensive Benefits Plan

The expenditures associated with Alternative 3B - are estimated to be $66,093,683. Of this total expenditure, $45,417,459 will be captured within the local impact area. The remainder of the expenditures will be captured within the state impact area and the nation. 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 the following tables. The regional economic effects are shown for the local, state, and national impact areas. In summary, the Civil Works expenditures $66,093,683 support a total of 681.7 full-time equivalent jobs, $41,053,072 in labor income, $44,744,926 in the gross regional product, and $74,549,165 in economic output in the local impact area. More broadly, these expenditures support 1,135.6 full-time equivalent jobs,

$79,275,158 in labor income, $104,081,288 in the gross regional product, and $179,568,201 in economic output in the nation.

Table 71. RED Alternative 3B Comprehensive Benefits Plan

Area	Jobs*	Labor Income	Value Added
Local			
Direct Impact	500.3	$32,233,920	$28,645,526
Secondary Impact	181.5	$8,819,152	$16,099,399
Total Impact	681.7	$41,053,072	$44,744,926
State			
Direct Impact	564.6	$37,365,083	$34,290,844
Secondary Impact	295.4	$17,914,597	$30,805,808
Total Impact	860.0	$55,279,680	$65,096,652
US			
Direct Impact	615.3	$42,165,490	$40,561,631
Secondary Impact	520.3	$37,109,668	$63,519,657
Total Impact	**1,135.6**	**$79,275,158**	**$104,081,288**

* Jobs are presented in full-time equivalence (FTE)

11. BENEFITS SUMMARY AND TENATIVILY SELECTED PLAN

11.1. NED and Comprehensive Benefits Plan Comparison

Table 72 below summarizes the analysis for each alternative and the ranking system used to select the tentatively selected plan.

Table 72. Alternative Summary

Consideration	Alt. 1. No Action	Alt. 3A. Max Net Economic Benefits/NED	Alt. 3B. Comprehensive Benefits
1. Account Analysis			
A. NED			
(1) Annual Net Benefits (2) Benefit cost ratio (3) Rank	$0 0.00 3rd	$1,093,000 2.43 1st	$254,000 1.11 2nd
B. RED			
(1) Employment (2) Labor Income (3) Rank	0 full time equivalents $0 3rd	370 full-time equivalent jobs, $25,879,000 in labor income 2nd	1,135 full-time equivalent jobs, $79,275,000 in labor income. 1st
C. OSE			
(1) Life Safety	No reduction in life safety risk. Rank=3rd.	Reduction in life safety risk for occupants of 42 structures due to reduction in inundation. Rank=2nd.	Reduction in life safety risk for occupants of 157 structures due to reduction in inundation. Rank=1st.
(2) Environmental Justice (Resilience)	No increase in resilience of at-risk communities. Potential reduction in	Increased resilience of communities that benefit. However, minimal benefit	Increased resilience of communities that benefit, including 9 reaches

Consideration	Alt. 1. No Action	Alt. 3A. Max Net Economic Benefits/NED	Alt. 3B. Comprehensive Benefits
	resilience due to climate change. Rank=3rd.	to communities identified as socially vulnerable due to focus on maximizing economic benefits. Rank=2nd.	identified as socially vulnerable. Benefits to a larger proportion of each community, including socially vulnerable populations, increases overall resilience. Rank=1st.
(3) Environmental Justice (Cohesion)	Loss of community cohesion as communities continue to be impacted and fragmented. Rank=3rd.	Benefits community cohesion by reducing risk to 42 at-risk structures; however, most at-risk structures—particularly those in socially vulnerable communities—remain at risk with a potential for future impacts that result in a loss of community cohesion. Rank=2nd.	Benefits community cohesion by reducing risk to 157 at-risk structures, with a greater focus on socially vulnerable communities. Much less risk remains in benefiting communities that could degrade community cohesion in the future. Rank=1st.
(4) Overall Rank	3rd	2nd	1st
D. EQ			
(1) Natural Environment	No change in the natural environment, including wetlands, aquatic habitat, riparian habitat, threatened and endangered species or critical habitat. Rank=1st.	No significant impacts to the natural environment, including wetlands, aquatic habitats, riparian habitats, threatened and endangered species or critical habitat. Rank 2nd (tie).	No significant impacts to the natural environment, including wetlands, aquatic habitat, riparian habitat, threatened and endangered species or critical habitat. Rank 2nd (tie).
(2) Physical Environment	No change in the physical environment, including climate, land use, cultural resources, air quality, water quality, or HTRW. Rank=1st.	No significant impacts to the physical environment, including climate, land use, cultural resources, air quality, water quality, or HTRW. All impacts would be minor and temporary. Rank=2nd (tie).	No significant impacts to the physical environment, including climate, land use, cultural resources, air quality, water quality, or HTRW. All impacts would be minor and temporary. Rank=2nd (tie).
(5) Rank	1st	2nd (tie)	2nd (tie).
2. Alternative Evaluation			
A. Criteria			
(1) Efficiency	No net economic benefits. Rank=3rd.	$1,093,000 in net benefits. Rank=1st.	$254,000 in net economic benefits. Rank=2nd.
(2) Effectiveness (Damage)	No damages reduced. Rank=3rd.	Reduces damages to 42 structures. Rank=2nd.	Reduces damages to 157 structures. Rank=1st.
(3) Effectiveness (Commercial/Industry)	No benefits to commerce or industry. Rank=3rd.	Reduces damages to 39 commercial and industrial facilities. Rank=2nd.	Reduces damages to 96 commercial and industrial facilities. Rank=1st.
(4) Effectiveness (Life Safety)	No reduction in life safety risk. Rank=3rd.	Reduction in life safety risk for occupants of 42 structures due to	Reduction in life safety risk for occupants of 157 structures due to

Consideration	Alt. 1. No Action	Alt. 3A. Max Net Economic Benefits/NED	Alt. 3B. Comprehensive Benefits
		reduction in inundation. Rank=2nd.	reduction in inundation. Rank=1st.
(5) Acceptability	Meets acceptability criteria. Rank=1st (tie).	Meets acceptability criteria. Rank=1st (tie).	Meets acceptability criteria. Rank=1st (tie).
(6) Completeness	Meets completeness criteria. Rank=1st (tie).	Meets completeness criteria. Rank=1st (tie).	Meets completeness criteria. Rank=1st (tie).
(7) Environmental Justice (Resilience)	No increase in resilience of at-risk communities. Potential reduction in resilience due to climate change. Rank=3rd.	Increased resilience of communities that benefit. However, minimal benefit to communities identified as socially vulnerable due to focus on maximizing economic benefits. Rank=2nd.	Increased resilience of communities that benefit, including 9 reaches identified as socially vulnerable. Benefits to a larger proportion of each community, including socially vulnerable populations, increases overall resilience. Rank=1st.
(8) Environmental Justice (Community Cohesion)	Loss of community cohesion as communities continue to be impacted and fragmented. Rank=3rd.	Benefits community cohesion by reducing risk to 31 at-risk structures; however, most at-risk structures—particularly those in socially vulnerable communities—remain at risk with a potential for future impacts that result in a loss of community cohesion. Rank=2nd.	Benefits community cohesion by reducing risk to 157 at-risk structures, with a greater focus on socially vulnerable communities. Much less risk remains in benefiting communities that could degrade community cohesion in the future. Rank=1st.
(9) Environmental Effects	No effect on environmental resources. Rank=1st.	No significant effects on environmental resources. Rank=2nd.	No significant effects on environmental resources. Rank=2nd.
(10) Rank	3rd	2nd	1st
B. Contribution to Objectives			
(1) Life Safety	No benefits to life and safety. Rank=3rd.	Reduction in life safety risk for occupants of 42 structures due to reduction in inundation. Rank=2nd.	Reduction in life safety risk for occupants of 157 structures due to reduction in inundation. Rank=1st.
(2) Economic damages	No reduction in economic damages. Rank=3rd.	Expected annual benefits of $1,856,000, which equals an approximate 45% reduction in expected annual damages. Rank=2nd.	Expected annual benefits of $2,592,000, which equates to an approximate 52% reduction in expected annual damages. Rank=1st.
(2) Industry & Commerce	No benefits to industry and commerce. Rank=3rd.	Decrease in damages to 39 commercial and industrial structures. Rank=2nd.	Decrease in damages to 96 commercial and industrial structures. Rank=1st.
(4) Rank	3rd	2nd	1st
C. Risk and Uncertainty			

Consideration	Alt. 1. No Action	Alt. 3A. Max Net Economic Benefits/NED	Alt. 3B. Comprehensive Benefits
(1) Residual Risk	No change in flood risk throughout the basin. Greatest residual risk. Rank=3rd.	Includes 4% of structures within the 1% annual exceedance probability floodplain. Rank=2nd.	Incorporates 22% of all structures within the 1% annual exceedance probability floodplain. Least residual risk due to climate change. Rank=1st.
(2) Uncertainty	Relies completely on nonfederal action to reduce flood risk. Rank=2nd.	Participation rates could affect benefits. Rank=1st (tie).	Participation rates could affect benefits. Rank=1st (tie).
(3) Rank	3rd	2nd	1st

11.2. Tentatively Selected Plan

The PDT has determined Alternative 3B the Comprehensive Benefits plan as our TSP alternative. A summary of Alternative 3B is in Table 73 below and more detailed information is in Section 8.10.

Table 73. TSP Plan Summary

Alternative 3B: Comprehensive Benefits Plan								
Reach	**Aggregation**	**Total**	**EAD Without**	**With EAD**	**Average Annual Benefits**	**Average Annual Costs**	**BCR**	**Net Benefits**
STC1B	0.01 AEP Floodplain	15	$1,016.37	$228.08	$788.29	$246.67	3.20	$541.62
STC1C	0.01 AEP Floodplain	19	$393.14	$156.13	$237.01	$258.25	0.92	-$21.24
STC1F	0.01 AEP Floodplain	1	$24.50	$9.36	$15.14	$24.59	0.62	-$9.45
TP10A	0.01 AEP Floodplain	4	$155.03	$49.56	$105.47	$60.98	1.73	$44.49
TP10B	0.01 AEP Floodplain	2	$183.72	$174.56	$9.16	$25.13	0.36	-$15.97
TP10C	0.01 AEP Floodplain	5	$212.71	$64.72	$147.99	$79.14	1.87	$68.85
TP10D	0.01 AEP Floodplain	1	$104.09	$70.18	$33.91	$16.07	2.11	$17.84
TP3C	0.01 AEP Floodplain	22	$66.83	$59.40	$7.43	$339.01	0.02	-$331.58
TP3F	0.01 AEP Floodplain	69	$2,398.92	$1,307.48	$1,091.44	$1,047.50	1.04	$43.94
TP8	0.01 AEP Floodplain	10	$180.52	$109.00	$71.52	$106.48	0.67	-$34.96
TP9A	0.01 AEP Floodplain	4	$66.44	$28.78	$37.66	$43.06	0.87	-$5.40
TP9C	0.01 AEP Floodplain	1	$11.19	$10.65	$0.54	$6.76	0.08	-$6.22
TP9D	0.01 AEP Floodplain	4	$130.46	$84.47	$45.99	$83.92	0.55	-$37.93
Total		**157**	**$4,943.92**	**$2,352.37**	**$2,591.55**	**$2,337.57**	**1.11**	**$253.98**

11.3. Residual Risk

The Tar Pamlico study area is impacted by both riverine and coastal storm surge flooding. However, due to the scope of this project, only the riverine flooding was considered for nonstructural plan development in the areas not impacted by coastal storm surge to ensure the nonstructural design was adequate.
Due to the selected plan only including nonstructural measures, there are no reductions to residual risk for roads, railways, vehicles, and structures not included in the final array. The life safety profile remains the same as well outside of the structures that are in the plan. Additionally, because nonstructural measures are voluntary, any structures that opt out of participation will see no benefits. The comprehensive benefits plan accounts for only 3.5% of total structures in the structure inventory and reduces annual damages by 32.6%. The total amount of residual damage across the study area is estimated to remain over $6 million in annual damages.

A total of 580 structures see damage at the 1% AEP across 30 different reaches. The final array of the comprehensive benefits plan consists of 155 structures or about 26% of structures seeing damage across 13 reaches. Within those reaches, the plan reduces damages by over 52%, but still has over $2.66 million in annual damages.

Table 74 below shows the breakdown of residual damages by reach with the reaches in the comprehensive benefits plan in red.

Table 74. Residual Damages by Reach

Reach	Without Project EAD	Damage Reduced	Residual Damages
CC	$41.77	$0.00	$41.77
FC1	$10.08	$0.00	$10.08
FC2	$42.87	$0.00	$42.87
GM	$22.36	$0.00	$22.36
STC1A	$31.91	$0.00	$31.91
STC1B	$1,154.94	$896.39	$258.55
STC1C	$446.10	$269.58	$176.52
STC1D	$32.68	$0.00	$32.68
STC1E	$7.47	$0.00	$7.47
STC1F	$27.64	$17.21	$10.43
STC2	$0.40	$0.00	$0.40
SWC	$190.69	$0.00	$190.69
TP10A	$176.23	$119.90	$56.33
TP10B	$208.79	$10.42	$198.37
TP10C	$241.83	$168.27	$73.56
TP10D	$118.33	$38.56	$79.77
TP11	$1.88	$0.00	$1.88
TP12	$74.51	$0.00	$74.51
TP13	$0.21	$0.00	$0.21
TP14	$171.30	$0.00	$171.30
TP15	$0.23	$0.00	$0.23
TP3A	$32.19	$0.00	$32.19
TP3B	$5.08	$0.00	$5.08
TP3C	$74.91	$8.87	$66.04
TP3D	$421.78	$0.00	$421.78
TP3E	$0.32	$0.00	$0.32
TP3F	$2,717.52	$1,235.19	$1,482.33
TP4	$72.74	$0.00	$72.74
TP5	$1,852.17	$0.00	$1,852.17
TP6	$78.91	$0.00	$78.91
TP7	$229.26	$0.00	$229.26
TP8	$208.10	$84.15	$123.95
TP9A	$75.55	$42.83	$32.72
TP9B	$17.24	$0.00	$17.24
TP9C	$12.70	$0.61	$12.09
TP9D	$148.25	$52.29	$95.96
Total	**$8,948.94**	**$2,944.27**	**$6,004.67**

12. TSP PARTICIPATION SENSITIVITY ANALYSIS

Participation in nonstructural measures is completely voluntary and up to the individual structure owner. While the BCR is calculated using a 100% participation rate, it is understood that fewer people will participate. To provide a complete picture to decision makers, a sensitivity analysis was performed based on the participation of the top 80% of structures in terms of individual BCR and the bottom 80% of structures in terms of BCR. The reality of participation will most likely fall somewhere in between.

A total of 157 structures were identified in the comprehensive benefit aggregation. A vast majority of these structures (96) were identified to be dry floodproofed. For the sensitivity analysis, the top and bottom 80% (126 structures) were identified in terms of BCR. They were identified using the EADTrace output from the FDA model. The EADTrace output identifies EAD by structure but does not include all uncertainties.

12.1. Top 80%

The top 80% of structures in the comp benefit aggregation includes a total of 126 structures. Table 75 below provides a full breakdown of the remaining structures by reach and the measures applied. Fourteen fewer structures were identified for elevation, nine fewer structures were identified for elevation and flood venting, and eight fewer structures were identified for dry floodproofing.

Table 75. Top 80% Comp Benefits Measures by Reach

Reach	Aggregation	Elevate	Elevate Flood Vent	Flood Vent	Dry Floodproof	Total
STC1B	0.01 AEP Floodplain	1	0	0	12	13
STC1C	0.01 AEP Floodplain	0	4	4	6	14
STC1F	0.01 AEP Floodplain	0	0	0	0	0
TP10A	0.01 AEP Floodplain	0	0	1	2	3
TP10B	0.01 AEP Floodplain	1	0	0	1	2
TP10C	0.01 AEP Floodplain	0	2	1	1	4
TP10D	0.01 AEP Floodplain	0	0	0	1	1
TP3C	0.01 AEP Floodplain	13	0	0	0	13
TP3F	0.01 AEP Floodplain	6	1	0	53	60
TP8	0.01 AEP Floodplain	0	1	0	9	10
TP9A	0.01 AEP Floodplain	0	0	2	1	3
TP9C	0.01 AEP Floodplain	0	0	0	1	1
TP9D	0.01 AEP Floodplain	0	1	0	1	2
Total	**Comp Benefits**	**21**	**9**	**8**	**88**	**126**

Overall, net benefits increase by about $450,000 annually if only the top 126 structures participate. The average annual costs are estimated to be about $600,000 less. The BCR is estimated to increase to 1.41.

