Flood Risk Management Feasibility Study

Peckman River Basin
New Jersey

Draft Integrated Feasibility Report and Environmental Assessment

Appendix B: Economics

US Army Corps of Engineers®
New York District

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Chapter 1: Introduction

An economic analysis was conducted to assist in the determination of the economic viability for Federal participation in the Peckman River Basin. Benefits were calculated for plans that are anticipated to be the most effective with respect to local support, survivability, and flood risk management. Structural and nonstructural alternatives were screened for relative cost-effectiveness based on the level of without- and with-project damages, and preliminary estimates of benefits and costs.

1.1 Benefit Types

Many benefits can be realized from implementing flood/storm damage reduction measures, including:

- Reduced inundation damage to structures and contents
- Reduced public emergency and evacuation costs
- Reduced relocation and reoccupation of displace residents
- Reduced Federal Insurance Administration (FIA) administrative costs
- Reduced road damages
- Reduction in lost business revenue
- Reduction in debris cleanup

While there are many benefits, the economic analysis for the Peckman River Basin study focused on evaluating the reduction in inundation damage to structures and contents. Reduction in damages to structures and contents typically produces the greatest benefits during an economic analysis, thus providing a general indication of the economic viability of the evaluated alternative.

1.2 Conditions

The methods for the economic analysis were completed in accordance with ER 1105-2-100. The screening of alternatives used an October 2017 price level and 2.75 percent discount rate for cost and benefits calculations. The base year is 2027 and the period of analysis is 50 years.

Chapter 2: Description of Study Area

The Peckman River Basin is located in Passaic and Essex Counties, New Jersey within New Jersey's 8th Congressional District (Figure 1). The drainage area is approximately 9.8 square miles and the Peckman River Basin is one of the sub-watersheds of the Passaic River. The confluence of the Peckman River with the Passaic River is located within the central section of the Passaic River Basin.

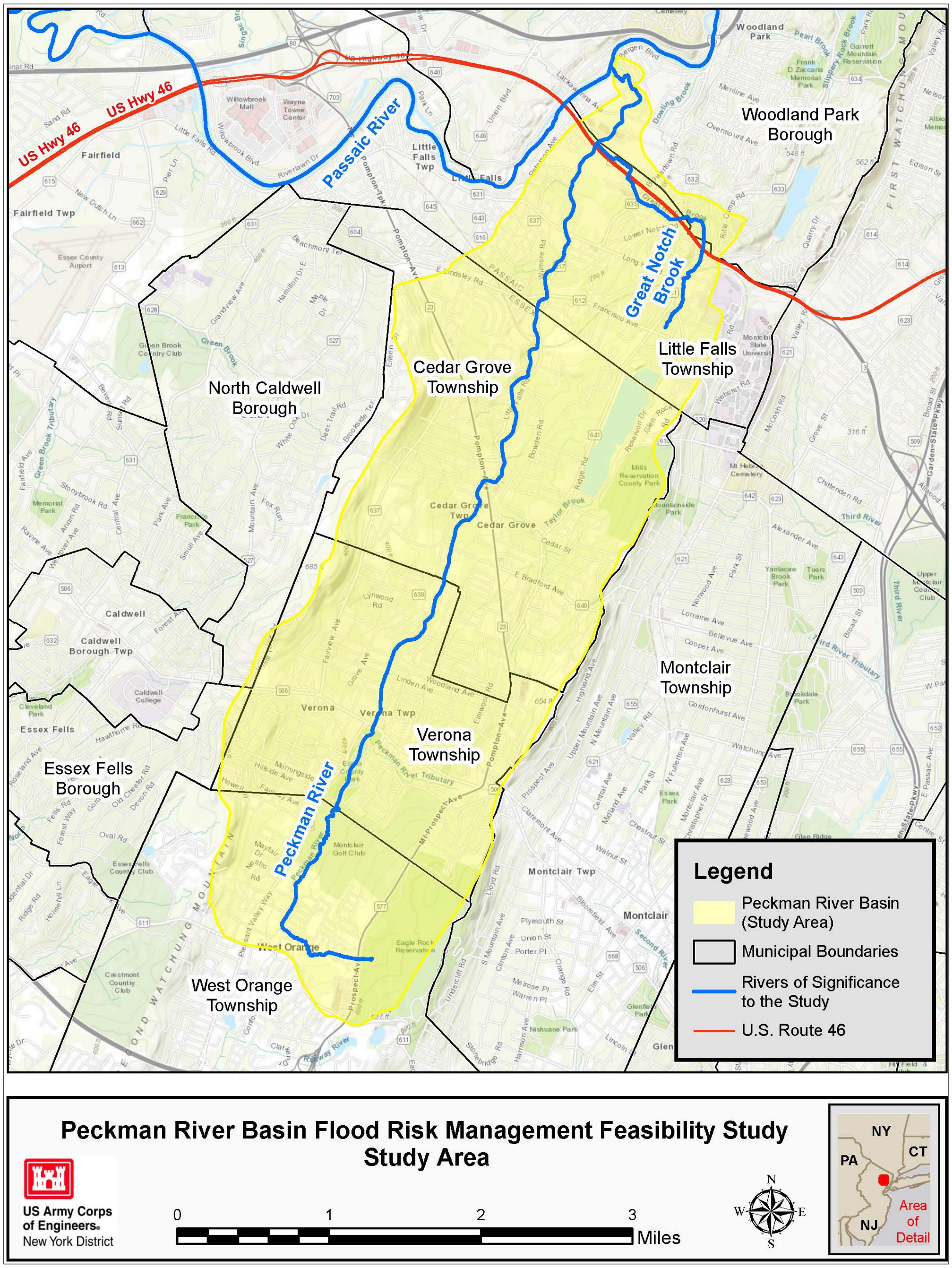

Figure 1. The Peckman River Basin (study area).

2.1 Municipalities within the Peckman River Basin

There are five municipalities in the Peckman River Basin (Figure 2). The Township of West Orange is situated in the central portion of Essex County and contains approximately 12.2 square miles with easy access to the Garden State Parkway and the New Jersey Parkway. It lies in eastern New Jersey within the New York Metropolitan Area, and is easily accessible to the highway and rail network which serves the northern New Jersey - New York Metropolitan complex. As the region grew, West Orange was able to capitalize on its proximity to emerge as a manufacturing economy in the early 1800s which continued into the early 20th century. Today, manufacturing in West Orange has been replaced by service, financial, and retail enterprises.

