Delaware River Basin Comprehensive Flood Risk Management Interim Feasibility Study and Integrated Environmental Assessment for New Jersey

Flooding in the Study Area, April 2005

June 2015

APPENDIX C: Draft Economic Analysis

U.S. ARMY CORPS OF ENGINEERS
PHILADELPHIA DISTRICT

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION

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Exhibit C-F National Flood Insurance Program (NFIP) Closed Claims Data

C1. INTRODUCTION

The purpose of the Delaware River Basin Comprehensive Flood Risk Management Interim Feasibility Study and Integrated EA for New Jersey is to evaluate the feasibility of implementing flood risk management measures in areas in which historical and potential flooding has been identified. This appendix describes the procedures used in the economic analysis of flood risk management needs along the banks of the Delaware River in the New Jersey portion of the Delaware River Basin. An overview of the locations of the communities evaluated in this study is displayed in Figures 1A and 1B. Several nonstructural and structural measures to reduce flood risk and improve environmental quality were evaluated (See Appendix H: Plan Formulation). The initial underlying assumptions in the conduct of the study included an FY2011 discount rate of 4.125%, December 2010 price level, and a 50-year period of analysis. The final evaluation applied the FY 14 discount rate of 3.5% and a 2014 price level (with sensitivity for the selected plans with the FY 15 discount rate of 3.375%).