Table 76. BCR of Top 80% Comp Benefit Structures

Top 80% Comp Benefits Costs	Contract Cost ($)	Contingency (%)	Contingency ($)	Total Cost
Construction Cost	$26,438	43%	$11,368	**$37,807**
Planning, Engineering, and Design	$3,146	43%	$1,353	**$4,499**
Construction Management	$1,666	43%	$716	**$2,382**

Real Estate	$4,603	0%	$0	**$4,603**
Total	**$35,852**		**$13,437**	**$49,290**
Interest During Construction (3 Months)				$152
Total Investment Cost				**$49,442**
Average Annual Costs				**$1,743**
Average Annual Benefits				**$2,451**
Net Benefits				**$708**
BCR				**1.41**

12.1.2. Bottom 80%

The bottom 80% of structures in the comprehensive benefits plan also include 126 structures. Table 77 below provides a complete overview of the structures included by reach. Most of the structures identified as bottom 80% were nonresidential structures identified for dry floodproofing. Compared to the full comprehensive benefits plan, two fewer structures are identified for flood venting and twenty-nine fewer structures are identified for dry floodproofing. This means that most of the structures that are seeing the highest benefits, are nonresidential structures being dry floodproofed.

Table 77. Bottom 80% Comp Benefits Measures by Reach

Reach	Aggregation	Elevate	Elevate Flood Vent	Flood Vent	Dry Floodproof	Total
STC1B	0.01 AEP Floodplain	1	0	0	7	8
STC1C	0.01 AEP Floodplain	1	7	3	4	15
STC1F	0.01 AEP Floodplain	0	0	0	1	1
TP10A	0.01 AEP Floodplain	0	1	0	0	1
TP10B	0.01 AEP Floodplain	1	0	0	1	2
TP10C	0.01 AEP Floodplain	0	3	1	0	4
TP10D	0.01 AEP Floodplain	0	0	0	0	0
TP3C	0.01 AEP Floodplain	22	0	0	0	22
TP3F	0.01 AEP Floodplain	10	5	0	40	55
TP8	0.01 AEP Floodplain	0	1	0	8	9
TP9A	0.01 AEP Floodplain	0	0	2	2	4
TP9C	0.01 AEP Floodplain	0	0	0	1	1
TP9D	0.01 AEP Floodplain	0	1	0	3	4
Total	**Comp Benefits**	**35**	**18**	**6**	**67**	**126**

Overall, the net benefits are estimated to be about -$1.21 million with a BCR of 0.36 with the bottom 80% of structures participating. The loss of the highest BCR structures leads to a plan that is not economically justified as illustrated in Table 78.

Table 78. BCR of Bottom 80% Comp Benefit Structures

Bottom 80% Comp Benefits Costs	Contract Cost ($)	Contingency (%)	Contingency ($)	Total Cost
Construction Cost	$26,549	43%	$11,416	**$37,965**
Planning, Engineering, and Design	$3,159	43%	$1,359	**$4,518**
Construction Management	$1,673	43%	$719	**$2,392**
Real Estate	$4,603	0%	$0	**$4,603**
Total	**$35,984**		**$13,494**	**$49,478**

Interest During Construction (3 Months)				$153
Total Investment Cost				**$49,631**
Average Annual Costs				**$1,750**
Average Annual Benefits				**$629**
Net Benefits				**($1,121)**
BCR				**0.36**

12.1.3. Conclusion

Overall, the loss of the highest BCR structures can lead to a plan that is not economically justified. However, participation would be expected for structures that would see a positive net benefit as illustrated in Table 79.

Table 79. Comprehensive Benefit Sensitivity Overview

	Top 80%	100%	Bottom 80%
Net Benefits	$707.84	$253.98	-$1,114.08
BCR	1.41	1.11	0.36

13. OPTIMIZATION OF NED AND SELECTED PLAN

After selection of the tentatively selected plan and following reviews, multiple changes were made to the NED and selected Comprehensive Benefits Alternatives. Below highlights the changes made to the modeling to address comments from the multiple reviews, followed by the finalized results for the FDA, Life Safety, OSE, and RED benefits categories.

13.1. Refinements of the NED Modeling

Changes to the NED modeling include updating the study year and structure value, removing two structures that have been flood proofed previously, calculating emergency and cleanup costs, and including new costs estimates.

13.1.1. Updated Interest, Study Year, and Structure Value Year

Values listed in the initial analysis were based on fiscal year (FY) 2022 price levels with benefits and costs being computed using the FY 2023 federal discount rate of 2.5 percent. In addition, the base study year was 2023. Since the initial report, the structure inventory has been indexed by 1.137 using the building cost indexes developed from Engineering News-Record (ENR) from 2022 to February 2024. This index was then applied to all applicable damage categories in the FDA benefit calculations. In addition, the base study year was updated to 2024 and the FY 2024 interest rate of 2.75 percent was incorporated.

13.1.2. Removing Floodproofed Utilities

During the refinement of Alternative 3A and 3B, two structures were identified as utility infrastructure. After discussing the structures with the utility provider, they informed the PDT the utility structures already had mitigation measures in place and would not be impacted by the modeled inundation. These structures were modified in FDA which resulted in one structure being taken out of Alternative 3A or the NED plan and both structures being taken out of Alternative 3B or the comprehensive benefits plan in Reach TP3F.

13.1.3. Emergency and Cleanup Costs

Emergency and cleanup costs were modeled and are presented below in Section 13.2.4 along with the methodology. Although the modeling does result in potential benefits, these benefits were not included in the final cost benefit calculation since there is a large amount of uncertainty around if these benefits will realistically occur.

13.1.4. Costs

Since the draft report, costs have been updated and include new E&D, S&A, and contingencies determined by the CSRA. Generally, the costs for the commercial structures have increased and the costs for residential structures has decreased. The updated costs estimated used attributes collected during the development and valuation of the structure inventory such as square footage, perimeter, and floodproofing height. Costs were developed based on the attributes, building type, and nonstructural measure for each structure in the comprehensive benefits plan. The updated costs are presented below in Section 13.2.2 and 13.2.3.

13.1.5. Target Stage Sensitivity Analysis

A target stage sensitivity analysis was conducted after TSP on the selected plan to determine the optimal flood proofing stage using costs from the TSP since the previous analysis only used BFE at the 0.01 AEP plus two feet. There were four different stages included in this analysis elevation to the BFE, BFE plus 1 foot, BFE plus 2 feet, and BFE plus 3 feet. Overall, the results for Alternative 3A or the NED plan indicated that the optimal elevation was between BFE plus 2 feet and BFE plus 3 feet for all reaches in the NED plan as illustrated in Table 80. After consulting with vertical team, it was determined the initial target stage of BFE plus 2 feet was sufficient.

Table 80. Target Stage Sensitivity Analysis (in $1,000s)

Reach	BFE 0.1 AEP Net Benefits	BFE+1 0.1 AEP Net Benefits	BFE+2 0.1 AEP Net Benefits	BFE+3 0.1 AEP Net Benefits	BFE 0.04 AEP Net Benefits	BFE+1 0.04 AEP Net Benefits	BFE+2 0.04 AEP Net Benefits	BFE+3 0.04 AEP Net Benefits	BFE 0.02 AEP Net Benefits	BFE+1 0.02 AEP Net Benefits	BFE+2 0.02 AEP Net Benefits	BFE+3 0.02 AEP Net Benefits	BFE 0.01 AEP Net Benefits	BFE+1 0.01 AEP Net Benefits	BFE+2 0.01 AEP Net Benefits	BFE+3 0.01 AEP Net Benefits
STC1B	$59.61	$93.50	$104.21	$104.21	$204.34	$470.76	$571.34	$587.87	$171.55	$476.17	$597.33	**$616.17**	$126.92	$459.23	$595.60	$514.39
TP10A	$73.02	$73.58	**$73.58**	$73.58	$46.71	$50.12	$51.51	$52.37	$46.71	$50.12	$51.51	$52.37	$45.36	$48.74	$50.14	$45.83
TP10C	$97.26	$102.59	$103.19	**$103.39**	$94.96	$93.12	$79.21	$80.04	$94.96	$93.12	$79.21	$80.04	$93.01	$91.12	$77.15	$27.85
TP10D	$0.00	$0.00	$0.00	$0.00	$1.13	$14.08	$19.84	$21.36	$1.13	$14.08	$19.84	$21.36	$1.13	$14.08	$19.84	**$21.36**
TP3F	$84.31	$84.31	$84.31	$84.31	$321.28	$402.31	**$402.83**	$401.92	$237.36	$348.73	$333.17	$335.80	$18.11	$142.22	$80.04	-$602.55
TP8	$0.00	$0.00	$0.00	$0.00	-$0.54	-$0.54	-$0.54	-$0.54	-$7.96	$1.62	**$5.53**	$5.53	-$45.81	-$41.26	-$34.77	-$100.71
TP9A	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	-$4.76	$1.50	$9.16	**$15.72**	-$21.72	-$14.84	-$4.56	-$44.59

13.2. Updated NED Model Results

13.2.1. Existing

This section presents the updated equivalent annual damages for the WOP and FWOP condition. To obtain equivalent annual damages, expected annual damages are interpolated between existing and future years and discounted back to present value in HEC-FDA. As previously noted, existing WOP and FWOP EAD estimates are similar, and therefore equivalent annual damages are near FWOP EAD estimates. Equivalent annual damages were calculated using the current federal discount rate of 2.75 percent.

Table 81. Updated Existing Conditions Results

Reach	Commercial	Industrial	Public	Residential	Total
CC	$12.39	$22.54	0	$6.84	$41.77
FC1	0	0	$8.87	$1.21	$10.08
FC2	0	$0.88	$6.56	$35.43	$42.87
GM	$18.29	0	$0.01	$4.06	$22.36
STC1A	$0.18	0	0	$31.73	$31.91
STC1B	$1,097.32	$51.14	0	$6.48	$1,154.94
STC1C	$273.12	$90.95	0	$82.03	$446.10
STC1D	$4.41	0	0	$28.26	$32.68
STC1E	$0.02	0	0	$7.45	$7.47
STC1F	$27.18	0	0	$0.45	$27.64
STC2	0	$0.40	0	0	$0.40
SWC	$7.55	$132.98	$0.39	$49.77	$190.69
TP10A	$154.50	0	0	$21.73	$176.23
TP10B	$85.46	$54.45	0	$68.85	$208.76
TP10C	$165.13	$17.74	0	$58.96	$241.83
TP10D	$116.68	$0.42	$1.11	$0.13	$118.33
TP11	0	0	0	$1.87	$1.88
TP12	$41.80	$0.12	0	$32.58	$74.51
TP13	0	0	0	$0.21	$0.21
TP14	$29.15	0	$119.52	$22.63	$171.30
TP15	0	0	0	$0.23	$0.23
TP3A	$15.38	0	0	$16.81	$32.19
TP3B	0	0	0	$5.08	$5.08
TP3C	$12.60	$0.84	$0.04	$61.43	$74.91
TP3D	$348.47	$0.30	0	$73.01	$421.78
TP3E	0	$0.31	0	0	$0.32
TP3F	$645.09	$1,815.57	$132.89	$123.97	$2,717.52

TP4	$12.23	$23.12	$19.08	$18.31	$72.74
TP5	$1,087.21	$122.04	$48.99	$593.93	$1,852.17
TP6	$78.56	$0.15	$0.02	$0.18	$78.91
TP7	$101.03	$8.55	$23.73	$95.95	$229.26
TP8	$99.15	$104.11	0	$4.85	$208.10
TP9A	$73.98	0	0	$1.57	$75.55
TP9B	$6.81	$10.43	0	0	$17.24
TP9C	$0.09	$6.24	$0.27	$6.10	$12.70
TP9D	$9.01	$128.97	$2.58	$7.68	$148.25
Total	**$4,522.82**	**$2,592.24**	**$364.08**	**$1,469.75**	**$8,948.89**

Notes: $1,000s; FY23 price level

13.2.2. Alternative 3A NED Plan

Following the determination of average annual benefits and average annual costs by reach for each of the four floodplains, an analysis was done to optimize the aggregation to select the floodplain that maximized net benefits. If a reach did not have a floodplain aggregation with positive net benefits, that reach was removed from the NED plan.

The final aggregation for the nonstructural analysis which reasonably maximizes net NED benefits includes 6 reaches and 37 total structures as illustrated in Table 82. The previous NED plan included TP8, but the reach dropped out of the NED plan after costs changes resulted in negative net benefits of $25 thousand. This decreased the number of structures in the NED plan to 37. The NED plan is almost exclusively dry floodproofing with 34 of the structures identified for that measure. The remaining three are elevations of residential structures with one structure having flood vents added as well.

Table 82. Final Optimized NED Plan Measures by Reach

Reach	Aggregation	Elevate	Elevate Flood Vent	Dry Floodproof	Total
STC1B	0.01 AEP Floodplain	1	0	14	15
TP10A	0.10 AEP Floodplain	0	0	2	2
TP10C	0.10 AEP Floodplain	0	1	1	2
TP10D	0.01 AEP Floodplain	0	0	1	1
TP3F	0.04 AEP Floodplain	1	0	15	16
TP8	0.02 AEP Floodplain	0	0	0	0
TP9A	0.02 AEP Floodplain	0	0	1	1
	NED Plan	**2**	**1**	**34**	**37**

The total construction costs of the identified 37 structures is estimated at just over $24 million. In addition to the construction costs, PED, Construction Management, and Real Estate costs were included. PED is estimated at 30.5% of construction costs, construction management is estimated at 14.5% of construction costs, and real estate is estimated at $35,451.61 per structure based on input from real estate, which includes a 25% contingency markup. A contingency of 43% is

added to construction, PED, and construction management. The interest during construction is estimated on the total of the costs plus contingencies. A contingency of 43% is added to construction, PED, and construction management. The interest during construction is estimated on the total of the costs plus contingencies and is over a 3-month construction period.

The total investment cost is estimated at $37.2 million as shown in Table 83 and costs for the NED plan by reach and aggregation are shown in Table 84. Average annual costs are calculated by using the FY24 rate of 2.75% with a period of 50 years. The average annual costs are estimated at about $1.4 million. With benefits just above $2 million, the net benefits are estimated at around $661 thousand. The NED plan has a benefit cost ratio of 1.48.

Table 83. Final NED Nonstructural Plan BCR (In $1,000)

Optimized Nonstructural Plan Costs	Contract Cost ($)	Contingency (%)	Contingency ($)	Total Cost
Construction Cost	$17,304	43%	$7,441,081	**$24,745**
Planning, Engineering, and Design	$5,277,929	43%	$2,269,510	**$7,547**
Construction Management	$2,509,230	43%	$1,078,969	**$3,588**
Real Estate	$1,311,710	0%	$0	**$1,311**
Total	**$26,403,708**		**$10,789,559**	**$37,193**
Interest During Construction (3 Months)				$115
Total Investment Cost				**$37,308**
Average Annual Costs				**$1,382**
Average Annual Benefits				**$2,043**
Net Benefits				**$661**
BCR				**1.48**

Table 84. Final NED Plan Costs

NED Plan								
Reach	**Aggregation**	**Total**	**Construction Costs**	**Contingencies**	**Real Estate**	**IDC**	**Total Cost**	**Average Annual Costs**
STC1B	1% AEP	15	$8,357,942	$3,593,915	$531,774	$38,616	$12,522,248	$463,836
TP10A	10% AEP	2	$991,176	$426,206	$70,903	$4,604	$1,492,889	$55,298
TP10C	10% AEP	2	$1,151,016	$494,937	$70,903	$5,311	$1,722,167	$63,791
TP10D	1% AEP	1	$566,817	$243,731	$35,452	$2,617	$848,617	$31,434
TP3F	4% AEP	16	$13,575,782	$5,837,586	$567,226	$61,807	$20,042,400	$742,389
TP9A	2% AEP	1	$449,265	$193,184	$35,452	$2,097	$679,998	$25,188
Total		**37**	**$25,091,998**	**$10,789,559**	**$1,311,710**	**$115,051**	**$37,308,319**	**$1,381,934**

The reaches and aggregations that made up the NED plan are listed in Table 85 along with the average annual benefits and costs for each reach.