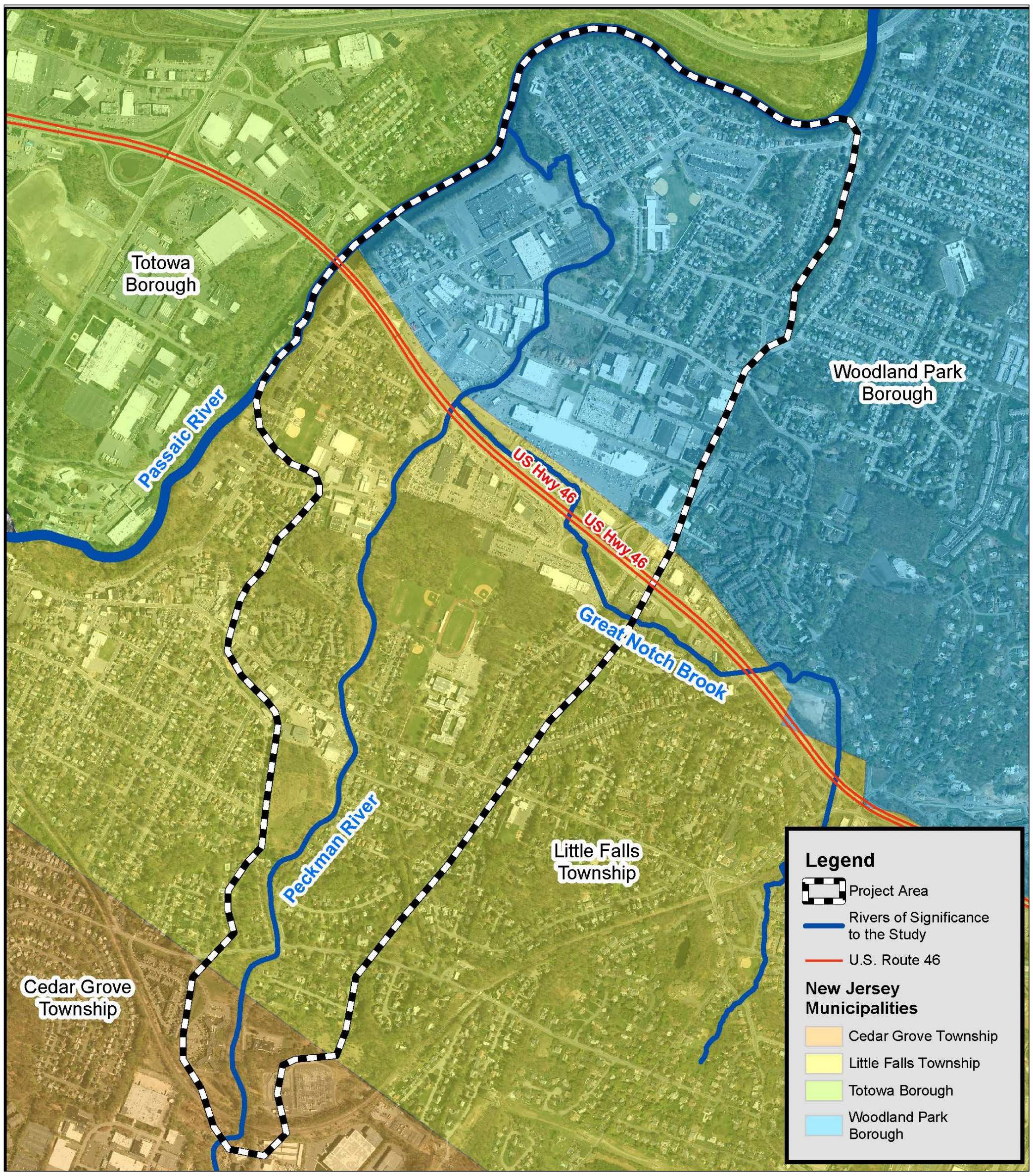

Figure 2. Municipalities within the study area.

The Township borders on nine developed suburban municipalities. These include: Montclair, Verona, Essex Falls, Roseland, Livingston, Millburn, Maplewood, South Orange, and Orange.

Moving to the northeast, the Township of Verona, also in Essex County, lies between two mountains, the First and Second Watchung Mountains, with the Peckman River flowing at the bottom of the valley. According to the United States Census Bureau, the township has a total area of 2.8 square miles, of which almost 99.3 percent is land and the remainder is water. Verona is bordered by Cedar Grove, Montclair, West Orange, Essex Fells and North Caldwell. The Township of Verona also provides easy access to the Garden State Parkway and the New Jersey Parkway

The Township of Cedar Grove is located further to the northeast in Essex County. Access to Cedar Grove is provided by a number of County and regional highways, including the Garden State Parkway to the east.

Towards the northeast, the Township of Little Falls covers 2.75 square miles within the southern border of Passaic County, adjacent to Essex County. The Township is bordered by six municipalities including the Borough of Woodland Park (formerly West Paterson), the City of Clifton, the Town of Montclair, the Township of Cedar Grove, the Township of North Caldwell and the Township of Wayne.

Little Falls is characterized by relatively hilly terrain in its eastern portion, containing suburban residential developments and institutional uses (Montclair State University). The western portion of the Township contains a less topographically diverse terrain; most of the land area is flat in closer proximity to the Passaic River. State Highway Route 46 (Route 46) comprises the eastern border of the Township, while the Passaic River comprises the north/northwest border of the Township. Great Notch Brook, a tributary to the Peckman River, is located in eastern Little Falls, and enters the river just downstream of Route 46. Areas of Little Falls in the vicinity of the Passaic River are flood hazard areas which have been prone to flooding in the past.

Finally, the Borough of Woodland Park is one of 16 municipalities in Passaic County. The borough is located in the northeastern section of New Jersey and the lower end of the county, about 20 miles west of New York City. Highway access is provided by Interstate 80 in the northern edge of the city and Route 46 along its southern border. Natural features, Garret Mountain on the east and the Passaic River on the west, form the Borough's other two borders. Woodland Park is situated to the north of the Township of Little Falls and approximately three square miles in size. Though a highly urbanized and developed municipality, with a mixture of residential, retail, office, and industrial properties, a significant portion of the borough remains open space due to municipal parkland, two County parks, and two reservoirs.

The downstream portion of the Peckman River in Woodland Park is within close proximity to Dowling Brook, which is also a tributary to the Passaic River. During extreme flooding events, diversion of flow from the Peckman River across Woodland Park to Dowling Brook has been reported.

2.2 Population

According to the 2010 U.S. Census, the population of the towns covered by Peckman River has grown as high has 33 percent since 2000. Table 1 presents a summary of the population data for the project area.

Table 1. Population of New Jersey, Little Falls, and Woodland Park (U.S. Census, 2010).

Municipality	2000 Census	2010 Census	% Change (rounded)
New Jersey	8,414,350	8,791,894	5%
Little Falls	10,855	14,432	33%
Woodland Park	10,987	11,819	8%

2.3 Employment and Income

Income: Median household income for the Borough of Woodland Park and the Township of Little Falls are $70,473 and $79,385 respectively, and both are higher than the median household income of both Passaic County and the state of New Jersey (Table 2).

Labor Force: The unemployment rates for the Borough of Woodland Park (4.1 percent) and the Township of Little Falls (5.9 percent) are lower than that for Passaic County (Table 3). Management, professional, and related occupations form the largest segment of the working population for both Woodland Park (39.5 percent) and Little Falls (43.7 percent). Sales and office occupations ranked second for Woodland Park (28.6 percent) and Little Falls (32.4 percent). These employment sectors are also ranked first and second for Passaic County and the state of New Jersey, respectively (Table 4).