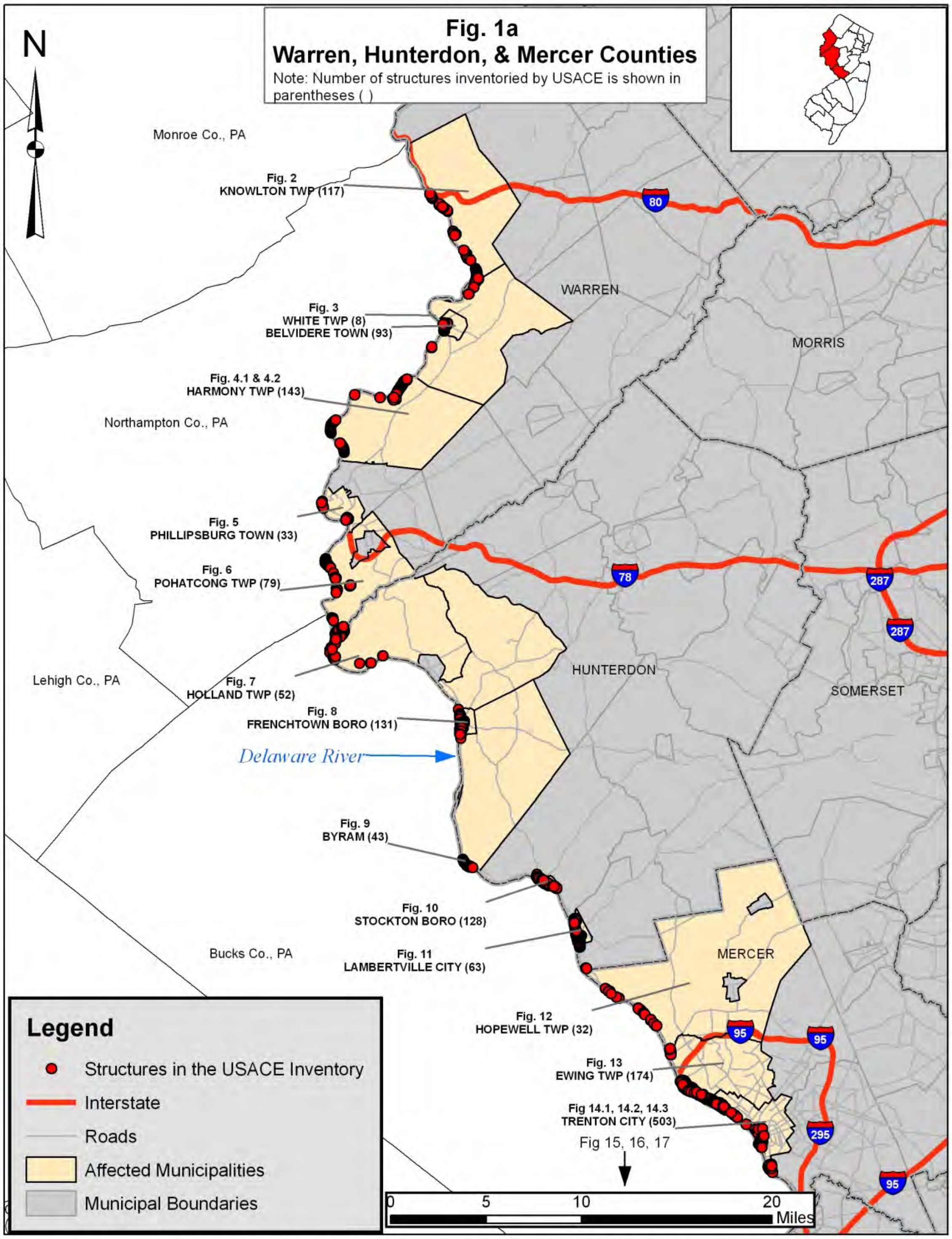
C2. STUDY AREA

The Delaware River Basin is approximately 12,839 square miles and spans four states; New York, Pennsylvania, New Jersey and Delaware. The New Jersey study area, shown in Figures 1A and 1B, spans four counties and is approximately 241 square miles in area. The geographic area of the study encompasses the 100-year or 1% annual chance of exceedance (ACE) floodplain in the municipalities listed in Section C2.1 (listed moving downstream on the Delaware River). The effective date of the Flood Insurance Rate Map (FIRM) for each community is shown in parentheses. The FIRMs were used to establish the geographic limit of the study area. The floodplains shown on the figures in this appendix were based upon FEMA's Q3 digital floodplain data.

The Delaware River has played a major role in the development of the United States. Indigenous Indian cultures, and later, pioneer settlers, used the river as a means of transportation. It was found to be less hazardous and more direct than the overland routes through the surrounding hilly forest terrain. Settlers found the area well suited for agriculture and the main stem of the Delaware a convenient way to transport manufactured goods downstream. Prior to the Industrial Revolution, commerce played an important role in the towns established along the river. In the 1800's, better port facilities located downstream as well as the newly built railways began successfully competing for the area's commercial activity. As commerce declined, an emphasis was placed on manufacturing.