Table 85. Final NED Plan Average Annual Costs and Benefit Summary (In $1,000)

NED Plan								
Reach	**Aggregation**	**Total**	**EAD Without**	**With EAD**	**Average Annual Benefits**	**Average Annual Costs**	**BCR**	**Net Benefits**
STC1B	1% AEP	15	$1,154.94	$258.55	$896.39	$463.84	1.93	$432.55
TP10A	10% AEP	2	$176.23	$68.72	$107.51	$55.30	1.94	$52.21
TP10C	10% AEP	2	$241.83	$78.88	$162.95	$63.79	2.55	$99.16
TP10D	1% AEP	1	$118.33	$79.77	$38.56	$31.43	1.23	$7.13
TP3F	4% AEP	16	$2,717.52	$1,904.74	$812.78	$742.39	1.09	$70.39
TP9A	2% AEP	1	$75.55	$50.83	$24.72	$25.19	0.98	($0.47)
Total		**37**	**$4,484.40**	**$2,441.49**	**$2,042.91**	**$1,381.93**	**1.48**	**$660.98**

13.2.3. Alternative 3B Comprehensive Benefits Plan

Per the 5 January 2021 SACW POLICY DIRECTIVE – Comprehensive Documentation of Benefits in Decision Document, all USACE planning study project delivery teams (PDTs) must evaluate and provide a complete accounting, consideration, and documentation of the total benefits of alternative plans across all benefit categories. Total benefits involve a summation of monetized and/or quantified benefits, along with a complete accounting of qualitative benefits, for project alternatives across national and regional economic, environmental, and social benefit categories. Therefore, the PDT formulated a comprehensive benefits plan which reasonably maximized benefits across all categories.

As a result of that analysis, 13 damage reaches with all structures in the 0.01 AEP floodplain were included. The 13 damage reaches total includes all 6 reaches in the NED plan at the 0.01 AEP aggregation as well as 7 additional reaches in the surrounding areas of the NED reaches. The 7 additional reaches were determined to have environmental justice and social vulnerability concerns that would warrant inclusion in a comprehensive benefit analysis and is discussed in detail above in Section 9 in comparison to the NED Plan. All reaches used the 0.01 AEP floodplain aggregation to minimize the impacts on community cohesion.

The formulated comprehensive benefits plan includes a total of 155 structures. Of these. 94 are recommended for dry floodproofing, 35 for elevation alone, 18 for elevation and flood vents, and 8 with only flood vents as presented in Table 86 .

Table 86. Final Comprehensive Benefits Plan Measure by Reach

Reach	Aggregation	Elevate	Elevate Flood Vent	Flood Vent	Dry Floodproof	Total
STC1B	0.01 AEP Floodplain	1	0	0	14	15
STC1C	0.01 AEP Floodplain	1	7	4	7	19
STC1F	0.01 AEP Floodplain	0	0	0	1	1
TP10A	0.01 AEP Floodplain	0	1	1	2	4
TP10B	0.01 AEP Floodplain	1	0	0	1	2
TP10C	0.01 AEP Floodplain	0	3	1	1	5
TP10D	0.01 AEP Floodplain	0	0	0	1	1
TP3C	0.01 AEP Floodplain	22	0	0	0	22
TP3F	0.01 AEP Floodplain	10	5	0	52	67
TP8	0.01 AEP Floodplain	0	1	0	9	10
TP9A	0.01 AEP Floodplain	0	0	2	2	4
TP9C	0.01 AEP Floodplain	0	0	0	1	1
TP9D	0.01 AEP Floodplain	0	1	0	3	4
Total	**Comp Benefits**	**35**	**18**	**8**	**94**	**155**

The total construction costs of the identified 155 structures are estimated at just under $45 million. In addition to the construction costs, PED, Construction Management, and Real Estate costs were included. PED is estimated at 30.5% of construction costs, construction management is estimated at 14.5% of construction costs, and real estate is estimated at $35,451.64 per structure. A contingency of 43% is added to construction, PED, and construction management. The interest during construction is estimated on the total of the costs plus contingencies and is over a 3-month construction period. The total investment cost is estimated at just over $99 million. Average annual costs are calculated by using the FY24 rate of 2.75% with a period of 50 years. The average annual costs are estimated at about $3.7 million. With benefits just over $2.9 million, the net benefits are estimated at -$723 thousand. This is a benefit cost ratio of 0.8. Table 87 through Table 89 illustrate the costs and benefits in each of reaches for the comprehensive benefits plan.

Table 87. Comprehensive Benefits Plan Final Costs

Alternative 3B: Comprehensive Benefits Plan								
Reach	**Aggregation**	**Total**	**Construction Costs**	**Contingencies**	**Real Estate**	**IDC**	**Total Cost**	**Average Annual Costs**
STC1B	0.01 AEP Floodplain	15	$8,357,942	$3,593,915	$531,774	$38,616	$12,522,248	$463,836
STC1C	0.01 AEP Floodplain	19	$6,828,556	$2,936,279	$673,581	$32,289	$10,470,705	$387,845
STC1F	0.01 AEP Floodplain	1	$877,317	$377,246	$35,452	$3,990	$1,294,005	$47,931
TP10A	0.01 AEP Floodplain	4	$1,591,386	$684,296	$141,806	$7,478	$2,424,967	$89,823
TP10B	0.01 AEP Floodplain	2	$458,083	$196,976	$70,903	$2,246	$728,207	$26,973
TP10C	0.01 AEP Floodplain	5	$1,623,444	$698,081	$177,258	$7,730	$2,506,512	$92,844
TP10D	0.01 AEP Floodplain	1	$566,817	$243,731	$35,452	$2,617	$848,617	$31,434
TP3C	0.01 AEP Floodplain	22	$5,570,981	$2,395,522	$779,935	$27,056	$8,773,494	$324,978
TP3F	0.01 AEP Floodplain	67	$31,419,356	$13,510,323	$2,375,258	$146,330	$47,451,266	$1,757,639
TP8	0.01 AEP Floodplain	10	$3,416,434	$1,469,067	$354,516	$16,209	$5,256,226	$194,695
TP9A	0.01 AEP Floodplain	4	$1,436,743	$617,799	$141,806	$6,794	$2,203,142	$81,606
TP9C	0.01 AEP Floodplain	1	$143,410	$61,666	$35,452	$744	$241,272	$8,937
TP9D	0.01 AEP Floodplain	4	$2,888,750	$1,242,163	$141,806	$13,217	$4,285,936	$158,755
Total		**155**	**$65,179,218**	**$28,027,064**	**$5,495,000**	**$305,316**	**$99,006,598**	**$3,667,295**

Table 88. Final Comprehensive Benefits Plan Average Annual Costs and Benefits (In $1,000)

Alternative 3B: Comprehensive Benefits Plan								
Reach	**Aggregation**	**Total**	**EAD Without**	**With EAD**	**Average Annual Benefits**	**Average Annual Costs**	**BCR**	**Net Benefits**
STC1B	0.01 AEP Floodplain	15	$1,154.94	$258.55	$896.39	$463.84	1.93	$432.55
STC1C	0.01 AEP Floodplain	19	$446.10	$176.51	$269.59	$387.84	0.70	($118.25)
STC1F	0.01 AEP Floodplain	1	$27.64	$10.43	$17.21	$47.93	0.36	($30.72)
TP10A	0.01 AEP Floodplain	4	$176.23	$56.33	$119.90	$89.82	1.33	$30.08
TP10B	0.01 AEP Floodplain	2	$208.76	$198.34	$10.42	$26.97	0.39	($16.55)
TP10C	0.01 AEP Floodplain	5	$241.83	$73.56	$168.27	$92.84	1.81	$75.43
TP10D	0.01 AEP Floodplain	1	$118.33	$79.77	$38.56	$31.43	1.23	$7.13
TP3C	0.01 AEP Floodplain	22	$74.91	$66.03	$8.88	$324.98	0.03	($316.10)
TP3F	0.01 AEP Floodplain	67	$2,717.52	$1,482.33	$1,235.19	$1,757.64	0.70	($522.45)
TP8	0.01 AEP Floodplain	10	$208.10	$123.95	$84.15	$194.70	0.43	($110.55)
TP9A	0.01 AEP Floodplain	4	$75.55	$32.72	$42.83	$81.61	0.52	($38.78)
TP9C	0.01 AEP Floodplain	1	$12.70	$12.10	$0.60	$8.94	0.07	($8.34)
TP9D	0.01 AEP Floodplain	4	$148.25	$95.96	$52.29	$158.76	0.33	($106.47)
Total		**155**	**$5,610.86**	**$2,666.58**	**$2,944.28**	**$3,667.30**	**0.80**	**($723.02)**

Table 89. Final Alternative 3B Comprehensive Benefit BCR (in $1,000s)

Comprehensive Benefits Costs	Contract Cost ($)	Contingency (%)	Contingency ($)	Total Cost
Construction Cost	$44,951	43%	$19,329	**$64,280**
Planning, Engineering, and Design	$13,710	43%	$5,895	**$19,605**
Construction Management	$6,518	43%	$2,802,740	**$9,321**
Real Estate	$5,495	0%	$0	**$5,495**
Total	**$70,674,218**		**$28,027,064**	**$98,701**
Interest During Construction (3 Months)				$305
Total Investment Cost				**$99,006**
Average Annual Costs				**$3,667**
Average Annual Benefits				**$2,944**
Net Benefits				**($723)**
BCR				**0.80**

13.2.4. Emergency and Cleanup Costs

Following Hurricanes Katrina and Rite, interviews were conducted with experts in the fields of debris collection, processing, and disposal to estimate the cost of debris removal following a storm event. The experts provided a minimum, most likely, and maximum estimate for cleanup associated with 2 feet, 5 feet, and 12 feet of flooding depth. A representative structure size in square feet was used for the residential and nonresidential occupancy categories. The experts were asked to estimate the percentage of total cleanup costs caused by floodwater and to exclude cleanup costs associated to high winds.

To account for the costs of cleanup in this study, the value for debris removal was assigned to each structure in the inventory based on the occupancy type of each structure in accordance with the expert recommendations. Then, a separate structure inventory with only the cleanup cost value was imported into HEC-FDA to model the specific expected cleanup costs for this study. The values were assigned the corresponding depth-damage function with uncertainty. For all structures, 100% damage was reached at 12 feet of flooding.

All values and depth-damage functions were selected according to the long-duration flooding data specified in a report titled "Development of Depth-Emergency Cost and Infrastructure Damage Relationships for Selected South Louisiana Parishes." The debris clean-up values provided in the report were expressed in 2010 price levels for the New Orleans area. These values were converted to 2024 price levels using the indexes provided by the Gordian "Square Foot Costs with RS Means Data."

The uncertainty surrounding debris percentage values at 2 feet, 5 feet and 12 depths of flooding were based on range of values provided by the four experts in the fields of debris collection,

processing, and disposal. The questionnaires used in the interview process were designed to elicit information from the experts regarding the cost of each stage of the debris cleanup process by structure occupancy type. The range of responses from the experts were used to calculate a mean value and standard deviation value for the cleanup costs percentages provided at 2 feet, 5 feet, and 12 feet depths of flooding. The mean values and the standard deviation values were entered into the HEC-FDA model as a normal probability distribution to represent the uncertainty surrounding the costs of debris removal for residential and non-residential structures. The depth-damage relationships containing the damage percentages at the various depths of flooding and the corresponding standard deviations representing the uncertainty are shown with in the depth–damage tables.

Table 90 below shows the standalone benefits of avoided cleanup costs as a result of the Comprehensive Benefits plan. Overall, there are about $220,000 in annual benefits. These benefits are derived from the updated characteristics of the structures.

Table 90. Cleanup Cost Benefits

Reach	Without	With	Benefits
STC1B	$68.84	$12.12	$56.72
STC1C	$33.77	$9.91	$23.86
STC1F	$2.81	$1.26	$1.55
TP10A	$31.02	$8.20	$22.82
TP10B	$11.22	$9.21	$2.01
TP10C	$21.86	$5.38	$16.48
TP10D	$11.32	$8.24	$3.08
TP3C	$12.01	$11.02	$0.99
TP3F	$146.95	$68.52	$78.43
TP8	$14.66	$7.85	$6.81
TP9A	$3.01	$1.03	$1.98
TP9C	$1.91	$0.88	$1.03
TP9D	$96.15	$92.17	$3.98
Total	**$455.53**	**$235.79**	**$219.74**

These benefits are not included in the overall BCR. However, if these benefits were added, the BCR rises from 0.90 to 0.96. No additional reaches achieve a BCR greater than one if the benefits are included. Table 91 below gives an updated BCR table including cleanup costs in the BCR of the Comprehensive Benefits plan.

Table 91. Comprehensive Benefits Plan BCR – With Cleanup Cost Benefits

Reach	Without	With	Benefits	Annual Costs	Net Benefits	BCR
STC1B	$1,223.78	$270.67	$953.11	$463.84	$489.27	2.05
STC1C	$479.87	$186.42	$293.45	$387.84	($94.39)	0.76
STC1F	$30.45	$11.69	$18.76	$47.93	($29.17)	0.39
TP10A	$207.25	$64.53	$142.72	$89.82	$52.90	1.59
TP10B	$219.98	$207.55	$12.43	$26.97	($14.54)	0.46
TP10C	$263.69	$78.94	$184.75	$92.84	$91.91	1.99
TP10D	$129.65	$88.01	$41.64	$31.43	$10.21	1.32
TP3C	$86.92	$77.05	$9.87	$324.98	($315.11)	0.03
TP3F	$2,864.47	$1,550.85	$1,313.62	$1,757.64	($444.02)	0.75
TP8	$222.76	$131.80	$90.96	$194.70	($103.74)	0.47
TP9A	$78.56	$33.75	$44.81	$81.61	($36.80)	0.55
TP9C	$14.61	$12.98	$1.63	$8.94	($7.31)	0.18
TP9D	$244.40	$188.13	$56.27	$158.76	($102.49)	0.35
Total	**$6,066.39**	**$2,902.37**	**$3,164.02**	**$3,667.30**	**($503.28)**	**0.86**

13.2.5. Participation Rate Sensitivity Analysis

Participation in nonstructural measures is completely voluntary and will vary based on several factors. While the BCR is calculated using a 100% participation rate, it is understood that fewer people will participate. To provide a complete picture to decision makers, a sensitivity analysis was performed based on the participation of the top and bottom 75%, 50%, and 25% of structures in terms of structure specific benefit-cost ratio.

A total of 155 structures were identified in the comprehensive benefit aggregation. A majority of these structures (94) were identified to be dry floodproofed. The top and bottom 117 (75%), 78 (50%), and 39 (25%) structures were used for the sensitivity analysis and were chosen based on the benefit-cost ration of the individual structure.

Each of these sensitivity aggregations was run through HEC-FDA to attain the corresponding benefits of only those structures. The included structures were assigned the previously identified nonstructural methodology and corresponding structure attribute modifications while the structures not in the aggregation were left with their existing conditions attributes. Costs were provided on a per-structure basis allowing for costs to only be applied for structures in the sensitivity run.

13.2.5.1. 75% Participation Sensitivity Analysis

A participation rate of 75% would indicate a total of 117 structures opted into participation. This means that the 38 structures with the best and worst identified benefit-cost ratio in the comprehensive benefits plan were excluded to simulate those structures opting out.

Table 92 provides a breakdown of the participating structures by reach and the measures applied of the top 75% of structures identified in the Comprehensive Benefits plan. There are 26 fewer structures being elevated, 5 fewer structures being elevated with flood vents, 2 fewer structures having just flood vent installation, and 5 fewer structures being dry floodproofed.

This is in line with expectations because the Comprehensive Benefits plan included areas identified as EJ communities. Those areas tend to be residential and lower income with lower structure values so they would be the first structures excluded in this sensitivity analysis.