Table 2. Income Comparison for the State, Counties, and Affected Municipalities (U.S. Census, 2010).

Indicator	New Jersey	Passaic County	Essex County	Woodland Park Borough	Little Falls Township
Per Capita Income	$38,000	$29,000	$33,000	$35,000	$39,000
Median Household Income	$74,000	$62,000	$55,000	$70,000	$79,000
Individual Below Poverty Level	10.4%	17.2%	16.3%	7.3%	6.3%

Table 3: Employment data (ACS, 2006-2010).

Indicator	New Jersey	Passaic County	Essex County	Woodland Park Borough	Little Falls Township
Population 16 years and over	6,893,000	387,000	623,000	10,000	12,000
In Labor Force	4,587,250	249,764	411,519	6,386	7,890
Employed	4,230,560	230,707	361,748	6,123	7,426
Unemployed	356,690	19,057	49,748	236	462
% Unemployment	7.8%	7.6%	12.1%	4.1%	5.9%

Table 4. Occupational Status for the State, Counties, and Affected Municipalities (US Census, 2010).

Occupation	New Jersey	Passaic County	Essex County	Woodland Park Borough	Little Falls Township
Management, professional, and related occupations	38.0%	30.0%	35.6%	39.5%	43.7%
Service occupations	13.6%	14.5%	15.8%	12.1%	9.5%
Sales and office occupations	28.5%	28.6%	28.9%	28.6%	32.4%
Farming, fishing, and forestry occupations	0.2%	0.1%	0.1%	0.0%	0.0%
Construction, extraction, and maintenance occupations	7.8%	8.3%	6.8%	7.3%	6.3%
Production, transportation, and material moving occupations	12.0%	18.4%	12.9%	12.5%	8.1%

2.4 Project Area

Analysis indicates that the downstream municipalities of Little Falls and Woodland Park are most affected by flooding from the Peckman River as they contain the majority of structures within the floodplain. The narrow floodplain in the municipalities of West Orange, Verona and Cedar Grove heavily limits the number of structures affected by damages. It was determined that Federal investment in a cost-shared flood risk management solution would not be economically justified in these upstream reaches and no alternatives were formulated to address flooding in the municipalities of West Orange, Verona and Cedar Grove, upstream of the railroad. The formulation focuses on Woodland Park and Little Falls, and the socioeconomic data were updated for just these two municipalities within the project area to 2016 estimates (Figure 3).

Figure 3. Project area.

2.4.1 Project Area Land Use

From the data obtained from NJDEP (Table 5 and Table 6), land use in Woodland Park is predominantly residential, followed by open space and commercial area (Figure 4). Similarly, land use in Little Falls Township is predominantly residential, followed by public and commercial area.

Table 5. Land Use in Woodland Park (NJDEP).

Land Use	Parcels	Acres (rounded)	Percentage (rounded)
Residential	3,968	763	45%
Commercial	424	211	12%
Industrial	65	44	3%
Public	56	45	3%
Open Space	70	521	31%
Others	93	112	7%
Total	**4,676**	**1,696**	**100%**

Table 6. Land Use in Little Falls (NJDEP).

Land Use	Parcels	Acres (rounded)	Percentage (rounded)
Residential	3,538	821	46%
Commercial	181	191	11%
Industrial	46	19	1%
Public	11	453	26%
Open Space	370	100	6%
Others	0	176	10%
Total	**4,146**	**1760**	**100%**

The project area is most densely developed along the Passaic River, with the oldest neighborhoods located along the river. Most residential development is made up of detached single-family homes.

The project area's two main commercial districts are located between Browertown Road and the Passaic River in Woodland Park, and along Main Street/East Main Street in Little Falls. Passaic Valley High School, with its track and baseball fields, is located at the eastern edge of the Main Street commercial corridor. The commercial districts are largely surrounded by residential development.

Relatively small parks including Peckman Preserve provide recreational opportunities and open space for residents. There are parks abutting the Passaic River that provide access to the water for residents and wildlife alike.

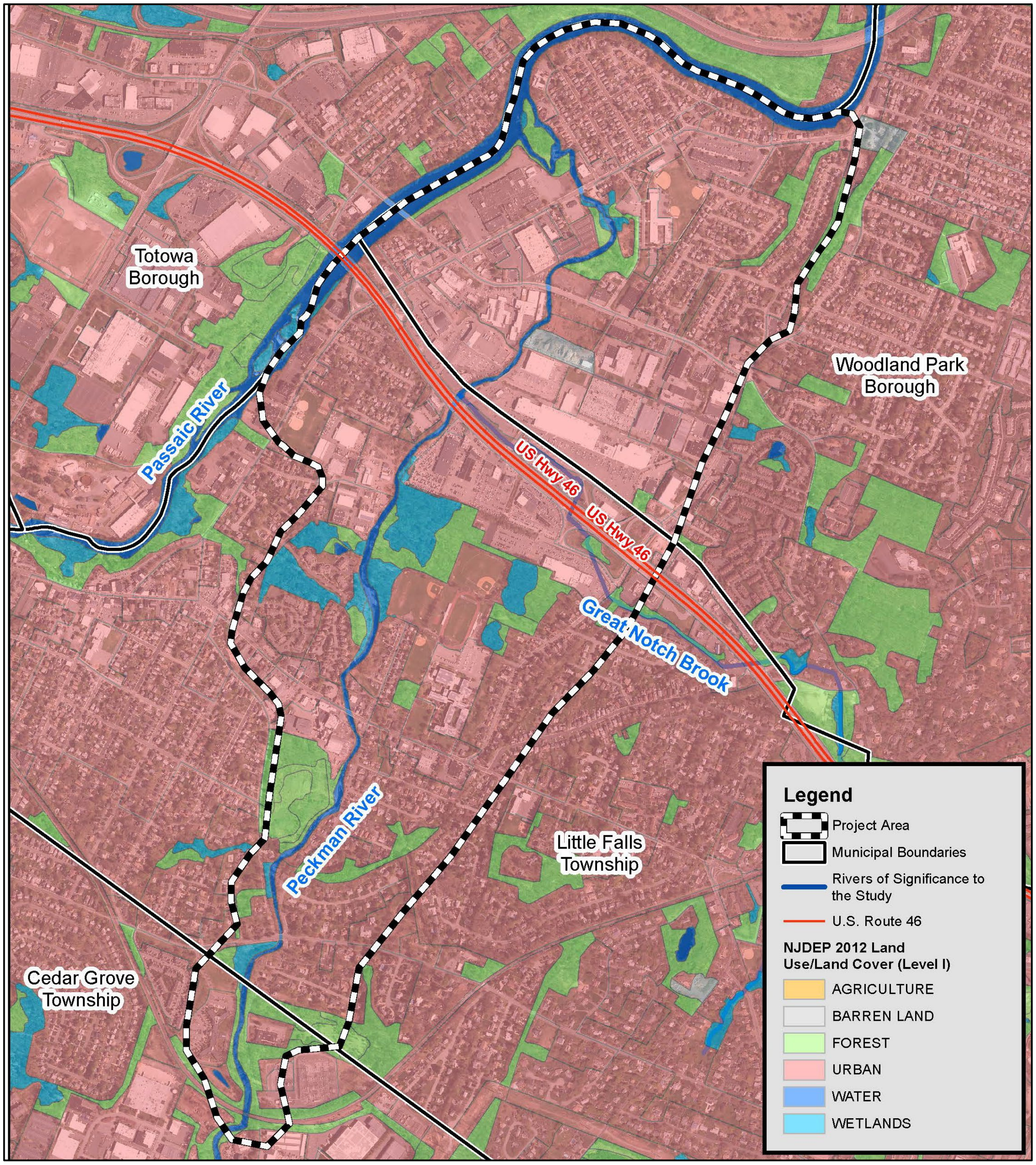

Figure 4. Land use within the project area.