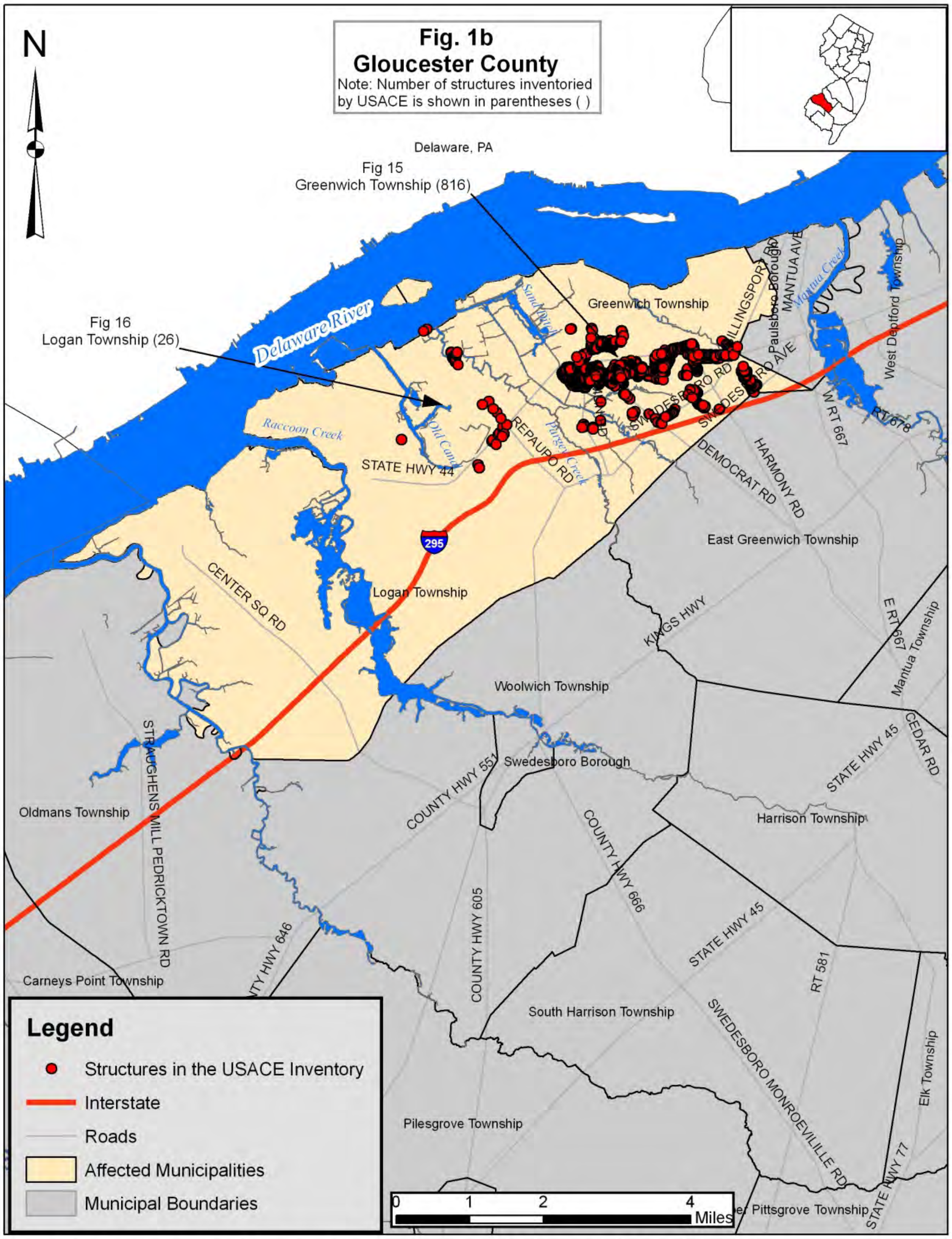
In more recent history, many manufacturing industries in the area have also declined, especially in the older, more urban communities such as Phillipsburg and Trenton. The service sector, as well as retail trade and government have, in general, supplanted manufacturing in the study area and many areas of New Jersey. However, these new jobs are typically located outside of the old industrial centers, as well as the floodplain itself. Several of the study area communities, most notably Lambertville, Stockton, and Frenchtown, have become tourism destinations in recent decades, with emphasis on community events, artists, and the landscape. The proximity to the river is a key part of these communities' identity and appeal.

Figure 1A: Project Area Map - Warren, Hunterdon, & Mercer Counties



Source: NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008; NJDOT, Roads 2008

Figure 1B: Project Area Map - Gloucester County



Source: NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008; NJDOT, Roads 2008

The following paragraphs provide a brief description of each municipality in the study area by county and corresponding location maps (Figures 2 through 17) which depict flood zones, and structures inventoried from the Upper Basin to the Lower Basin.

C2.1. **Warren County**

C2.1.1. ***Knowlton Township***

This rural community has excellent transportation access to the surrounding area, including Pennsylvania, via Interstate 80 and Route 46. Development in the floodplain consists of single-story residential structures, many with basements, on individual lots. These buildings are located on either side of a road parallel to the river. Agricultural uses are predominant beyond the floodplain.

C2.1.2. ***White Township***

This is a rural community with extensive agriculture uses, with the floodplain consisting mainly of several single-width rows of single-family structures on a low-lying section of the Delaware River bank.

C2.1.3. ***Belvidere, Town of***

The county seat of Warren County, Belvidere is a densely-developed small town with a sizable downtown area, with mixed residential and commercial uses. The floodplain along the Delaware River is mainly composed of residential structures on the riverbank, while commercial and residential buildings are intermixed in the floodplain of the Pequest River in the downtown.

C2.1.4. ***Harmony Township***

This is a rural community with extensive agricultural uses. The floodplain is predominantly occupied by single-family residential structures, one to two rows deep. The Hutchinson area is the lowest-lying section of the township, immediately adjacent to the banks of the Delaware River. The floodplain is generally backed by higher bluffs and hills.