Table 92. 75% Participation (Top Structures) by Reach

Reach	Aggregation	Dry Floodproof	Elevate	Elevate Flood Vent	Flood Vent	Total
STC1B	1% AEP Floodplain	12	1	0	0	13
STC1C	1% AEP Floodplain	6	0	4	4	14
STC1F	1% AEP Floodplain	0	0	0	0	0
TP10A	1% AEP Floodplain	2	0	0	1	3
TP10B	1% AEP Floodplain	1	1	0	0	2
TP10C	1% AEP Floodplain	1	0	2	1	4
TP10D	1% AEP Floodplain	1	0	0	0	1
TP3C	1% AEP Floodplain	0	8	0	0	8
TP3F	1% AEP Floodplain	51	4	1	0	56
TP8	1% AEP Floodplain	9	0	1	0	10
TP9A	1% AEP Floodplain	1	0	0	2	3
TP9C	1% AEP Floodplain	1	0	0	0	1
TP9D	1% AEP Floodplain	1	0	1	0	2
Total	**Comp Benefits**	**86**	**14**	**9**	**8**	**117**

Table 93 provides a breakdown of the participating structures by reach and the measures applied of the bottom 75% of structures identified in the Comprehensive Benefits plan. There are 35 fewer structures being dry floodproofed which indicates that it is the most efficient measure in the study area. Each of the other measures saw one structure not participate in this analysis.
This is also in line with expectations because this sensitivity excludes the most efficient structures. Those structures tended to be nonresidential structures identified for dry floodproofing.

Table 93. 75% Participation (Bottom Structures) by Reach

Reach	Aggregation	Dry Floodproof	Elevate	Elevate Flood Vent	Flood Vent	Total
STC1B	1% AEP Floodplain	7	1	0	0	8
STC1C	1% AEP Floodplain	4	1	7	4	16
STC1F	1% AEP Floodplain	1	0	0	0	1
TP10A	1% AEP Floodplain	0	0	1	1	2
TP10B	1% AEP Floodplain	1	1	0	0	2
TP10C	1% AEP Floodplain	0	0	2	0	2
TP10D	1% AEP Floodplain	0	0	0	0	0
TP3C	1% AEP Floodplain	0	22	0	0	22
TP3F	1% AEP Floodplain	33	9	5	0	47
TP8	1% AEP Floodplain	8	0	1	0	9
TP9A	1% AEP Floodplain	1	0	0	2	3
TP9C	1% AEP Floodplain	1	0	0	0	1
TP9D	1% AEP Floodplain	3	0	1	0	4
Total	**Comp Benefits**	**59**	**34**	**17**	**7**	**117**

Benefits decreased to $2.92 million annually in the top 75% sensitivity analysis compared to the Comprehensive Benefits plan, but the annual costs decreased to $3.1 million per year. This means that the net benefits rose to over $133 thousand per year if the bottom 38 structures do not participate. Table 94 provides a breakdown of the benefits by reach for the participation of the top 75% of structures.

Table 94. **Top 75% Participation Benefits**

Reach	Without	With	Benefits	Annual Costs	Net Benefits	BCR
STC1B	$1,154.94	$267.07	$887.87	$403.64	$484.23	2.20
STC1C	$446.10	$181.17	$264.93	$326.32	-$61.39	0.81
STC1F	$27.64	$10.43	$17.21	$47.93	-$30.72	0.36
TP10A	$176.23	$56.33	$119.90	$89.82	$30.08	1.33
TP10B	$208.76	$198.34	$10.42	$26.97	-$16.55	0.39
TP10C	$241.83	$73.56	$168.27	$92.84	$75.43	1.81
TP10D	$118.33	$79.77	$38.56	$31.43	$7.13	1.23
TP3C	$74.91	$71.13	$3.78	$52.66	-$48.88	0.07
TP3F	$2,717.52	$1,485.11	$1,232.41	$1,612.72	-$380.31	0.76
TP8	$208.10	$124.18	$83.92	$185.23	-$101.31	0.45
TP9A	$75.55	$33.00	$42.55	$77.30	-$34.75	0.55
TP9C	$12.70	$12.70	$0.00	$0.00	$0.00	0.00
TP9D	$148.25	$95.96	$52.29	$158.76	-$106.47	0.33
Total	**$5,610.86**	**$2,688.75**	**$2,922.11**	**$3,105.63**	**-$183.52**	**0.94**

Benefits decreased to just over $510,000 in the bottom 75% participation rate analysis. Costs also fell to just over $2.1 million. Leaving net benefits to -$1.6 million overall. This indicates that the top 38 structure participation is vital in the viability of this project. Most of these structures are nonresidential and are identified for dry floodproofing. Table 95 provides a breakdown of benefits by reach for the participation of the bottom 75% of structures.

Table 95. **Bottom 75% Participation Benefits**

Reach	Without	With	Benefits	Annual Costs	Net Benefits	BCR
STC1B	$1,154.94	$1,088.36	$66.58	$186.58	-$120.00	0.36
STC1C	$446.10	$352.12	$93.98	$297.53	-$203.55	0.32
STC1F	$27.64	$10.43	$17.21	$47.93	-$30.72	0.36
TP10A	$176.23	$163.83	$12.40	$34.53	-$22.13	0.36
TP10B	$208.76	$198.34	$10.42	$26.97	-$16.55	0.39
TP10C	$241.83	$238.19	$3.64	$26.25	-$22.61	0.14
TP10D	$118.33	$118.33	$0.00	$0.00	$0.00	0.00
TP3C	$74.91	$66.03	$8.88	$324.98	-$316.10	0.03
TP3F	$2,717.52	$2,537.77	$179.75	$821.13	-$641.38	0.22
TP8	$208.10	$160.61	$47.49	$152.06	-$104.57	0.31
TP9A	$75.55	$57.04	$18.51	$56.42	-$37.91	0.33
TP9C	$12.70	$12.10	$0.60	$8.94	-$8.34	0.07
TP9D	$148.25	$95.96	$52.29	$158.76	-$106.47	0.33
Total	**$5,610.86**	**$5,099.11**	**$511.75**	**$2,142.07**	**-$1,630.32**	**0.24**

Table 96 provides a breakdown of the total costs, average annual costs, average annual benefits, net benefits, and BCR of the top 75% participation sensitivity analysis. The BCR rises to 0.94 because annual costs fall to $3.1 million while annual benefits only drop to $2.92 million annually.

Table 96. Top 75% Participation Benefit-Cost Ratio (In $1,000)

Top 75%	Contract Costs	Contingency (%)	Contingency ($)	Total Cost
Construction Cost	$38,310	43%	$16,473	$54,783
PED	$11,684	43%	$5,024	$16,708
Construction Management	$5,555	43%	$2,388	$7,943
Real Estate	$4,147		$0.00	$4,147
Total	**$59,697**		**$23,886,566.35**	**$83,584**
IDC				$258
Total Investment Cost				**$83,843**
Average Annual Costs				**$3,105**
Average Annual Benefits				**$2,922**
Net Benefits				**($183)**
BCR				**0.94**

Table 97 provides a breakdown of the total costs, average annual costs, average annual benefits, net benefits, and BCR of the bottom 75% participation sensitivity analysis. The BCR falls to 0.24 because with annual costs falling to about $2.14 million and annual benefits dropping to only about $512,000 annually.

Table 97. BCR of Bottom 75% Comp Benefit Structures (In $1,000)

Bottom 75%	Contract Costs	Contingency (%)	Contingency ($)	Total Cost
Construction Cost	$25,804	43%	$11,096	$36,899
PED	$7,870	43%	$3,384	$11,254
Construction Management	$3,742	43%	$1,609	$5,350
Real Estate	$4,148		$0	$4,148
Total	**$41,563**		**$16,089**	**$57,652**
IDC				$178
Total Investment Cost				$57,830
Average Annual Costs				**$2,142**
Average Annual Benefits				**$512**
Net Benefits				**($1,630)**
BCR				**0.24**

13.2.5.2. 50% Participation Sensitivity Analysis

A participation rate of 50% would indicate a total of 78 structures opted into participation. This means that the 77 structures with the best and worst identified benefit-cost ratio in the comprehensive benefits plan were excluded to simulate those structures opting out.

Table 98 provides a breakdown of the participating structures by reach and the measures applied of the top 50% of structures identified in the Comprehensive Benefits plan. There are 31 fewer structures being elevated, 12 fewer structures being elevated with flood vents, 5 fewer structures having just flood vent installation, and 29 fewer structures being dry floodproofed.

With the top half of the structures opting to participate, more residential structures are left out than nonresidential structures. This continues to be in line with expectations as those structures tended to be included for EJ concerns.

Table 98. Top 50% Comp Benefits Measures by Reach

Reach	Aggregation	Dry Floodproof	Elevate	Elevate Flood Vent	Flood Vent	Total
STC1B	1% AEP Floodplain	9	0	0	0	9
STC1C	1% AEP Floodplain	4	0	4	2	10
STC1F	1% AEP Floodplain	0	0	0	0	0
TP10A	1% AEP Floodplain	2	0	1	0	3
TP10B	1% AEP Floodplain	1	1	0	0	2
TP10C	1% AEP Floodplain	1	0	1	1	3
TP10D	1% AEP Floodplain	1	0	0	0	1
TP3C	1% AEP Floodplain	0	0	0	0	0
TP3F	1% AEP Floodplain	38	3	0	0	41
TP8	1% AEP Floodplain	5	0	0	0	5
TP9A	1% AEP Floodplain	2	0	0	0	2
TP9C	1% AEP Floodplain	0	0	0	0	0
TP9D	1% AEP Floodplain	2	0	0	0	2
Total	**Comp Benefits**	**65**	**4**	**6**	**3**	**78**

Table **99** provides a breakdown of the participating structures by reach and the measures applied of the bottom 50% of structures identified in the Comprehensive Benefits plan. There are 65 fewer structures being dry floodproofed which indicates that it is the most efficient measure in the study area. There are 4 fewer structures identified to elevate, 6 fewer structures identified to elevate and flood vent, and 2 fewer structures identified for just flood vents. Each of the other measures saw one structure not participate in this analysis. This is also in line with expectations because this sensitivity excludes the most efficient structures. Those structures tended to be nonresidential structures identified for dry floodproofing.

Table 99. Bottom 50% Comp Benefits Measures by Reach

Reach	Aggregation	Dry Floodproof	Elevate	Elevate Flood Vent	Flood Vent	Total
STC1B	1% AEP Floodplain	5	1	0	0	6
STC1C	1% AEP Floodplain	3	1	3	3	10
STC1F	1% AEP Floodplain	1	0	0	0	1
TP10A	1% AEP Floodplain	0	0	0	1	1
TP10B	1% AEP Floodplain	0	0	0	0	0
TP10C	1% AEP Floodplain	0	0	2	0	2
TP10D	1% AEP Floodplain	0	0	0	0	0
TP3C	1% AEP Floodplain	0	22	0	0	22
TP3F	1% AEP Floodplain	14	7	5	0	26
TP8	1% AEP Floodplain	4	0	1	0	5
TP9A	1% AEP Floodplain	0	0	0	2	2
TP9C	1% AEP Floodplain	1	0	0	0	1
TP9D	1% AEP Floodplain	1	0	1	0	2
Total	**Comp Benefits**	**29**	**31**	**12**	**6**	**78**

Benefits decreased to $2.81 million annually in the top 50% sensitivity analysis compared to the Comprehensive Benefits plan, but the annual costs decreased to $2.4 million per year. This means that the net benefits rose to over $335 thousand per year if the bottom 77 structures do not participate. Table 100 provides a breakdown of the benefits by reach for the participation of the top 50% of structures.

Table 100. Top 50% Participation Benefits

Reach	Without	With	Benefits	Annual Costs	Net Benefits	BCR
STC1B	$1,154.94	$289.89	$865.05	$328.34	$536.71	2.63
STC1C	$446.10	$193.82	$252.28	$268.35	-$16.07	0.94
STC1F	$27.64	$27.64	$0.00	$0.00	$0.00	0.00
TP10A	$176.23	$56.59	$119.64	$87.95	$31.69	1.36
TP10B	$208.76	$198.34	$10.42	$26.97	-$16.55	0.39
TP10C	$241.83	$77.08	$164.75	$66.60	$98.15	2.47
TP10D	$118.33	$79.77	$38.56	$31.43	$7.13	1.23
TP3C	$74.91	$74.91	$0.00	$0.00	$0.00	0.00
TP3F	$2,717.52	$1,515.75	$1,201.77	$1,352.49	-$150.72	0.89
TP8	$208.10	$139.85	$68.25	$114.80	-$46.55	0.59
TP9A	$75.55	$33.00	$42.55	$77.30	-$34.75	0.55
TP9C	$12.70	$12.70	$0.00	$0.00	$0.00	0.00
TP9D	$148.25	$99.25	$49.00	$122.60	-$73.60	0.40
Total	**$5,610.86**	**$2,798.59**	**$2,812.27**	**$2,476.82**	**$335.45**	**1.14**

Benefits decreased to just over $136,000 in the bottom 50% participation rate analysis. Costs also fell to just under $1.2 million. Leaving net benefits to about -$1.1 million overall. Table 101 provides a breakdown of benefits by reach for the participation of the bottom 50% of structures.

Table 101. Bottom 50% Participation Benefits

Reach	Without	With	Benefits	Annual Costs	Net Benefits	BCR
STC1B	$1,154.94	$1,122.69	$32.25	$135.50	-$103.25	0.24
STC1C	$446.10	$427.49	$18.61	$122.30	-$103.69	0.15
STC1F	$27.64	$10.43	$17.21	$47.93	-$30.72	0.36
TP10A	$176.23	$175.96	$0.27	$1.88	-$1.61	0.14
TP10B	$208.76	$208.76	$0.00	$0.00	$0.00	0.00
TP10C	$241.83	$238.19	$3.64	$26.25	-$22.61	0.14
TP10D	$118.33	$118.33	$0.00	$0.00	$0.00	0.00
TP3C	$74.91	$66.03	$8.88	$324.98	-$316.10	0.03
TP3F	$2,717.52	$2,683.41	$34.11	$405.15	-$371.04	0.08
TP8	$208.10	$191.34	$16.76	$79.90	-$63.14	0.21
TP9A	$75.55	$75.23	$0.32	$4.31	-$3.99	0.07
TP9C	$12.70	$12.10	$0.60	$8.94	-$8.34	0.07
TP9D	$148.25	$144.86	$3.39	$36.16	-$32.77	0.09
Total	**$5,610.86**	**$5,474.82**	**$136.04**	**$1,193.28**	**-$1,057.24**	**0.11**

Table 102 provides a breakdown of the total costs, average annual costs, average annual benefits, net benefits, and BCR of the top 50% participation sensitivity analysis. The BCR rises to 1.14 because annual costs fall to $2.47 million while annual benefits only drop to $2.81 million annually.

Table 102. BCR of Top 50% Comp Benefit Structures (In $1,000s)

Top 50%	Contract Costs	Contingency (%)	Contingency ($)	Total Cost
Construction Cost	$30,815	43%	$13,251	$44,066
PED	$9,399	43%	$4,041	$13,440
Construction Management	$4,468	43%	$1,921	$6,390
Real Estate	$2,765		$0	$2,765
Total	**$47,447**		**$19,213**	**$66,661**
IDC				$206
Total Investment Cost				$66,867
Average Annual Costs				**$2,477**
Average Annual Benefits				**$2,812**
Net Benefits				**$335**
BCR				**1.14**

Table 103 provides a breakdown of the total costs, average annual costs, average annual benefits, net benefits, and BCR of the bottom 50% participation sensitivity analysis. The BCR falls to 0.11 because with annual costs falling to about $1.2 million and annual benefits dropping to only about $136,000 annually.

Table 103. BCR of Bottom 50% Comp Benefit Structures (In $1,000s)

Bottom 50%	Contract Costs	Contingency (%)	Contingency ($)	Total Cost
Construction Cost	$14,155	43%	$6,087	$20,242
PED	$4,317	43%	$1,856	$6,174
Construction Management	$2,053	43%	$883	$2,935
Real Estate	$2,765		$0	$2,765
Total	**$23,290**		**$8,826**	**$32,116**
IDC				$99
Total Investment Cost				$32,215
Average Annual Costs				**$1,193**
Average Annual Benefits				**$136**
Net Benefits				**($1,057)**
BCR				**0.11**

13.2.5.3. 25% Participation Sensitivity Analysis

A participation rate of 25% would indicate a total of 39 structures opted into participation. This means that the 116 structures with the best and worst identified benefit-cost ratio in the comprehensive benefits plan were excluded to simulate those structures opting out.