2.4.2 Project Area Transportation

Vehicle: The project area is connected to major population centers, including New York City, through a network of highways, railways, and bridges (Figure 5). Route 46 functions as the dividing line between Woodland Park and Little Falls. Other major roads of note are Paterson Avenue and Browerton Road, which both run north-south on the east side of the Peckman River starting from Main Street/East Main Street and converging at the northeastern tip of the project area near the Passaic River (Paterson Avenue becomes McBride Avenue). There are four bridges along Route 46 and five bridges on the Peckman

River. The bridge at McBride Avenue is a 69-foot wide vehicular bridge. It is located immediately before the Peckman River's discharge into Passaic River. South of the McBride Avenue bridge is another 64-foot wide vehicular bridge. It is located along Lackawanna Avenue. Another bridge in the project area is the one the runs along Route 46. It is 142 feet wide and provides both pedestrian and vehicular access. South of the Route 46 is a 57-foot wide bridge running along East Main Street. It provides both pedestrian and vehicular access. Additionally, a bridge is located at Francisco Avenue right next to its intersection with Cedar Grove Road. It is a vehicular, 57-foot wide bridge.

There are seven additional bridges just outside the project area. Outside of the project area, but nearby, are Interstate 80 and the Garden State Parkway.

Figure 5. Important transportation routes.

Rail: Both the Little Falls station and Montclair State University station of NJ Transit serve Little Falls, offering service on the Montclair-Boonton Line to Hoboken Terminal in Hoboken, or from Montclair State University Station on Midtown Direct trains to New York City's Pennsylvania Station in Midtown Manhattan via the Secaucus Junction. Outside the project area, but nearby are five NJ Transit train stations.

Chapter 3: Existing and Without-Project Conditions

3.1 Existing Conditions/Problem Identification

Residents, businesses, and infrastructure in the Peckman River Basin experience repeated, significant flood damage due to flash flooding in the Peckman River and its tributaries, and overbank and backwater flooding from the Passaic River. Extensive development of the basin has led to the interrelated problems of flooding and ecosystem degradation. The majority of the watershed is heavily developed (71 percent). Half of the basin is dominated by residential housing. Undeveloped areas of remaining forested areas, reservoirs, and wetlands along the river corridor comprise only 29 percent of the basin. Commercial and residential development in the watershed has reduced the water holding capacity of the landscape and altered the natural dynamics of the river system. Storms deposit large amounts of rain in the watershed, producing significant runoff. This quickly surpasses the capacity of the rivers, streams, and bridges and culvert openings, resulting in flooding which first begins to occur at the 10 percent flood event. Peckman River typically causes overbank flooding in Woodland Park at the Memorial Middle School on Memorial Drive with a 20 percent flood event. The neighborhood east of the Memorial Middle school which includes Dowling Parkway and Wallace Lane is inundated by that event flood as well. Marked degradation of the river basin ecology has occurred with areas impacted by stream bank erosion, loss of riparian habitat, and the occurrence of invasive species.

Some of the most severe flood damages in the Peckman River Basin were caused by hurricanes and tropical storms. Hurricane Floyd (1999) caused an estimated $12.1 million (FY 18 P.L.) in flood-related losses to communities in the Peckman River Basin, and resulted in the death of one resident. Hundreds of homes and businesses in Little Falls and Woodland Park were affected by flooding. The Woodland Park business district was one of the hardest hit areas, with over three feet of flood water inundating structures and roads. In Little Falls, businesses were inundated with over four feet of water and the Jackson Park residential area suffered extensive flooding. Hurricane Doria in August 1971 caused an estimated $12 million (FY 18 P.L.) in flood-related damages (Figure 12). A storm event in May 1968 caused an estimated $18.6 million (FY 18 P.L.) in flood related losses. A storm event in July 1945 resulted in one death within the project area. Flood damage has resulted in the displacement of residents and businesses, and the expensive repair of infrastructure. During Hurricane Floyd hundreds of homes and businesses were affected by flooding in the Township of Little Falls and the Borough of Woodland Park. In Woodland Park, the business district north of Route 46 was one of the hardest hit areas, with over 3 feet of flood water inundating structures. In Little Falls, businesses south of Route 46 were inundated with over 4 feet of water and residential areas suffered extensive flooding from flood waters diverting from the Peckman River towards the west into the Passaic River. Almost all of Hurricane Floyd flood damages to areas within the Peckman River Basin were a result of Peckman River flooding, as flooding from the Passaic River in this area was of a much lesser magnitude.

3.2 Future Without-Project Conditions

The future without-project condition serves as the base condition to use as a comparison for all the other alternatives. The period of analysis used in the comparison of potential costs and benefits of alternative plans is 2027 through 2076.

In the absence of Federal action, flooding problems in the Peckman River Basin associated with rainfall events are expected to continue. Communities in the basin will continue to experience damages to structures, their contents, vehicles, and infrastructure caused by flash flooding in the Peckman River and its tributaries, and overbank and backwater flooding from the Passaic River. This would likely result in the continued maintenance and reconstruction of infrastructure and facilities, and repairs to houses and roads following storm events. Residents and businesses would be impacted by flooded roads and structures. Residents would be at continued risk of harm due to direct flood hazards and reduced access by emergency services during storm events. Equivalent annual damages (EAD) in the future without-project condition from 2027-2076 were calculated at $20,626,000 (FY18 P.L.).

Chapter 4: Alternatives

The main report fully describes plan formulation, comparison, selection, and optimization. This section presents a summary of this work. Please refer to the main report for detailed information.

The following eleven alternatives were developed to meet planning objectives and avoid planning constraints. These plans do not include the alternatives considered during feasibility-level design; see Chapter 5 – 7 for information about these plans. All alternatives are described in detail in Appendix C-2.