Table 104 provides a breakdown of the participating structures by reach and the measures applied of the top 25% of structures identified in the Comprehensive Benefits plan. There are 34 fewer structures being elevated, 17 fewer structures being elevated with flood vents, 7 fewer structures having just flood vent installation, and 58 fewer structures being dry floodproofed.
With only the top 39 structures participating, it is in line that the most efficient nonresidential structures being dry floodproofed would be among the final array. Only one structure from each of the other measures remains.

Table 104. Top 25% Comp Benefits Measures by Reach

Reach	Aggregation	Dry Floodproof	Elevate	Elevate Flood Vent	Flood Vent	Total
STC1B	1% AEP Floodplain	7	0	0	0	7
STC1C	1% AEP Floodplain	3	0	0	0	3
STC1F	1% AEP Floodplain	0	0	0	0	0
TP10A	1% AEP Floodplain	2	0	0	0	2
TP10B	1% AEP Floodplain	0	0	0	0	0
TP10C	1% AEP Floodplain	1	0	1	1	3
TP10D	1% AEP Floodplain	1	0	0	0	1
TP3C	1% AEP Floodplain	0	0	0	0	0
TP3F	1% AEP Floodplain	20	1	0	0	21
TP8	1% AEP Floodplain	1	0	0	0	1
TP9A	1% AEP Floodplain	1	0	0	0	1
TP9C	1% AEP Floodplain	0	0	0	0	0
TP9D	1% AEP Floodplain	0	0	0	0	0
Total	**Comp Benefits**	**36**	**1**	**1**	**1**	**39**

Table 105 provides a breakdown of the participating structures by reach and the measures applied of the bottom 25% of structures identified in the Comprehensive Benefits plan. There are 89 fewer structures being dry floodproofed which indicates that it is the most efficient measure in the study area.
This is also in line with expectations because this sensitivity excludes the most efficient structures. Those structures tended to be nonresidential structures identified for dry floodproofing.

Table 105. Bottom 25% Comp Benefits Measures by Reach

Reach	Aggregation	Dry Floodproof	Elevate	Elevate Flood Vent	Flood Vent	Total
STC1B	1% AEP Floodplain	2	0	0	0	2
STC1C	1% AEP Floodplain	0	1	2	0	3
STC1F	1% AEP Floodplain	0	0	0	0	0
TP10A	1% AEP Floodplain	0	0	0	0	0
TP10B	1% AEP Floodplain	0	0	0	0	0
TP10C	1% AEP Floodplain	0	0	0	0	0
TP10D	1% AEP Floodplain	0	0	0	0	0
TP3C	1% AEP Floodplain	0	19	0	0	19
TP3F	1% AEP Floodplain	2	6	3	0	11
TP8	1% AEP Floodplain	0	0	1	0	1
TP9A	1% AEP Floodplain	0	0	0	2	2
TP9C	1% AEP Floodplain	1	0	0	0	1
TP9D	1% AEP Floodplain	0	0	0	0	0
Total	**Comp Benefits**	**5**	**26**	**6**	**2**	**39**

Benefits decreased to $2.45 million annually in the top 25% sensitivity analysis compared to the Comprehensive Benefits plan, but the annual costs decreased to $1.5 million per year. This means that the net benefits rose to over 900 thousand per year if the bottom 116 structures do not participate. Table 106 provides a breakdown of the benefits by reach for the participation of the top 25% of structures.

Table 106. Top 25% Participation Benefits

Reach	Without	With	Benefits	Annual Costs	Net Benefits	BCR
STC1B	$1,154.94	$324.10	$830.84	$277.25	$553.59	3.00
STC1C	$446.10	$270.79	$175.31	$90.31	$85.00	1.94
STC1F	$27.64	$27.64	$0.00	$0.00	$0.00	0.00
TP10A	$176.23	$68.72	$107.51	$55.30	$52.21	1.94
TP10B	$208.76	$208.76	$0.00	$0.00	$0.00	0.00
TP10C	$241.83	$77.08	$164.75	$66.60	$98.15	2.47
TP10D	$118.33	$79.77	$38.56	$31.43	$7.13	1.23
TP3C	$74.91	$74.91	$0.00	$0.00	$0.00	0.00
TP3F	$2,717.52	$1,649.43	$1,068.09	$954.72	$113.37	1.12
TP8	$208.10	$170.63	$37.47	$42.64	-$5.17	0.88
TP9A	$75.55	$50.83	$24.72	$25.19	-$0.47	0.98
TP9C	$12.70	$12.70	$0.00	$0.00	$0.00	0.00
TP9D	$148.25	$148.25	$0.00	$0.00	$0.00	0.00
Total	**$5,610.86**	**$3,163.61**	**$2,447.25**	**$1,543.44**	**$903.81**	**1.59**

Benefits decreased to just over $23,000 in the bottom 25% participation rate analysis. Costs also fell to just over $572 thousand. Leaving net benefits to about -$548 thousand overall. Table 107 provides a breakdown of benefits by reach for the participation of the bottom 25% of structures.

Table 107. Bottom 25% Participation Benefits

Reach	Without	With	Benefits	Annual Costs	Net Benefits	BCR
STC1B	$1,154.94	$1,145.76	$9.18	$60.20	-$51.02	0.15
STC1C	$446.10	$441.36	$4.74	$61.52	-$56.78	0.08
STC1F	$27.64	$27.64	$0.00	$0.00	$0.00	0.00
TP10A	$176.23	$176.23	$0.00	$0.00	$0.00	0.00
TP10B	$208.76	$208.76	$0.00	$0.00	$0.00	0.00
TP10C	$241.83	$241.83	$0.00	$0.00	$0.00	0.00
TP10D	$118.33	$118.33	$0.00	$0.00	$0.00	0.00
TP3C	$74.91	$69.80	$5.11	$272.32	-$267.21	0.02
TP3F	$2,717.52	$2,714.12	$3.40	$155.29	-$151.89	0.02
TP8	$208.10	$207.88	$0.22	$9.46	-$9.24	0.02
TP9A	$75.55	$75.23	$0.32	$4.31	-$3.99	0.07
TP9C	$12.70	$12.10	$0.60	$8.94	-$8.34	0.07
TP9D	$148.25	$148.25	$0.00	$0.00	$0.00	0.00
Total	**$5,610.86**	**$5,587.29**	**$23.57**	**$572.03**	**-$548.46**	**0.04**

Table 108 provides a breakdown of the total costs, average annual costs, average annual benefits, net benefits, and BCR of the top 25% participation sensitivity analysis. The BCR rises to 1.59 because annual costs fall to about $1.5 million while benefits only drop to about $2.45 million annually.

Table 108. BCR of Top 25% Comp Benefit Structures (In $1,000s)

Top 25%	Contract Costs	Contingency (%)	Contingency ($)	Total Cost
Construction Cost	$19,367	43%	$8,328	$27,695
PED	$5,907	43%	$2,540	$8,447
Construction Management	$2,808	43%	$1,208	$4,016
Real Estate	$1,383		$0	$1,383
Total	**$29,465**		**$12,075**	**$41,540**
IDC				$128
Total Investment Cost				$41,668
Average Annual Costs				**$1,543**
Average Annual Benefits				**$2,447**
Net Benefits				**$904**
BCR				**1.59**

Table 109 provides a breakdown of the total costs, average annual costs, average annual benefits, net benefits, and BCR of the bottom 25% participation sensitivity analysis. The BCR falls to 0.04 because while annual costs fall to only $572,033, annual benefits drop to only $23,570 annually.

Table 109. BCR of Bottom 25% Comp Benefit Structures (In $1,000s)

Bottom 25%	Contract Costs	Contingency (%)	Contingency ($)	Total Cost
Construction Cost	$6,758,160	$0	$2,906,009	$9,664,169
PED	$2,061,221	$0	$886,325	$2,947,546
Construction Management	$979,944	$0	$421,376	$1,401,320
Real Estate	$1,382,613	$0	$0	$1,382,613
Total	**$11,181,938**		**$4,213,710**	**$15,395,648**
IDC				$47,624
Total Investment Cost				$15,443,272
Average Annual Costs				**$572,033**
Average Annual Benefits				**$23,570**
Net Benefits				**($548,463)**
BCR				**0.04**

13.2.5.4. Conclusion

The participation rate with the highest net benefits is the top 25%. Benefits exceed $900 thousand per year with very minimal loss to overall benefits. However, any lost participation from lower BCR structures tend to move the overall BCR closer to 1 with the nonparticipation of only the bottom 38 structures raises the BCR positive. The recommended plan is very reliant on the participation of the top structures.

Table 110. Comprehensive Benefit Sensitivity Overview (In $1,000s)

Participation Rate	Annual Benefits	Annual Costs	Net Benefits	BCR
100% Participation	$2,944.28	$3,667.30	($723.02)	0.80
Top 75%	$2,922.11	$3,105.63	($183.52)	0.94
Top 50%	$2,812.27	$2,476.82	$335.45	1.14
Top 25%	$2,447.25	$1,543.44	$903.81	1.59
Bottom 75%	$511.75	$2,142.07	($1,630.32)	0.24
Bottom 50%	$136.04	$1,193.28	($1,057.24)	0.11
Bottom 25%	$23.57	$572.03	($548.46)	0.04

13.3. Update Life Safety Analysis OSE

13.3.1. Life Loss Estimation Method

Detailed life loss modeling (i.e., LifeSim modeling) could not be accurately completed for this study due to only having one-dimensional (1D) steady flow Hydrologic Engineering Center River Analysis System (HEC-RAS) modeling in most areas. The LifeSim methodology relies on depth, hydraulic timing, velocity, and depth times velocity. 1D steady flow HEC-RAS modeling only produces maximum depth results. Life loss was estimated based on the maximum depth on structures along with a qualitative understanding of the velocity of floodwaters. This qualitative life loss analysis uses the LifeSim methodology.

Depth is one of the primary factors in determining the potential for loss of life. In LifeSim, high hazard depth is defined as a structure being inundated by a depth of at least four feet relative to first floor elevation. This analysis focuses on the frequency of depths occurring in this high hazard category in the existing and future without-project (FWOP) conditions and how that exposure changes with the nonstructural plan. The figure below identifies the criteria for high hazard depths from the LifeSim methodology.

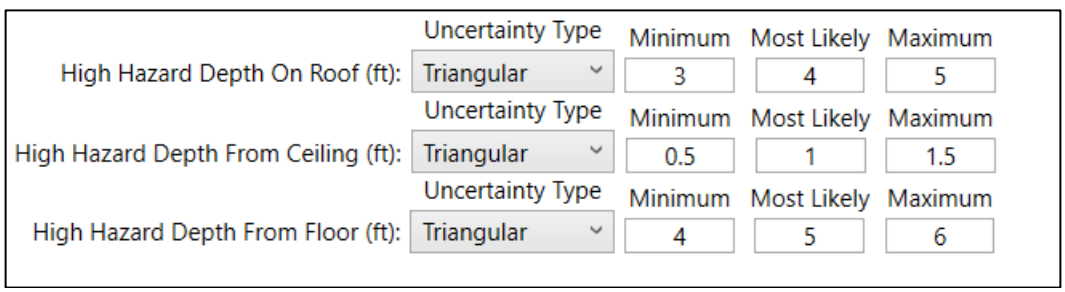

Figure 54 High Hazard Depth Chart

A major component that drives life loss in LifeSim is the structure stability threshold, which is a relationship of depth and velocity of floodwaters. The curve in Figure 55 represents the stability threshold for wood-anchored structure, which is representative of the majority of residential structures in the study area. As shown in Figure 55, it requires significant velocities (i.e., greater than 9ft/s) for relatively low depths (i.e., less than 4ft). The team has a qualitative understanding that the velocities of floodwaters across the range of scenarios is generally not fast. It's highly unlikely that velocities in this area will exceed the wood-anchored stability criteria (i.e., get swept off its foundation or collapse), which decreases the overall life safety risk for the area.

Additionally, because the plans are exclusively nonstructural, depth is the only physical characteristic being altered that will impact life safety. As the depth on the structure decreases, the ability to withstand additional velocity increases. This means that a structure is more likely to remain stable following the implementation of elevation. The life loss analysis is driven by the reduction of depth on structures.

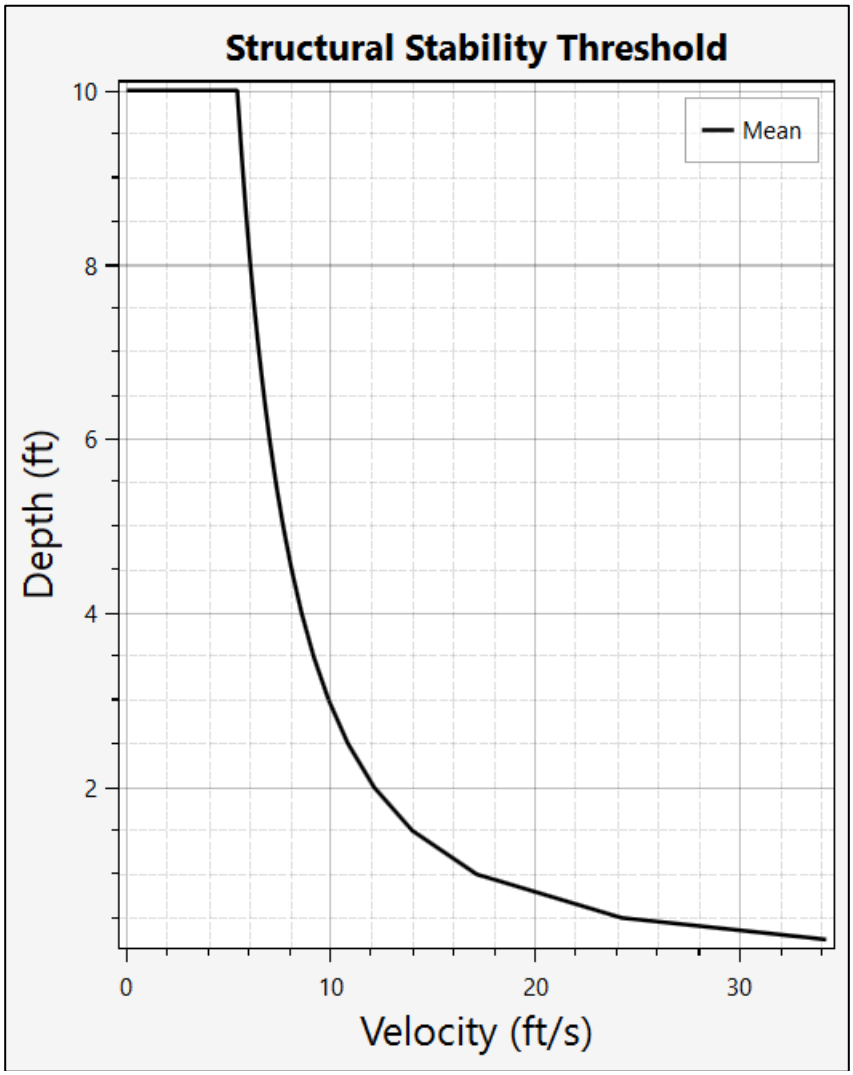

Figure 55 Structural Stability Threshold Curve (Wood-Anchored)

Following the implementation of nonstructural measures, any changes to first-floor elevations and subsequent flood depths (i.e., elevation) will be the main factor in potential life loss reductions. The nonstructural measures considered in the Tar Pamlico Feasibility Study are elevation, flood vents, flood vents and elevation, and floodproofing. Flood vents and floodproofing measures do not change the first-floor elevation and therefore does not change potential life loss compared to the FWOP. Only residential structures are considered for elevation (with or without flood vents) and only residential structures will have a significant change in potential life safety risk; these are the only types of structures included in the life loss calculation.

For all structures, the population at risk will have an improved perception of flood risk following the implementation of any nonstructural measures, including flood vents and floodproofing. This population will have an increased awareness of flooding, which will likely reduce potential life loss, but is not part of the life loss calculation for this predominantly qualitative analysis.

In order to calculate life loss, an estimate of population per structure is needed. All structures considered in the comprehensive benefits (Comprehensive Benefits) plan and National Economic Development

(NED) plan are residential. The most readily available information for estimating population is the U.S. Census Bureau's "persons per household" statistic. The three North Carolina counties with proposed nonstructural measures are Nash, Edgecombe, and Washington. The 2018-2022 average persons per household for each county is shown in the table below. The average occupancy rate based on this statistic is 2.4 persons. This occupancy rate is assumed for all structures across the three alternatives in this life loss analysis.

Table 111 Persons Per Household – U.S. Census Bureau (2018-2022)

North Carolina County	Persons Per Household
Nash	2.46
Edgecombe	2.50
Washington	2.23
Average	***2.40***

As previously stated, detailed life loss modeling (i.e., LifeSim modeling) could not be accurately completed for this study due to only having 1D steady flow HEC-RAS modeling available in most areas. The 1D steady flow HEC-RAS modeling only produces maximum depth results. Life loss was estimated based on the maximum depth on structures along with a qualitative understanding of the velocity of floodwaters. This qualitative life loss analysis uses the LifeSim methodology by incorporating the high hazard depth thresholds and the average LifeSim fatality rates for low hazard (1.4011E-05) and high hazard structures (7.1E-01). Any structures with depths above 4ft were assumed to be "high hazard" and the 7.1E-01 fatality rate was applied. Any structures with less than 4ft of depth were assumed to be "low hazard" and the 1.4011E-05 fatality rate was applied.

The figure below shows the 0.04 AEP and 0.002 AEP flood extents, and the structures included in both the NED plan and the Comprehensive Benefits plan. As shown below, the majority of structures included in the Comprehensive Benefits plan are located in or around Greenville, NC and Rocky Mount, NC. It's also notable that there are very few blue structures (i.e., structures included in the NED plan).

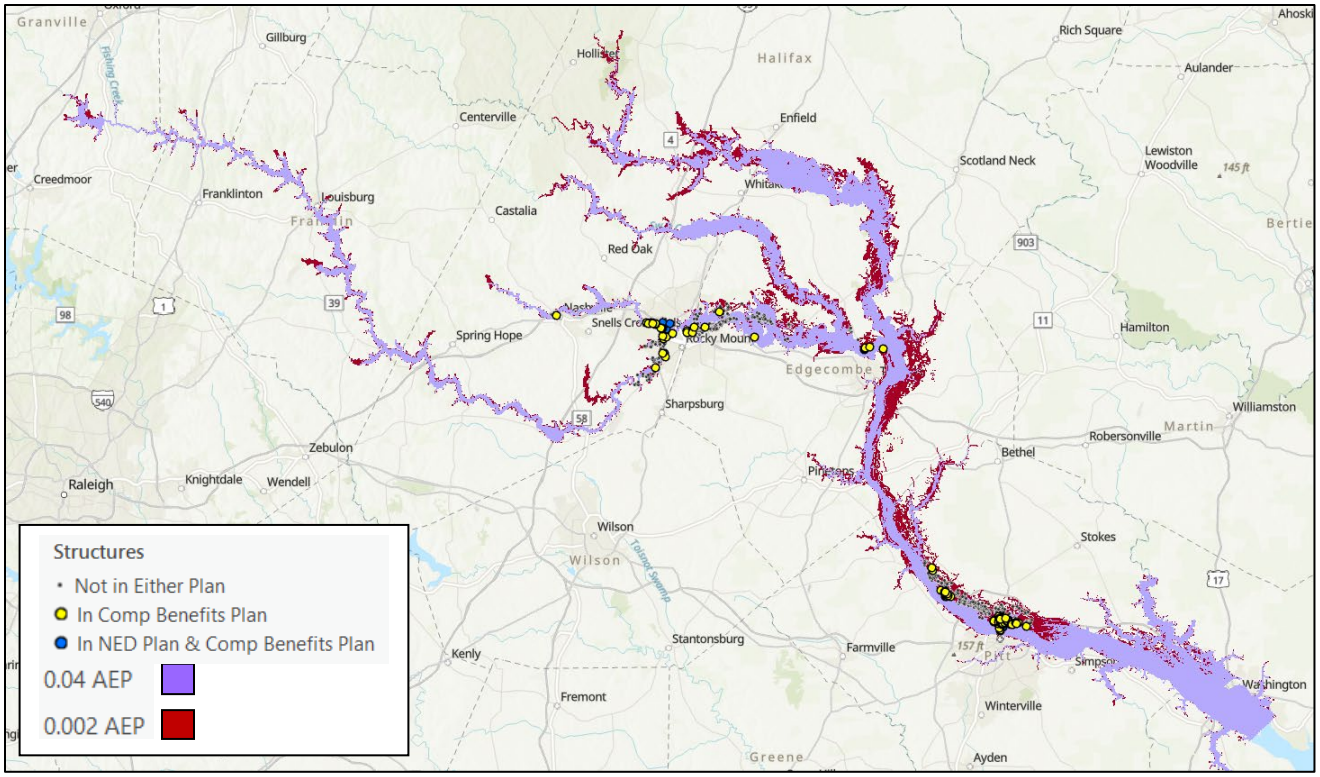

Figure 56 Comprehensive Benefits Plan & NED Plan Structure Locations

13.3.2. Existing and Future Without Project Conditions

All structural measures and alternatives were screened based on changes in water surface elevations on structures, which considered both life loss consequences and economic consequences. The FWOP life safety analysis focuses on the 53 structures with recommendations to be elevated in the selected Comprehensive Benefits plan to show the estimated life loss if these structures are not elevated.

13.3.2.1. Flood Depth

The table below shows the depths at the 0.04, 0.01, and 0.002 AEP events for the 53 structures that are recommended to be elevated in the Comprehensive Benefits plan. There are hundreds of other structures impacted by the analyzed hydraulic scenarios, but the life loss analysis focuses on how the NED and Comprehensive Benefits plans impact the specific structures' life safety risk identified for elevation. The data is from the structure detail output from the HEC-FDA model. Negative depth values indicate the structure is flooded, but the water surface elevations are below the first-floor elevation of the structure.

Table 112. FWOP - Depth by Structure

Structure	Occ Type	SID Reach	Elevation (ft)	FWOP Depth at 0.04 AEP	FWOP Depth at 0.01 AEP	FWOP Depth at 0.002 AEP
5367	R06	STC1B	2.72	-0.16	0.72	1.76
5114	R04	STC1C	3.01	-0.68	1.01	2.8
5117	R06	STC1C	2.86	-0.6	0.86	2.38
5265	R04	STC1C	0.52	-2.56	-1.48	-0.35
5269	R04	STC1C	0.55	-2.54	-1.45	-0.3
5306	R04	STC1C	0.88	-2.28	-1.12	0.11

Structure	Occ Type	SID Reach	Elevation (ft)	FWOP Depth at 0.04 AEP	FWOP Depth at 0.01 AEP	FWOP Depth at 0.002 AEP
5322	R06	STC1C	2.02	-1.44	0.02	1.55
5327	R04	STC1C	2.88	-0.58	0.88	2.41
5354	R06	STC1C	3.78	0.21	1.78	3.43
5097	R04	TP10A	3.42	-0.97	1.42	3.3
1232	R07	TP10B	4.05	0.33	2.05	4.04
5193	R04	TP10C	0.77	-1.99	-1.23	-0.02
5211	R06	TP10C	6.58	3.28	4.58	6.08
5236	R04	TP10C	1.61	-1.73	-0.39	1.09
1412	R07	TP3C	1.18	-9.02	-0.82	2.73
1497	R07	TP3C	1.21	-8.72	-0.79	2.76
1519	R07	TP3C	1.02	-9.32	-0.98	2.58
1818	R07	TP3C	0.96	-10.53	-1.04	2.52
1898	R07	TP3C	2.09	-9	0.09	3.65
1899	R07	TP3C	3.01	-1.99	1.01	4.57
1909	R07	TP3C	2.31	-9.42	0.31	3.86
1910	R07	TP3C	2.64	-9.19	0.64	4.2
1912	R07	TP3C	2.13	-9.7	0.13	3.69
1916	R07	TP3C	0.7	-9.4	-1.3	2.26
1917	R07	TP3C	1.45	-3.54	-0.55	3.01
1918	R07	TP3C	2.19	-9.8	0.19	3.74
2049	R07	TP3C	1.19	-9.17	-0.81	2.73
2162	R07	TP3C	0.55	-9.63	-1.45	2.09
3206	R04	TP3C	1.48	-7.66	-0.52	2.93
3320	R07	TP3C	1.04	-9.31	-0.96	2.56
3378	R04	TP3C	2.16	-2.81	0.16	3.66
3385	R07	TP3C	0.54	-9.31	-1.46	2.06
3400	R07	TP3C	0.62	-8.73	-1.38	2.16
3401	R07	TP3C	0.9	-9.6	-1.1	2.43
3404	R07	TP3C	0.66	-8.9	-1.34	2.19
3410	R07	TP3C	0.7	-9.12	-1.3	2.15
1440	R04	TP3F	2.52	-9	0.52	3.73
1505	R04	TP3F	2.3	-7.26	0.3	3.54
1585	R04	TP3F	1.26	-9	-0.74	2.49
1588	R04	TP3F	2.88	-8	0.88	4.11
1597	R04	TP3F	5.2	0.4	3.2	6.44
1606	R07	TP3F	0.8	-10.93	-1.2	2.03
1757	R04	TP3F	1.01	-8	-0.99	2.16
1936	R04	TP3F	1.06	-8	-0.94	2.29
1952	R07	TP3F	1.03	-9.4	-0.97	2.18
2247	R07	TP3F	1.16	-9.4	-0.84	2.4

Structure	Occ Type	SID Reach	Elevation (ft)	FWOP Depth at 0.04 AEP	FWOP Depth at 0.01 AEP	FWOP Depth at 0.002 AEP
2419	R07	TP3F	0.98	-9.4	-1.02	2.23
2637	R04	TP3F	3.07	-1.72	1.07	4.31
2671	R04	TP3F	2.04	-8	0.04	3.28
2907	R07	TP3F	1.32	-8.43	-0.68	2.52
3125	R07	TP3F	1.04	-9.4	-0.96	2.29
5902	R06	TP8	1.86	-9.4	-0.14	3.08
5367	R06	STC1B	2.72	-0.16	0.72	1.76

The tables below show the FWOP condition's structures inundated, population at risk, and calculated life loss for the 0.04, 0.01, and 0.002 AEP events. To estimate population at risk, the most readily available information for estimating population is the U.S. Census Bureau's "Persons Per Household" statistic. The three North Carolina counties with proposed nonstructural measures are Nash, Edgecombe, and Washington. The average occupancy rate for these three counties is 2.4 persons. This occupancy rate is assumed for all structures in this life safety analysis.

Low hazard depths are defined as structures inundated by less than 4ft above the first-floor elevation (i.e., the structures with negative depths are not included as this represents flood depths below the first floor). High hazard depths are defined as structures inundated by at least 4ft above the first-floor elevation.

Table 113. FWOP Estimated Life Loss

Hazard Zone	FWOP 0.04 AEP		
	Structures Inundated	**Population at Risk**	**Estimated Life Loss**
Low Hazard Depth	5	12	0
High Hazard Depth	0	0	0

Hazard Zone	FWOP 0.01 AEP		
	Structures Inundated	Population at Risk	Estimated Life Loss
Low Hazard Depth	22	52.8	0.001
High Hazard Depth	1	2.4	1.704

Hazard Zone	FWOP 0.002 AEP		
	Structures Inundated	**Population at Risk**	**Estimated Life Loss**
Low Hazard Depth	43	103.2	0.001
High Hazard Depth	7	16.8	11.928

13.3.3. Alternative 3A the NED Plan

The NED Plan was identified as the aggregation that reasonably maximized net benefits that accrued to the NED account. NED was measured by the decreased expected annual damages from the without-project to the with-project condition. This analysis looks at the changes in depths of the structures that were identified for elevation in this aggregation.

13.3.3.1. Flood Depth

A total of 42 structures across 7 damage reaches have been identified for nonstructural measures in the NED plan. A total of 3 structures are recommended to be elevated and will see a decrease in depths at the structure level.

Table 114. Recommended Nonstructural Measure Breakdown by Reach

Reach	Aggregation	Elevate	Elevate & Flood Vent	Dry Floodproof	Total
STC1B	0.01 AEP Floodplain	1	0	14	15
TP10A	0.1 AEP Floodplain	0	0	2	2
TP10C	0.1 AEP Floodplain	0	1	1	2
TP10D	0.01 AEP Floodplain	0	0	1	1
TP3F	0.04 AEP Floodplain	1	0	15	16
TP8*	0.2 AEP Floodplain	0	0	4	4
TP9A	0.2 AEP Floodplain	0	0	1	1
	Total	**2**	**1**	**38**	**41**

*TP8 is no longer in the NED Plan

The average elevation across these structures is 1.84 feet which would translate to 1.84 less depth at the first floor on average. The implication is that these structures see a decrease in overall life loss risk because water is not expected to reach the living area of these structures. The table below shows each structure's depth at the 0.04 AEP, 0.01 AEP, and 0.002 AEP events. As stated above, 3 structures are recommended to be elevated; these structures are bolded in the table below. As previously stated, this analysis focuses on the 53 structures proposed to be elevated in the Comprehensive Benefits plan; Table 115 shows the depth of these 53 structures at the 0.04 AEP, 0.01 AEP, and 0.002 AEP vents under the NED Plan.

Table 115. NED Plan - Depth by Structure

Structure	Occ Type	SID Reach	Elevation (ft)	NED Depth at 0.04 AEP	NED Depth at 0.01 AEP	NED Depth at 0.002 AEP
5367	R06	STC1B	2.72	-2.89	-2	-0.97
5114	R04	STC1C	3.01	-0.68	1.01	2.8
5117	R06	STC1C	2.86	-0.6	0.86	2.38
5265	R04	STC1C	0.52	-2.56	-1.48	-0.35
5269	R04	STC1C	0.55	-2.54	-1.45	-0.3
5306	R04	STC1C	0.88	-2.28	-1.12	0.11
5322	R06	STC1C	2.02	-1.44	0.02	1.55
5327	R04	STC1C	2.88	-0.58	0.88	2.41

Structure	Occ Type	SID Reach	Elevation (ft)	NED Depth at 0.04 AEP	NED Depth at 0.01 AEP	NED Depth at 0.002 AEP
5354	R06	STC1C	3.78	0.21	1.78	3.43
5097	R04	TP10A	3.42	-0.97	1.42	3.3
1232	R07	TP10B	4.05	0.33	2.05	4.04
5193	R04	TP10C	0.77	-1.99	-1.23	-0.02
5211	R06	TP10C	6.58	3.28	4.58	6.08
5236	R04	TP10C	1.61	-3.34	-2	-0.52
1412	R07	TP3C	1.18	-9.02	-0.82	2.73
1497	R07	TP3C	1.21	-8.72	-0.79	2.76
1519	R07	TP3C	1.02	-9.32	-0.98	2.58
1818	R07	TP3C	0.96	-10.53	-1.04	2.52
1898	R07	TP3C	2.09	-9	0.09	3.65
1899	R07	TP3C	3.01	-1.99	1.01	4.57
1909	R07	TP3C	2.31	-9.42	0.31	3.86
1910	R07	TP3C	2.64	-9.19	0.64	4.2
1912	R07	TP3C	2.13	-9.7	0.13	3.69
1916	R07	TP3C	0.7	-9.4	-1.3	2.26
1917	R07	TP3C	1.45	-3.54	-0.55	3.01
1918	R07	TP3C	2.19	-9.8	0.19	3.74
2049	R07	TP3C	1.19	-10.36	-2	1.54
2162	R07	TP3C	0.55	-9.63	-1.45	2.09
3206	R04	TP3C	1.48	-7.66	-0.52	2.93
3320	R07	TP3C	1.04	-9.31	-0.96	2.56
3378	R04	TP3C	2.16	-2.81	0.16	3.66
3385	R07	TP3C	0.54	-9.31	-1.46	2.06
3400	R07	TP3C	0.62	-8.73	-1.38	2.16
3401	R07	TP3C	0.9	-9.6	-1.1	2.43
3404	R07	TP3C	0.66	-8.9	-1.34	2.19
3410	R07	TP3C	0.7	-9.12	-1.3	2.15
1440	R04	TP3F	2.52	-9	0.52	3.73
1505	R04	TP3F	2.3	-7.26	0.3	3.54
1585	R04	TP3F	1.26	-9	-0.74	2.49
1588	R04	TP3F	2.88	-8	0.88	4.11
1597	R04	TP3F	5.2	0.4	3.2	6.44
1606	R07	TP3F	0.8	-10.93	-1.2	2.03
1757	R04	TP3F	1.01	-8	-0.99	2.16
1936	R04	TP3F	1.06	-8	-0.94	2.29
1952	R07	TP3F	1.03	-9.4	-0.97	2.18
2247	R07	TP3F	1.16	-9.4	-0.84	2.4
2419	R07	TP3F	0.98	-9.4	-1.02	2.23
2637	R04	TP3F	3.07	-1.72	1.07	4.31

Structure	Occ Type	SID Reach	Elevation (ft)	NED Depth at 0.04 AEP	NED Depth at 0.01 AEP	NED Depth at 0.002 AEP
2671	R04	TP3F	2.04	-8	0.04	3.28
2907	R07	TP3F	1.32	-8.43	-0.68	2.52
3125	R07	TP3F	1.04	-9.4	-0.96	2.29
5718	R06	TP9D	3.08	0.4	1.08	1.77
5367	R06	STC1B	2.72	-2.89	-2	-0.97

To estimate population at risk, the most readily available information for estimating population is the U.S. Census Bureau's "Persons Per Household" statistic. The three North Carolina counties with proposed nonstructural measures are Nash, Edgecombe, and Washington. The average occupancy rate for these three counties is 2.4 persons. This occupancy rate is assumed for all structures in this life safety analysis. The tables below show the NED plan's estimated structures inundated, population at risk, and life loss for the 0.04 AEP, 0.01 AEP, and 0.002 AEP events.