- Alternative 1: No Action
- Alternative 2: Nonstructural Plan
- Alternative 3: Peckman River Diversion Culvert
- Alternative 4: Channel Modifications Upstream and Downstream of Route 46
- Alternative 5: Levee/Floodwall System Upstream and Downstream of Route 46
- Alternative 6: Levee/Floodwall System Downstream of Route 46
- Alternative 7: Channel Modifications Downstream of Route 46
- Alternative 8: Channel Modifications Upstream of Route 46 with Peckman River Diversion Culvert
- Alternative 9: Levee/Floodwall System Upstream of Route 46 with Peckman River Diversion Culvert
- Alternative 10a: Nonstructural Measures (2 percent floodplain) Upstream of Route 46 with Peckman River Diversion Culvert
- Alternative 10b: Nonstructural Measures (10 percent floodplain) Upstream of Route 46 with Peckman River Diversion Culvert

Chapter 5: Economic Analysis Method

The economic analysis evaluated flood/storm-related damages to structures and their contents within the 0.2 percent chance (500-year) flood event in the study area. The majority of the structures within the floodplain are located in Little Falls Township and Woodland Park Borough, both located in Passaic County. Flood damage calculations were performed using the Hydrologic Engineering Center's Flood Damage Analysis (HEC-FDA) computer program, version 1.4.2. The economic analysis was in the Fiscal Year (FY) 2018 price level and Federal discount rate of 2.75 percent during analyses and plan formulation conducted during FY18. Optimization of the Tentatively Selected Plan (TSP) was conducted at FY19 price levels and 2.875% Federal discount rate. Details of the methodology and approach for the economic analysis are described in the following sections.

5.1 Study Area Reaches

The study area was divided into eleven stream reaches along the Peckman River and each of these were divided into left bank and right bank areas, giving a total of 22 study reaches. Reach selection was determined by considering the water surface profiles within each reach and to provide adequate flexibility for evaluation of any likely plan alternative. Study area stream reaches are presented in Table 7. Stream stationing in Table 7 reflects changes to correspond to revised H&H data following FY18 evaluations.

Table 7. Study area reaches

Reach Name	Beginning Station	Ending Station	Stream Bank	Road	Municipality
R1	450	1350	Left	McBride Ave.	Woodland Park Borough
R2	450	1350	Right		
R3	1350	2830	Left	Lackawanna Ave.	Woodland Park Borough
R4	1350	2830	Right		
R5	2830	4480	Left	Rt. 46	Little Falls Township
R6	2830	4480	Right		

Table 7 – Study Area Reaches (Cont.)

Reach Name	Beginning Station	Ending Station	Stream Bank	Road	Municipality
R7	4480	4958.82	Left		
R8	4480	4958.82	Right		Little Falls Township
R9	4958.82	6048	Left		
R10	4958.82	6048	Right		Little Falls Township
R11	6048	6742.38	Left		
R12	6048	6742.38	Right		Little Falls Township
R13	6742.38	7860	Left		
R14	6742.38	7860	Right	E. Main Street	Little Falls Township
R15	7860	8749.36	Left		
R16	7860	8749.36	Right		Little Falls Township
R17	8749.36	10370	Left		
R18	8749.36	10370	Right	Francisco Ave	Little Falls Township
R19	10370	11193.40	Left		
R20	10370	11193.40	Right		Little Falls Township
R21	11193.40	11883.19	Left		
R22	11193.40	11883.19	Right		Cedar Grove Township

5.2 Structure Inventory

A structure inventory was developed in order to estimate without –project and with-project damages and potential benefits of considered alternatives. The structural base data was generated through inspection of structures in the project area obtained through a "windshield survey". Each structure was assigned a unique structure identification number during the identification of all structures for inventory. Topographic mapping at 1"=100' scale, with 2-foot contour intervals was used as a base map during development of the structure inventory.

Ground elevations were estimated using the base map. To estimate the main floor elevations, crews were sent into the project area to count the steps from ground elevation to the main door. Steps were estimated to be eight inches high. The height of the steps was then added to the ground elevation at each structure to estimate the main floor elevation for each structure. The crew members were also tasked with checking the sides and backs of each structure for the low openings, and estimating the elevations of the low openings. The datum of the base mapping and resulting estimated elevations was NGVD29, which was also the datum of the water surface elevations generated and used in this study. Following FY18 analyses for formulation of the TSP, elevations of both hydraulics and structures were converted to NAVD88 datum. The conversion from NGVD29 to NAVD88 is -0.968' at Little Falls and -0.974' at Woodland Park. A standard deviation of error for first floor elevations of 0.6 feet was applied based on recommendations in the USACE Engineering Manual, EM 1110-2-1619, Table 6-5, and the 2-foot contour interval mapping that was used as the study base mapping.

Digital mapping in Microstation was used to obtain areas (square feet) of structures. Polygons representing footprints of structures were measured. Sizes were adjusted as necessary, according to observations in the field, to account for the presence of decks, attached garages, other ancillary structures adjoining the main structure, and number of stories.

5.3 Structure Values

The replacement value for single family residential and municipal structures were estimated based on the characteristics of the structure and RSMeans Square Foot Costs data. Structure replacement values of the remaining damage categories, which are multi-family residential, commercial, industrial, and utilities, were estimated with the Marshall & Swift Valuation Service. The characteristics of each structure were used to select the appropriate structure type for use in these valuation systems. The estimated dollar-per-square-foot values were multiplied by the structure size to estimate the replacement value.

The depreciated replacement value of each structure was estimated based on the replacement value of the structure and the condition of the structure. The depreciation was based on factors for each valuation system related to the condition. The replacement value was multiplied by the depreciation factor to estimate the amount of depreciation to apply to the replacement value of the structure. Structure depreciated replacement values were initially estimated in October 2006 (FY 07) price levels. Price levels of structures were brought to October 2018 (FY 19) price levels with appropriate RSMeans and Marshall & Swift indices.

Table 8 shows the number and development value of structures impacted by flood events for the without project, base condition. "Impacted" means having a flood stage above lowest adjacent ground level in the without project base year condition, and the values are total depreciated structure replacement values.

Table 8. Number and Value of Structures Impacted by Flood Event (FY19 P.L.).

%-Chance Flood Event	Residential Structures		Non-residential Structures		Totals	
	Number	Value ($,000)	Number	Value ($,000)	Number	Value ($,000)
50%	60	$13,417	5	$1,915	65	$15,332
20%	131	$30,943	28	$24,672	159	$55,615
10%	252	$59,839	52	$79,478	304	$139,318
4%	376	$88,588	80	$131,937	456	$220,525
2%	436	$109,350	94	$152,690	530	$262,040
1%	525	$131,139	116	$184,618	641	$315,756
0.40%	617	$155,284	141	$212,072	758	$367,356
0.20%	633	$159,838	143	$213,005	776	$372,843

5.4 Depth-Damage Functions

Depth-damage functions (DDF), also known as Occupancy Types in HEC-FDA, are used to estimate flood damage under each condition and flood event that is modeled. These provide the percentage of structure and content values that are expected to be damaged by flooding at various depths. Residential DDFs applied during FY18 plan formulation in the Peckman River study were developed by the USACE Institute for Water Resources and were provided for use in Economic Guidance Memorandum (EGM) 04-01, Generic Depth-Damage Relationships for Residential Structures with Basements, and EGM 01-03, Generic Depth-Damage Relationships for Residential Structures without Basements. Nonresidential structures in the study area were assigned DDFs based on data developed during the Passaic River Basin Study (PRB) during FY18 plan formulation. The PRB DDFs were originally developed in 1982 as part of the Passaic River Basin Feasibility Study in northern New Jersey. The functions were later updated in 1995. For the PRB DDFs, content value was set to equal the depreciated replacement value of the structure. The PRB functions were considered applicable because the study area is within the Passaic

River Basin. The PRB DDFs also included functions that captured "Other" damages. Other damages generally include landscaping, vehicles, storage sheds, garage, clean up, and extra housing costs. Other damages were calculated as a percentage of structure value.