Table 116. NED Plan Estimated Life Loss

Hazard Zone	NED Plan 0.04 AEP		
	Structures Inundated	Population at Risk	Estimated Life Loss
Low Hazard Depth	5	12	0
High Hazard Depth	0	0	0

Hazard Zone	NED Plan 0.01 AEP		
	Structures Inundated	Population at Risk	Estimated Life Loss
Low Hazard Depth	21	50.4	0.001
High Hazard Depth	1	2.4	1.704

Hazard Zone	NED Plan 0.002 AEP		
	Structures Inundated	Population at Risk	Estimated Life Loss
Low Hazard Depth	41	98.4	0.001
High Hazard Depth	7	16.8	11.928

13.3.3.2. Risk Perception

As previously stated, while the proposed nonstructural measure for nonresidential structures does not change depth of water in the structure, it does provide an additional level of awareness to the employees at these structures. Dry floodproofing requires the closure of openings such as doors and windows. These additional requirements will lead to training and awareness of how to act in a flooding situation. Similarly, floodproofing residential structures increases the awareness of the risk to not only the residents in those homes, but throughout the community. Because nonstructural plans are formulated at the community level for structures experiencing similar flood risks, the awareness throughout the community is high even if individuals opt out of participating.

13.3.4. Alternative 3B Comprehensive Benefits Plan

The Comprehensive Benefits aggregation reasonably maximized the net benefits across all benefit categories. The most at-risk structures were considered for the Comprehensive Benefits plan and

structures located in Environmental Justice communities. The most at-risk structures included residential structures with relatively high flood depths and relatively high economic consequences. A structure's economic consequences strongly correlate to a structure's potential loss of life consequences and was a consideration in aggregation.

13.3.4.1. Flood Depth

A total of 155 structures across 13 damage reaches have been identified for nonstructural measures. A total of 53 structures are recommended to be elevated, which results in decreased first floor flood depths. The life safety analysis for the Comprehensive Benefits plan focuses on the elevated structures as the flood vented and dry floodproofed structures will not experience a significant decrease in flood depths and life safety risk.

Table 117. Recommended Nonstructural Measure Breakdown by Reach

Reach	Elevate & Flood Vent	Elevate	Flood Vent	Dry Floodproof	Total
STC1B	1	0	0	14	15
STC1C	1	7	4	7	19
STC1F	0	0	0	1	1
TP10A	0	1	1	2	4
TP10B	1	0	0	1	2
TP10C	0	3	1	1	5
TP10D	0	0	0	1	1
TP3C	22	0	0	0	22
TP3F	10	5	0	52	67
TP8	0	1	0	9	10
TP9A	0	0	2	2	4
TP9C	0	0	0	1	1
TP9D	0	1	0	3	4
Total	**35**	**18**	**8**	**94**	**155**

The average elevation across these structures is 1.86 feet. The implication is that these structures see a decrease in overall life safety risk because water is not expected to reach the first-floor elevation of these structures.

Five of the 53 structures that are proposed to be elevated under the Comprehensive Benefits plan are inundated above the first floor at the FWOP 0.04 AEP event. The maximum depth at this event is 3.28 feet, but the average depth is -5.96 feet. This means 0 structures fall into the high hazard zone as defined in LifeSim. Of the 53 structures that are proposed to be elevated under the Comprehensive Benefits plan zero structures are inundated above the first-floor elevation. The maximum depth at this event is -2.68 feet and the average is -7.83 feet.

23 of the 53 structures that are proposed to be elevated under the Comprehensive Benefits plan are inundated above the first-floor elevation at the FWOP 0.01 AEP event. The maximum depth is 4.58 feet, and the average depth is -0.14 feet. There is one structure in the high hazard zone as defined by LifeSim. In the Comprehensive Benefits Plan 0.01 AEP event, zero structures are inundated. Because the 0.01 AEP event is the target stage plus 2 feet, all structures experience -2 feet of depth during this event, which indicates 0 structures are inundated above the first floor.

51 of the 53 structures that are proposed to be elevated under the Comprehensive Benefits plan are inundated above the first-floor elevation. at the FWOP 0.002 AEP event. The maximum depth is 6.44 feet with an average depth of 2.68 feet. A total of 7 structures has a depth greater than 4 feet which indicates high hazard as defined in LifeSim. For the Comprehensive Benefits plan at the 0.002 AEP event, 38 structures are inundated with the maximum depth still at 1.56 feet. The average depth decreases to 0.82 feet. No structures are in the high hazard zone. The table below provides the summary of the structure depths in the Comprehensive Benefits plan. Overall, depths are significantly decreased across the range of events compared to the FWOP condition.

Table 118. Comprehensive Benefits Plan – Depth by Structure

Structure	Occ Type	SID Reach	Elevation (ft)	Comp Depth at 0.04 AEP	Comp Depth at 0.01 AEP	Comp Depth at 0.002 AEP
1232	R07	TP10B	4.05	-3.73	-2	-0.01
1412	R07	TP3C	1.18	-10.2	-2	1.55
1440	R04	TP3F	2.52	-11.52	-2	1.21
1497	R07	TP3C	1.21	-9.92	-2	1.56
1505	R04	TP3F	2.3	-9.55	-2	1.24
1519	R07	TP3C	1.02	-10.35	-2	1.56
1585	R04	TP3F	1.26	-10.27	-2	1.23
1588	R04	TP3F	2.88	-10.87	-2	1.23
1597	R04	TP3F	5.2	-4.8	-2	1.24
1606	R07	TP3F	0.8	-11.73	-2	1.24
1757	R04	TP3F	1.01	-9.01	-2	1.16
1818	R07	TP3C	0.96	-11.5	-2	1.56
1898	R07	TP3C	2.09	-11.09	-2	1.56
1899	R07	TP3C	3.01	-5	-2	1.56
1909	R07	TP3C	2.31	-11.72	-2	1.56
1910	R07	TP3C	2.64	-11.83	-2	1.56
1912	R07	TP3C	2.13	-11.83	-2	1.56
1916	R07	TP3C	0.7	-10.1	-2	1.56
1917	R07	TP3C	1.45	-5	-2	1.56
1918	R07	TP3C	2.19	-11.99	-2	1.55
1936	R04	TP3F	1.06	-9.06	-2	1.23
1952	R07	TP3F	1.03	-10.43	-2	1.16
2049	R07	TP3C	1.19	-10.36	-2	1.54
2162	R07	TP3C	0.55	-10.18	-2	1.54
2247	R07	TP3F	1.16	-10.55	-2	1.24
2419	R07	TP3F	0.98	-10.38	-2	1.25
2637	R04	TP3F	3.07	-4.79	-2	1.24
2671	R04	TP3F	2.04	-10.04	-2	1.24
2907	R07	TP3F	1.32	-9.76	-2	1.2
3125	R07	TP3F	1.04	-10.44	-2	1.25
3206	R04	TP3C	1.48	-9.13	-2	1.45
3320	R07	TP3C	1.04	-10.35	-2	1.52

Structure	Occ Type	SID Reach	Elevation (ft)	Comp Depth at 0.04 AEP	Comp Depth at 0.01 AEP	Comp Depth at 0.002 AEP
3378	R04	TP3C	2.16	-4.98	-2	1.5
3385	R07	TP3C	0.54	-9.85	-2	1.52
3400	R07	TP3C	0.62	-9.35	-2	1.53
3401	R07	TP3C	0.9	-10.5	-2	1.52
3404	R07	TP3C	0.66	-9.56	-2	1.53
3410	R07	TP3C	0.7	-9.82	-2	1.45
5097	R04	TP10A	3.42	-4.4	-2	-0.12
5114	R04	STC1C	3.01	-3.69	-2	-0.21
5117	R06	STC1C	2.86	-3.46	-2	-0.47
5193	R04	TP10C	0.77	-2.77	-2	-0.8
5211	R06	TP10C	6.58	-3.3	-2	-0.5
5236	R04	TP10C	1.61	-3.34	-2	-0.52
5265	R04	STC1C	0.52	-3.08	-2	-0.86
5269	R04	STC1C	0.55	-3.08	-2	-0.85
5306	R04	STC1C	0.88	-3.16	-2	-0.77
5322	R06	STC1C	2.02	-3.46	-2	-0.47
5327	R04	STC1C	2.88	-3.46	-2	-0.47
5354	R06	STC1C	3.78	-3.57	-2	-0.35
5367	R06	STC1B	2.72	-2.89	-2	-0.97
5902	R06	TP8	1.86	-11.26	-2	1.21
1232	R07	TP10B	4.05	-3.73	-2	-0.01

To estimate population at risk, the most readily available information for estimating population is the U.S. Census Bureau's "Persons Per Household" statistic. The three North Carolina counties with proposed nonstructural measures are Nash, Edgecombe, and Washington. The average occupancy rate for these three counties is 2.4 persons. This occupancy rate is assumed for all structures in this life safety analysis. The tables below show the Comprehensive Benefits plan's estimated structures inundated, population at risk, and life loss for the 0.04 AEP, 0.01 AEP, and 0.002 AEP events.

Table 119. Comprehensive Benefits Plan Estimated Life Loss

Hazard Zone	Comp Benefits Plan 0.04 AEP		
	Structures Inundated	Population at Risk	Estimated Life Loss
Low Hazard Depth	0	0	0
High Hazard Depth	0	0	0

Hazard Zone	Comp Benefits Plan 0.01 AEP		
	Structures Inundated	Population at Risk	Estimated Life Loss
Low Hazard Depth	0	0	0
High Hazard Depth	0	0	0

Hazard Zone	Comp Benefits Plan 0.002 AEP

	Structures Inundated	Population at Risk	Estimated Life Loss
Low Hazard Depth	38	91.2	0.001
High Hazard Depth	0	0	0

13.3.4.2. Risk Perception

While the proposed nonstructural measure for nonresidential structures does not change depth of water in the structure, it does provide an additional level of awareness to the employees at these structures. Dry floodproofing requires the closure of openings such as doors and windows. These additional requirements will lead to training and awareness of how to act in a flooding situation. It is very difficult to quantify these impacts, but it is important to acknowledge that they occur.

13.3.5. Conclusion

The overall risk of life loss in the study area is not estimated to be very significant prior to the implementation of the recommended plan, however, the plan will decrease the overall life safety risk compared to the FWOP condition. The increase in first-floor elevations to the structures recommended for elevation paired with the additional awareness in structures with dry floodproofing measures will lead to lower life safety risk in the future with-project conditions, especially with the Comprehensive Benefits plan because significantly more structures are included in the nonstructural implementation.

13.4. RED

he U.S. Army Corps of Engineers (USACE) Institute for Water Resources, Louis Berger, and Michigan State University have developed a regional economic impact modeling tool, RECONS (Regional Economic System), that provides estimates of jobs and other economic measures such as labor income, value added, and sales that are supported by USACE programs, projects, and activities. This modeling tool automates calculations and generates estimates of jobs, labor income, value added, and sales through the use of IMPLAN®'s multipliers and ratios, customized impact areas for USACE project locations, and customized spending profiles for USACE projects, business lines, and work activities. RECONS allows the USACE to evaluate the regional economic impact and contribution associated with USACE expenditures, activities, and infrastructure. These benefits are short term and only last through construction.

13.4.1. RED Alternative 3A NED Plan

The expenditures associated with Alternative 3A - are estimated to be $37,192,904. Of this total expenditure, $25,557,771 will be captured within the local impact area. The remainder of the expenditures will be captured within the state impact area and the nation. 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 the following tables. The regional economic effects are shown for the local, state, and national impact areas. In summary, the Civil Works expenditures $37,192,904 support a total of 397.1 full-time equivalent jobs, $23,101,799 in labor income, $25,179,316 in the gross regional product, and $41,951,059 in economic output in the local impact area. More broadly, these expenditures support 661.5 full-time equivalent jobs, $44,610,517 in labor income, $58,569,673 in the gross regional product, and $101,048,431 in economic output in the nation as illustrated in Table 120.

Table 120. RED Alternative 3A NED Plan

Area	Local Capture	Output	Jobs*	Labor Income	Value Added
Local					
Direct Impact		$25,557,771	291.5	$18,138,997	$16,119,700
Secondary Impact		$16,393,288	105.7	$4,962,802	$9,059,617
Total Impact	$25,557,771	$41,951,059	397.1	$23,101,799	$25,179,316
State					
Direct Impact		$29,923,342	329.0	$21,026,457	$19,296,490
Secondary Impact		$30,922,544	172.0	$10,081,083	$17,335,355
Total Impact	$29,923,342	$60,845,887	501.1	$31,107,540	$36,631,845
US					
Direct Impact		$35,491,397	358.6	$23,727,790	$22,825,251
Secondary Impact		$65,557,034	303.0	$20,882,727	$35,744,422
Total Impact	$35,491,397	$101,048,431	661.5	$44,610,517	$58,569,673

* Jobs are presented in full-time equivalence (FTE)

13.4.2. RED Alternative 3B Comprehensive Benefits Plan

The expenditures associated with Alternative 3B - are estimated to be $98,700,317. Of this total expenditure, $67,823,692 will be captured within the local impact area. The remainder of the expenditures will be captured within the state impact area and the nation. 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 the following tables. The regional economic effects are shown for the local, state, and national impact areas. In summary, the Civil Works expenditures $98,700,317 support a total of 1,053.9 full-time equivalent jobs, $61,306,180 in labor income, $66,819,372 in the gross regional product, and $111,327,224 in economic output in the local impact area. More broadly, these expenditures support 1,755.5 full-time equivalent jobs, $118,384,737 in labor income, $155,428,714 in the gross regional product, and $268,156,314 in economic output in the nation.as illustrated in Table 121.

Table 121. RED Alternative 3B NED Plan

Area	Local Capture	Output	Jobs*	Labor Income	Value Added
Local					
Direct Impact		$67,823,692	773.5	$48,136,190	$42,777,500
Secondary Impact		$43,503,532	280.5	$13,169,990	$24,041,871
Total Impact	$67,823,692	$111,327,224	1,053.9	$61,306,180	$66,819,372
State					
Direct Impact		$79,408,786	873.1	$55,798,761	$51,207,877
Secondary Impact		$82,060,409	456.6	$26,752,578	$46,003,534
Total Impact	$79,408,786	$161,469,195	1,329.7	$82,551,338	$97,211,411
US					
Direct Impact		$94,184,959	951.5	$62,967,398	$60,572,292
Secondary Impact		$173,971,356	804.0	$55,417,339	$94,856,422
Total Impact	$94,184,959	$268,156,314	1,755.5	$118,384,737	$155,428,714

* Jobs are presented in full-time equivalence (FTE)

14. CONCLUSION AND SELECTED PLAN

Both Alternative 3A and 3B meet federal objectives; however, contribution to objectives and avoidance of constraints for these were also evaluated. Additionally, alternatives were evaluated based on completeness, effectiveness, efficiency, acceptability, environmental justice (resilience), environmental justice (community cohesion), and environmental effects. Alternatives were also evaluated with respect to the Principles and Guidelines four accounts (i.e., NED, RED, OSE, EQ).

Alternative 3A has the greatest net economic benefits ($802,000) and BCR (1.65) and, thus, represents the NED Plan. Although Alternative 3A represents the NED plan, Alternative 3B represents the plan that reasonably maximizes benefits across all four accounts (i.e., NED, RED, OSE, and EQ) as illustrated in Table 122. Therefore, Alternative 3B was selected as the recommended plan. The additional increment in study cost between Alternative 3A and 3B is primarily justified based on the OSE account due to the benefits associated with environmental justice. Alternative 3B incorporates an additional 118 structures—all of which are within communities that are identified as socially vulnerable, and therefore less resilient; or disadvantaged as defined by the EJScreen and/or the Climate and Economic Justice Screening Tool (CEJST) (Section 9.1.3 and 9.1.4). The identified communities have substantial expected annual damages under the "future without project" (FWOP) condition. Taken together, these conditions emphasize the increased burden that flood risk places on disadvantaged communities, whereby the reaches are generally characterized by historically underserved populations with low income that also have increased vulnerabilities in the face of climate change. Thus, these represent among the least resilient communities within the basin. Alternatives 3B would improve community cohesion in the face of continued flood risk by helping to ensure that communities remain intact by providing equal assistance to all individuals, including those individuals that represent socially vulnerable and historically underserved populations. In doing so, Alternative 3B would promote and preserve diversity and equal opportunity within communities benefited by Alternative 3B.

Table 122. Summary of Accounts

Consideration	Alt. 1. No Action	Alt. 3A. Max Net Economic Benefits/NED	Alt. 3B. Comprehensive Benefits
1. Account Analysis			
A. NED			
(1) Annual Net Benefits (2) BCR (3) Rank	(1) $0 (2) 0.00 (3) 2nd	(1) $661,000 (2) 1.48 (3) 1st	(1) ($723,000) (2) 0.8 (3) 3rd
B. RED			
(1) Employment (2) Labor Income (3) Rank	(1) 0 full time equivalents (2) $0 in labor income (3) 3rd	(1) 661.5 full-time equivalent jobs, (2) $44,610,517 in labor income (3) 2nd	(1) 1,755.5 full-time equivalent jobs, (2) $118,384,737 in labor income (3) 1st
C. OSE			
(1) Life Safety (2) Rank	(1) No reduction in life safety risk. (2) 3rd	(1) Reduction in life safety risk for occupants of 37 structures due to reduction in inundation and increase in flood awareness. (2) 2nd	(1) Reduction in life safety risk for occupants of 155 structures due to reduction in inundation and increase in flood awareness. (2) 1st
(1) Environmental Justice (Resilience) (2) Rank	(1) No increase in resilience of at-risk communities; potential reduction in resilience due to climate change. (2) 3rd	(1) Increased resilience of communities that benefit; however, minimal benefit to communities identified as socially vulnerable due to focus on maximizing economic benefits. (2) 2nd	(1) Increased resilience of communities that benefit, including 9 reaches identified as socially vulnerable. Benefits to a larger proportion of each community, including socially vulnerable populations, increases overall resilience. (2) 1st
(1) Environmental Justice (Cohesion) (2) Rank	(1) Loss of community cohesion as communities continue to be impacted and fragmented. (2) 3rd	(1) Benefits community cohesion by reducing risk to 37 at-risk structures; however, most at-risk structures—particularly those in socially vulnerable communities—remain at risk with a potential for future impacts that result in a loss of community cohesion. (2) 2nd	(1) Benefits community cohesion by reducing risk to 155 at-risk structures, with a greater focus on socially vulnerable communities. Much less risk remains in benefiting communities that could degrade community cohesion in the future. (2) 1st

Consideration	Alt. 1. No Action	Alt. 3A. Max Net Economic Benefits/NED	Alt. 3B. Comprehensive Benefits
Overall Rank for OSE account	3rd	2nd	1st
D. EQ			
(1) Natural Environment (2) Rank	(1) No change in the natural environment, including wetlands, aquatic habitat, riparian habitat, threatened and endangered species or critical habitat. (2) 1st	(1) No significant impacts to the natural environment, including wetlands, aquatic habitats, riparian habitats, threatened and endangered species or critical habitat. (2) 2nd (tie)	(1) No significant impacts to the natural environment, including wetlands, aquatic habitat, riparian habitat, threatened and endangered species or critical habitat. (2) 2nd (tie)
(1) Physical Environment (2) Rank	(1) No change in the physical environment, including climate, land use, cultural resources, air quality, water quality, or HTRW. (2) 1st	(1) No significant impacts to the physical environment, including climate, land use, cultural resources, air quality, water quality, or HTRW. All impacts would be minor and temporary. (2) 2nd (tie)	(1) No significant impacts to the physical environment, including climate, land use, cultural resources, air quality, water quality, or HTRW. All impacts would be minor and temporary. (2) 2nd (tie)
Overall Rank for EQ account	1st	2nd (tie)	2nd (tie)
2. Alternative Evaluation			
A. Criteria			
(1) Efficiency (2) Rank	(1) No net economic benefits. (2) 2nd	(1) $661,000 in net benefits. (2) 1st	(1) (-$723,000) in net economic benefits. (2) 3rd
(1) Effectiveness (Damages reduced) (2) Rank	(1) No damages reduced. (2) 3rd	(1) Reduces damages to 37 residential and commercial structures. (2) 2nd	(1) Reduces damages to 155 residential and commercial structures. (2) 1st
(1) Effectiveness (Commercial/Industry) (2) Rank	(1) No benefits to commerce or industry. (2) 3rd	(1) Reduces damages to 34 commercial and industrial facilities. (2) 2nd	(1) Reduces damages to 94 commercial and industrial facilities. (2) 1st
(1) Effectiveness (Life Safety) (2) Rank	(1) No reduction in life safety risk. (2) 3rd	(1) Reduction in life safety risk for occupants of 37 structures due to reduction in inundation. (2) 2nd	(1) Reduction in life safety risk for occupants of 155 structures due to reduction in inundation. (2) 1st
(1) Acceptability (2) Rank	(1) Meets acceptability criteria.	(1) Meets acceptability criteria.	(1) Meets acceptability criteria.

Consideration	Alt. 1. No Action	Alt. 3A. Max Net Economic Benefits/NED	Alt. 3B. Comprehensive Benefits
	(2) 1st (tie)	(2) 1st (tie)	(2) 1st (tie)
(1) Completeness (2) Rank	(1) Does not meet completeness criteria. (2) 3rd	(1) Meets completeness criteria, benefitting 37 structures in total. (2) 2nd	(1) Meets completeness criteria, benefitting 155 structures in total. (2) 1st
(1) Environmental Justice (Resilience) (2) Rank	(1) No increase in resilience of at-risk communities. Potential reduction in resilience due to climate change. (2) 3rd	(1) Increased resilience of communities that benefit. However, minimal benefit to communities identified as socially vulnerable due to focus on maximizing economic benefits. (2) 2nd	(1) Increased resilience of communities that benefit, including 9 reaches identified as socially vulnerable. Benefits to a larger proportion of each community, including socially vulnerable populations, increases overall resilience. (2) 1st
(1) Environmental Justice (Community Cohesion) (2) Rank	(1) Loss of community cohesion as communities continue to be impacted and fragmented. (2) 3rd	(1) Benefits community cohesion by reducing risk to 37 at-risk structures; however, most at-risk structures—particularly those in socially vulnerable communities—remain at risk with a potential for future impacts that result in a loss of community cohesion. (2) 2nd	(1) Benefits community cohesion by reducing risk to 155 at-risk structures, with a greater focus on socially vulnerable communities. Much less risk remains in benefiting communities that could degrade community cohesion in the future. (2) 1st
(1) Environmental Effects (2) Rank	(1) No effect on environmental resources. (2) 1st	(1) No significant effects on environmental resources. (2) 2nd (tie)	(1) No significant effects on environmental resources. (2) 2nd (tie)
Overall Rank Criteria	3rd	2nd	1st
B. Contribution to Objectives			
(1) Life Safety (2) Rank	(1) No benefits to life and safety. (2) 3rd	(1) Reduction in life safety risk for occupants of 37 structures due to reduction in inundation. (2) 2nd	(1) Reduction in life safety risk for occupants of 155 structures due to reduction in inundation. (2)1st
(1) Economic damages (2) Rank	(1) No reduction in economic damages. (2) 3rd	(1) Expected annual benefits of $2,043,000 which equals an approximate 46%	(1) Expected annual benefits of $2,944,000, which equates to an approximate 52%

Consideration	Alt. 1. No Action	Alt. 3A. Max Net Economic Benefits/NED	Alt. 3B. Comprehensive Benefits
		reduction in expected annual damages. (2) 2nd	reduction in expected annual damages. (2) 1st
(1) Industry & Commerce (2) Rank	(1) No benefits to industry and commerce. (2) 3rd	(1) Decrease in damages to 34 commercial and industrial structures. (2) 2nd	(1) Decrease in damages to 94 commercial and industrial structures. (2) 1st
Overall Rank Contribution to Objectives	3rd	2nd	1st
C. Risk and Uncertainty			
(1) Residual Risk (2) Rank	(1) No change in flood risk throughout the basin. Greatest residual risk. (2) 3rd	(1) Includes 4% of structures within the 1% AEP floodplain. (2) 2nd	(1) Includes 22% of all structures within the 1% AEP floodplain. Least residual risk due to climate change. (2) 1st
(1) Uncertainty (2) Rank	(1) Relies completely on nonfederal action to reduce flood risk. (2) 2nd	(1) Participation rates could affect benefits. (2) 1st (tie)	(1) Participation rates could affect benefits. (2) 1st (tie)
Overall Rank Risk and Uncertainty	3rd	2nd	1st

14.1. Selected Plan 7% Interest Rate

The executive branch uses as a principal performance metric for a project's inclusion in its budget request the project's benefit-cost ratio (BCR) calculated with a 7% discount rate (i.e., ratio of the present value of benefits to the present value of costs discounted at 7%). For most water resource projects, which have concentrated up-front costs and benefits accruing over decades, the 7% discount rate results in a lower BCR than the BCR that was calculated in the planning process using lower water planning discount rates. The use of a 7% discount rate for executive branch budgeting for the Corps is consistent with general guidance from the Office of Management and Budget (OMB) for discounting federal programs: this guidance is elaborated in Circular A-94. Since 1992, OMB has recommended a 7% discount rate for BCAs of most federal programs. Table 123 through Table 125.

Table 123.Alternative 3B Costs at 7%

Alternative 3B: Comprehensive Benefits Plan								
Reach	**Aggregation**	**Total**	**Construction Costs**	**Contingencies**	**Real Estate**	**IDC**	**Total Cost**	**Average Annual Costs**
STC1B	0.01 AEP Floodplain	15	$8,357,942	$3,593,915	$531,774	$106,207	$12,589,838	$912,258
STC1C	0.01 AEP Floodplain	19	$6,828,556	$1,987,005	$673,581	$88,807	$10,527,222	$762,801
STC1F	0.01 AEP Floodplain	1	$877,317	$198,114	$35,452	$10,975	$1,300,989	$94,269
TP10A	0.01 AEP Floodplain	4	$1,591,386	$474,545	$141,806	$20,567	$2,438,056	$176,661
TP10B	0.01 AEP Floodplain	2	$458,083	$191,717	$70,903	$6,176	$732,138	$53,051
TP10C	0.01 AEP Floodplain	5	$1,623,444	$617,969	$177,258	$21,259	$2,520,042	$182,602
TP10D	0.01 AEP Floodplain	1	$566,817	$125,666	$35,452	$7,197	$853,197	$61,823
TP3C	0.01 AEP Floodplain	22	$5,570,981	$2,640,658	$779,935	$74,412	$8,820,851	$639,158
TP3F	0.01 AEP Floodplain	67	$31,419,356	$8,148,212	$2,375,258	$402,455	$47,707,391	$3,456,870
TP8	0.01 AEP Floodplain	10	$3,416,434	$795,470	$354,516	$44,580	$5,284,597	$382,921
TP9A	0.01 AEP Floodplain	4	$1,436,743	$322,150	$141,806	$18,686	$2,215,034	$160,501
TP9C	0.01 AEP Floodplain	1	$143,410	$46,470	$35,452	$2,046	$242,574	$17,577
TP9D	0.01 AEP Floodplain	4	$2,888,750	$669,564	$141,806	$36,351	$4,309,070	$312,235
Total		**155**	**$65,179,218**	**$19,811,455**	**$5,495,000**	**$839,718**	**$99,540,999**	**$7,212,726**

Table 124. Alternative 3B Benefits with 7% Interest Rate

Alternative 3B: Comprehensive Benefits Plan								
Reach	**Aggregation**	**Total**	**EAD Without**	**With EAD**	**Average Annual Benefits**	**Average Annual Costs**	**BCR**	**Net Benefits**
STC1B	0.01 AEP Floodplain	15	$1,154.94	$258.55	$896.39	$912.26	0.98	($15.87)
STC1C	0.01 AEP Floodplain	19	$446.10	$176.51	$269.59	$762.80	0.35	($493.21)
STC1F	0.01 AEP Floodplain	1	$27.64	$10.43	$17.21	$94.27	0.18	($77.06)
TP10A	0.01 AEP Floodplain	4	$176.06	$56.14	$119.92	$176.66	0.68	($56.74)
TP10B	0.01 AEP Floodplain	2	$207.52	$197.12	$10.40	$53.05	0.20	($42.65)
TP10C	0.01 AEP Floodplain	5	$241.54	$73.24	$168.30	$182.60	0.92	($14.30)
TP10D	0.01 AEP Floodplain	1	$117.89	$79.38	$38.51	$61.82	0.62	($23.31)
TP3C	0.01 AEP Floodplain	22	$74.87	$66.01	$8.86	$639.16	0.01	($630.30)
TP3F	0.01 AEP Floodplain	67	$2,714.38	$1,481.53	$1,232.85	$3,456.87	0.36	($2,224.02)
TP8	0.01 AEP Floodplain	10	$208.10	$123.95	$84.15	$382.92	0.22	($298.77)
TP9A	0.01 AEP Floodplain	4	$75.55	$32.72	$42.83	$160.50	0.27	($117.67)
TP9C	0.01 AEP Floodplain	1	$12.70	$12.10	$0.60	$17.58	0.03	($16.98)
TP9D	0.01 AEP Floodplain	4	$148.25	$95.96	$52.29	$312.23	0.17	($259.94)
Total		155	$5,605.54	$2,663.64	$2,941.90	$7,212.73	0.41	($4,270.83)

Table 125. Alternative 3B Summary 7% Interest Rate

Comprehensive Benefits Costs	Contract Cost ($)	Contingency (%)	Contingency ($)	Total Cost
Construction Cost	$44,951,218	43%	$19,329,024	**$64,280,242**

Planning, Engineering, and Design	$13,710,000	43%	$5,895,300	**$19,605,300**
Construction Management	$6,518,000	43%	$2,802,740	**$9,320,740**
Real Estate	$5,495,000	0%	$0	**$5,495,000**
Total	**$70,674,218**		**$28,027,064**	**$98,701,282**
Interest During Construction (3 Months)				$839,718
Total Investment Cost				**$99,540,999**
Average Annual Costs				**$7,213**
Average Annual Benefits				**$2,942**
Net Benefits				**($4,271)**
BCR				**0.41**