Occupancy types that were developed during the North Atlantic Coast Comprehensive Study (NACCS) were applied in the economic modeling of the Peckman River study for both residential and non-residential structures during FY19 optimization of the TSP. The NACCS occupancy types were developed by expert elicitation and focused on the region affected by Superstorm Sandy, which includes the Peckman River project area. However, CSVRs were not developed during the NACCS expert elicitation for the NACCS damage functions. The CSVRs of the Passaic River Basin regional damage functions were therefore applied to the NACCS functions. These were originally developed using empirical data and documented in the Passaic River Basin, New Jersey and New York, Phase I General Design Memorandum, dated December 1987 and then updated in the Computation of Flood Damage Survey Data for the Passaic River Basin, dated January 1995. The later report states that content damages were calculated as a percent of structure value. A 100% CSVR was therefore applied to the NACCS damage functions for all structures in the Peckman River project area. Flooding of basements of both residential and non-residential structures modeled to only result from overland flow entering structures at ground level and not from sewer backup or leaks in foundations caused by hydrostatic pressure. All occupancy types applied during plan optimization include measures of uncertainty in the form of standard deviations of error of the percent damage estimates for each flood depth in the function.

Estimates of flood damage to automobiles were made with the HEC-FDA model. Automobile data was included in the structure inventory in order to model these. Occupancy types that were developed by the U.S. Army Corps of Engineers' (USACE) Institute for Water Resources (IWR) and were presented in EGM 09-04, Generic Depth-Damage Relationships for Vehicles were applied to estimate flood damage to vehicles.

5.5 Hydrology and Hydraulics

Hydrologic engineering inputs are required for eight flood frequency events to adequately define the stage-probability function of the stream within HEC-FDA. Peckman River hydrology and hydraulics were developed for the 50 percent (2-year), 20 percent (5-year), 10 percent (10-year), 4 percent (25-year), 2 percent (50-year), 1 percent (100-year), 0.4 percent (250-year) and 0.2 percent (500-year) flood events for both existing and future conditions. Stream flows were developed with a Hydrologic Engineering Center, Hydrologic Modeling System (HEC-HMS) hydrologic model of the basin. Water surface profiles that were developed with a Hydrologic Engineering Center, River Analysis System (HEC-RAS) model of the study area. The water surface profiles include estimated stream discharges/flows from watershed runoff and water surface elevations for each of the eight flood events along with stream invert stages at each modeled cross-section. During TSP optimization HEC-RAS modeling was made with unsteady flow, with both 1-dimensional and 2-dimensional (2D) model areas. Joint probability analysis was performed to incorporate backwater effects of the Passaic River (see appendices C1 and C2.) Stage-frequency data was therefore used in the HEC-FDA model instead of stage-discharge data. Water surface profiles for both present and future conditions were provided and applied in HEC-FDA modeling. Ten year equivalent record lengths were used as the HEC-FDA model uncertainty inputs for the stage-frequency data.

5.6 Damage Estimation

Flood damage calculations were performed using the HEC-FDA computer model, as previously mentioned. Physical damages within the 0.2 percent floodplain were classified as single family and multi-family residential, commercial, industrial, municipal and damage to utilities. The estimated total depreciated replacement value of these properties, including contents, is more than $754 million within the 0.2 percent chance floodplain in FY 19 price levels.

Water surface profiles, DDFs, and structure inventory data were imported into HEC-FDA. Future condition water surface profiles were configured in HEC-FDA to take effect at the end of the 50-year period of analysis. The economic period of analysis of the study ranges from 2027 to 2076. Equivalent annual damages and benefits were calculated with the FY 18 Federal discount rate of 2.875 percent.

HEC-FDA integrates hydrologic, hydraulic and economic data to estimate flood damage by severity/frequency of event. The model has the capability to apply risk-based analysis procedures consistent with both ER 1105-2-101 and EM 1110-2-1619. This capability includes accounting for uncertainties in economic and hydrologic and hydraulic (H&H) inputs. This is done with the use of statistical distributions and standard deviations as measurements of error for primary input variables required to model flooding in a floodplain. The program performs several thousand iterations of Monte Carlo simulation to select values of input variables based on the distributions and standard deviations of error specified by the uncertainty inputs in each iteration. Ranges of possible values in the most significant input variables are applied in the model. These are described by probability distributions and standard deviations of error. Variables with estimated uncertainties are those that have the greatest effect on expected annual damage for the condition/plan being evaluated. Uncertainty inputs for the Peckman River analysis include those for discharge frequency, first floor elevations, depreciated structure value, content-to-structure value ratios, and other-to-structure value ratios. The HEC-FDA program allows uncertainty in discharge frequency to be calculated using equivalent record length, for which USACE Engineering Manual, EM 1110-2-1619, Table 4-5, was consulted. For Peckman River basin models, an equivalent record length of 10 years was applied. A first floor standard deviation of 0.6 feet was selected based on recommendations in the USACE Engineering Manual, EM 1110-2-1619, Table 6-5, and the 2-foot contour intervals provided in the project topographic mapping.

Chapter 6: Evaluation of Alternatives

Several flood risk management alternatives were formulated to provide flood risk reduction and were evaluated in this analysis. The alternatives were evaluated based on their costs and benefits to determine the economic viability of each alternative. These alternatives were evaluated for economic feasibility in FY18 based on a 2.75 percent discount rate and a period of analysis of 50 years (2027 – 2076).

The alternatives listed in Chapter 4 were included in the analysis. The results of the HEC-FDA models were used to estimate the damages for each alternative and the benefits of the with-project alternatives. The benefits of implementing the alternatives represent flood damages avoided by the project, compared to the No Action Alternative. Benefits were calculated as the difference in damages before and after project implementation. Benefits were then amortized over a 50-year period (2027 through 2076) to identify equivalent annual benefits using FY 18 price levels and discount rate of 2.75 percent. Table 9 presents equivalent annual damage of the without project condition and with each alternative (i.e., residual flood damage) and the resulting equivalent annual benefits.

Table 9. Equivalent Annual Damage and Benefits by Alternative ($1,000s; FY 18 P.L.).

Alternative	Without Project Annual Damage	With Project (Residual) Annual Damage	With Project Annual Benefits
Alt 1 - No Action	$20,626	$0	$0
Alt 2 - Nonstructural (1% floodplain)	$20,626	$3,223	$17,403
Alt 3 - Diversion Culvert	$20,626	$4,597	$16,029
Alt 4 - Channel Modification US & DS of Rt 46	$20,626	$3,850	$16,776
Alt 5 - Levees/Floodwalls US & DS of Rt 46	$20,626	$2,790	$17,836
Alt 6 - Levees/Floodwalls DS of Rt 46	$20,626	$13,837	$6,789
Alt 7 - Channel Modification DS of Rt 46	$20,626	$6,149	$14,477
Alt 8 - Channel Modification US of Rt 46 + Diversion Culvert	$20,626	$296	$20,330
Alt 9 - Levees/Floodwalls US of Rt 46 + Diversion Culvert	$20,626	$1,302	$19,324
Alt 10a - Nonstructural (2% floodplain) US of Rt 46 + Diversion Culvert	$20,626	$478	$20,148
Alt 10b - Nonstructural (10% floodplain) US of Rt 46 + Diversion Culvert	$20,626	$1,263	$19,363

Discount rate of 2.75 percent from 2027 through 2076

6.1 Results of Screening Evaluation

The project costs and benefits were evaluated for each alternative for an initial screening analysis. Costs and benefits were further refined later in the planning process. The net benefits and benefit-to-cost ratios (BCR) were reviewed to determine which alternatives are economically justified (Table 10).

Table 10. Economic Summary ($1,000s; FY18 P.L.).

Alternative	Total Implementation Cost[1]	Annual Cost[2]	Annual Benefits	Net Benefits	Benefit -Cost Ratio
Alt 2 - Nonstructural (1%-chance floodplain)	$200,928	$8,100	$17,403	$9,303	2.1
Alt 3: Diversion Culvert	$97,609	$4,100	$16,029	$11,929	3.9
Alt 4: Channel Modification US & DS of Rt 46	$274,231	$12,000	$16,776	$4,776	1.4
Alt 5 - Levees/Floodwalls US & DS of Rt 46	$214,372	$9,300	$17,836	$8,536	1.9
Alt 6 - Levees/Floodwalls DS of Rt 46	$145,499	$7,300	$6,789	($511)	0.93
Alt 7 - Channel Modification DS of Rt 46	$106,540	$4,500	$14,477	$9,977	3.2
Alt 8 - Channel Modification US of Rt 46 + Diversion Culvert	$213,231	$9,400	$20,330	$10,930	2.2
Alt 9 - Levees/Floodwalls US of Rt 46 + Diversion Culvert	$267,448	$11,148	$19,324	$8,176	1.7
Alt 10a - Nonstructural (2%-chance floodplain) US of Rt 46 + Diversion Culvert	$206,812	$8,400	$20,148	$11,748	2.4
Alt 10b - Nonstructural (10%-chance floodplain) US of Rt 46 + Diversion Culvert	$154,394	$6,507	$19,363	$12,856	3.0

[1] Total implementation cost includes interest during construction at 2.75 percent and annual operation and maintenance costs.
[2] Annual cost includes annual operation and maintenance costs.

6.2 Tentatively Selected Plan (May 2018)

The Tentatively Selected Plan (TSP) is comprised of nonstructural measures in the ten percent floodplain upstream of Route 46 along with a diversion culvert, associated weirs, channel modification, and levees/floodwalls. The diversion culvert is 1,500 feet long and would be constructed between the Peckman and Passaic Rivers. It would divert floodwaters from the Peckman River to the Passaic River during and after storms. The diversion culvert inlet at the Peckman River would consist of a weir that would limit flow and create a pool near the inlet. Channel modifications in the Peckman River near the diversion culvert opening, and levees and/or floodwalls downstream of the ponding weir to the Route 46 Bridge would be built. The plan includes nonstructural measures to structures within the 10 percent event floodplain.

Note this plan was optimized, as described later in this chapter.

6.3 Tentatively Selected Plan Optimization

Optimization of Alternative 10b included evaluation of plans with modified features to those of the TSP. The H&H analyses were also modified to include unsteady flow and two-dimensional modeling, stream stationing, and elevation datum, as previously described. Joint probability analysis was performed and included in the water surface profiles to incorporate backwater effects of the Passaic River in the economic analysis.

The study team focused an economic optimization analysis on the sizing of the diversion culvert, which is the most prominent and costly feature of the plan. Costs and benefits were calculated for two plans with different culvert sizes: 35-foot wide, and 40-foot wide. The TSP presented in the previous version of this draft report in May 2018 included a 35-foot wide diversion culvert, and is denoted as Alternative 10b-35. It includes the design refinements described in Section 3.13.2. A plan that includes a 40-foot wide diversion culvert (Alternative 10b-40) was considered to understand the efficiency of a plan that could convey a greater volume of floodwater over time to the Passaic River. It includes the design refinements described in Section 3.13.2 as slightly modified to reflect the difference in culvert size. Appendix C-2 includes detailed information about these refinements.

A plan with a narrower diversion culvert was not considered. There is an inverse relationship between culvert width and levee height. The inclusion of higher levees in any plan was calculated to significantly increase project cost, and thus would not economically perform as well as plans with narrower culvert sizes.

The economic analysis reflects the two-dimensional HEC-FDA modeling results that reflect Passaic River backwater flooding on project performance. Because of this, the with-project (i.e., residual) vary from those developed and used for plan formulation and comparison (Table 9). Project costs, and economic damages benefits for Alternative 10b-35 and Alternative 10b-40 were developed and compared as part of the economic optimization analysis (Table 11).

Table 11. Economic Summary ($1,000s; FY18 P.L.)

Alternative	Total Implementation Cost[1]	Annual Cost[2]	Without Project Damages	With Project Damages	Annual Benefits	Net Benefits	Benefit-Cost Ratio
10b-35	$84,690	$3,526	$17,387	$9,351	$8,036	$ 4,510	2.2
10b-40	$82,735	$3,449	$17,387	$9,447	$7,940	$ 4,491	2.3

[1]FY19 Price Level in $1,000s. Total implementation cost includes interest during construction at 2.875 percent.
[2]Annual cost includes annual Operation, Maintenance, Repair, Replacement, and Rehabilitation costs.

The results of the economic optimization analysis illustrated that Alternative 10b-35 and Alternative 10b-40 provide very similar net economic benefits (Table 18). Typically, the plan with the greatest net economic benefits is selected as the preferred plan. However, USACE guidance allows the selection of a plan of lesser cost when the net economic benefits are similar. Because the plans provide very similar net economic benefits but differ in cost, Alternative 10b-40 was selected as the optimized TSP.

Chapter 7: Tentatively Selected Plan

7.1 Cost Estimate

A more detailed cost estimate of the plan was completed using MCASES, Second Generation (MII). Initial first cost is $139,744,000 (Table 12) for construction, including lands and damages, design, supervision and associated administration costs. In addition, annual OMRR&R costs are incorporated into the cost estimate.

Table 12. Construction Cost of the Tentatively Selected Plan ($1,000s; FY19 P.L.)

Cost Component	Total Cost
01 Lands and Damages	$14,149
02 Relocations	$473
06 Fish & Wildlife Facilities	$2,249
09 Channels & Canals	$17,633
11 Levees & Floodwalls	$10,846
15 Floodway Control & Diversion Str	$57,595
18 Cultural Resource Preservation	$2,279
19 Buildings, Grounds & Utilities	$11,034
30 Planning, Engineering, and Design	$15,316
31 Construction Management	$8,169
Total First Cost	**$139,744**

Table 13 presents the results of the evaluation of the Tentatively Selected Plan.

Table 13. Tentatively Selected Plan Economic Summary ($1,000s; FY19 P.L.)

Implementation First Cost	Interest During Construction	Total Investment Cost	Total Annual Cost	Equivalent Annual Benefits	Net Benefits	Benefit-Cost Ratio
$139,744	$5,246	$144,990	$6,013	$7,940	$1,927	1.3

* Total annual costs include interest during construction and OMRR&R

* Interest rate of 2.875 percent from 2027 through 2076

7.2 Risk and Uncertainty

Because uncertainty has been defined for key input parameters in the economic analysis, uncertainty in the expected benefits may be calculated. HEC-FDA calculates the distribution of equivalent annual damage reduced by plan in terms of the probability that the damage reduced exceeds certain values of probabilities, (e.g. .75, .50, and .25). For example, there is a .75 probability that the damage reduced by Alternative 10b-40 exceeds $5,353,000, a 0.50 probability that it exceeds $7,872,000 and a 0.25 probability it exceeds $10,587,000. Table 14 presents the distribution of equivalent annual benefits for Alternative 10b-40, the Tentatively Selected Plan, along with the distribution of net benefits and benefit-to-cost ratios.

Table 14. Tentatively Selected Plan, Alternative 10b Large Plan Economic Summary with Uncertainty (in $1,000s FY19 P.L.)

	Annual Cost	Annual Benefits	Net Benefits	BCR	Probability Distribution Quartiles		
					0.75	0.5	0.25
Mean	$6,013	$7,940	$1,927	1.3			
EAB					$5,353	$7,872	$10,587
ENB					($660)	$1,859	$4,574
BCR					.9	1.3	1.8

Note: EAB: Equivalent Annual Benefits/ ENB: Equivalent Net Benefits / BCR: Benefit-to-Cost Ratio. Annual costs include interest during construction at FY19 Federal discount rate of 2.875 percent. The 0.50 quartile is the median estimate; it differs from the mean when the probability distribution is asymmetrical.

The hydrologic and hydraulic performance of a project may be described by annual exceedance probability, long-term risk and assurance, or conditional non-exceedance probabilities. Annual exceedance probability is the probability that flooding will occur at a given location in any given year considering the full range of possible annual floods and project performance; the target stage is defined as the water surface elevation that results in significant damages, usually considered 5 percent of damages. Long-term risk is the probability of a target stage, which is typically the start of without project condition significant damage, being exceeded within the 10-, 30-, and 50-year timeframes. Conditional non-exceedance probabilities represent the chance of containing specific flood events within the target stage. Table 15 presents the annual exceedance probability and Table 16 presents both long-term risk and assurance for Alternative 10b-40.

Table 15. Annual Exceedance Probability Without Project: Alternative 10b-40

		Without Project Condition		Recommended Plan 10b-40
Reach	**Target Stage**	**Annual Exceedance Probability**	**Target Stage**	**Annual Exceedance Probability**
R1	126.41	0.198	126.41	0.198
R10	137	0.999	140	0.0021
R11	143.22	0.0524	143.22	0.0495
R12	141.4	0.999	143	0.0696
R13	145.78	0.1023	145.78	0.1025
R14	144.75	0.9963	144.75	0.999
R15	155.04	0.3409	155.04	0.3378
R16	154.57	0.7893	154.57	0.5211
R17	166.9	0.0386	166.9	0.0374
R18	165.24	0.2837	165.24	0.2032
R19	178.04	0.0976	178.04	0.0975
R2	125.5	0.2616	125.5	0.2617
R20	176.83	0.2525	176.83	0.251
R21	181.5	0.999	181.5	0.999
R22	184.62	0.0496	184.62	0.0498
R3	128.48	0.129	128.48	0.1334
R4	127.65	0.2064	127.65	0.1858
R5	131.67	0.7589	131.67	0.0307
R6	131.96	0.2904	131.96	0.0242
R7	136	0.999	139	0.0101
R8	136.66	0.2666	139	0.0101
R9	137.13	0.999	137.13	0.2217

Table 16. Project Performance: Alternative 10b-40

	Long Term Risk (years)			Conditional Non-Exceedance Probability by Events					
Reach	10 Year	30 Year	50 Year	10.0%	4.0%	2.0%	1.0%	0.4%	0.2%
R1	0.8899	0.9987	1	0.2214	0.0772	0.0242	0.0241	0.0209	0.0207
R10	0.0207	0.0608	0.0993	0.9984	0.9984	0.9982	0.9926	0.9562	0.8543
R11	0.3979	0.7818	0.9209	0.8312	0.5525	0.4116	0.3142	0.203	0.127
R12	0.514	0.8852	0.9729	0.7066	0.4202	0.2963	0.2165	0.1293	0.0757
R13	0.6607	0.9609	0.9955	0.5178	0.2623	0.1336	0.0585	0.0301	0.013
R14	1	1	1	0	0	0	0	0	0
R15	0.9838	1	1	0.036	0.0344	0.0323	0.0316	0.0231	0.015
R16	0.9994	1	1	0.0013	0.0026	0.003	0.0033	0.0031	0.0031
R17	0.3167	0.681	0.8511	0.9539	0.5819	0.4312	0.3356	0.1964	0.1318
R18	0.8968	0.9989	1	0.2487	0.1716	0.1541	0.1124	0.06	0.0339
R19	0.6415	0.9539	0.9941	0.5242	0.2982	0.2197	0.1368	0.0858	0.0532
R2	0.9519	0.9999	1	0.1282	0.0387	0.0089	0.009	0.0083	0.0083
R20	0.9444	0.9998	1	0.1246	0.0288	0.0287	0.0251	0.0131	0.0066
R21	1	1	1	0	0	0	0	0	0
R22	0.3997	0.7836	0.922	0.8279	0.5345	0.4062	0.3113	0.2412	0.1777
R3	0.761	0.9864	0.9992	0.4318	0.222	0.1544	0.1534	0.0824	0.082
R4	0.8719	0.9979	1	0.2456	0.1011	0.0778	0.0767	0.0552	0.0549
R5	0.2676	0.6072	0.7893	0.95	0.7128	0.5555	0.4324	0.251	0.2502
R6	0.2173	0.5206	0.7063	0.9692	0.8234	0.6032	0.4615	0.2742	0.2734
R7	0.0967	0.2629	0.3985	0.9998	0.9985	0.9183	0.8333	0.8141	0.8135
R8	0.0967	0.2629	0.3985	0.9998	0.9985	0.9183	0.8333	0.8141	0.8135
R9	0.9184	0.9995	1	0.1784	0.015	0	0	0	0