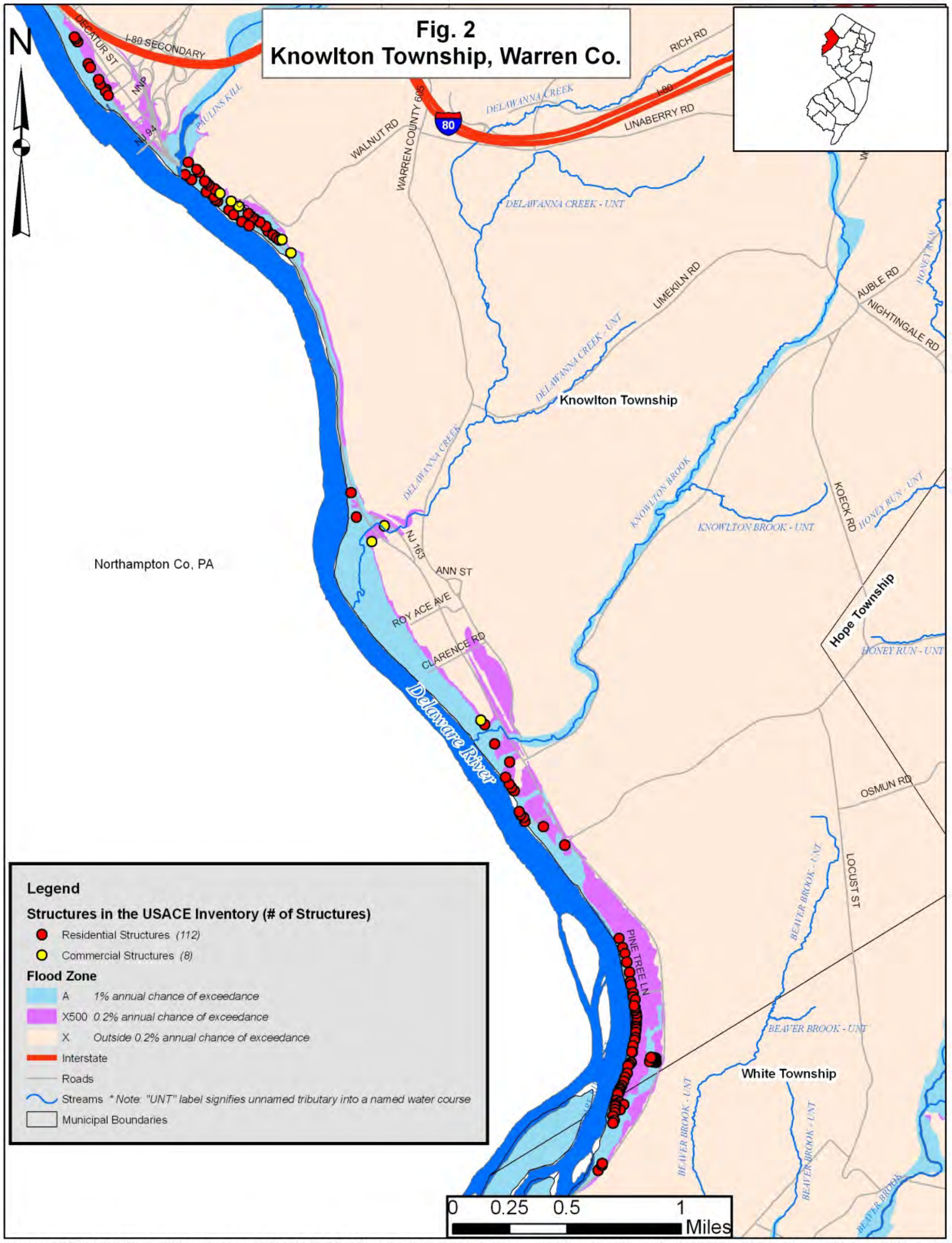
C2.1.5. ***Phillipsburg, Town of***

After Trenton, this is the second largest and densest community in the study area. Phillipsburg developed as a transportation hub and manufacturing center; however, these industries have declined greatly since their peak. There are two floodplain areas: the Union Square business and residential district centered on the Northampton Street Bridge across the Delaware River, and the residential area on the Lopatcong Creek in the southern section of the community.

C2.1.6. ***Pohatcong Township***

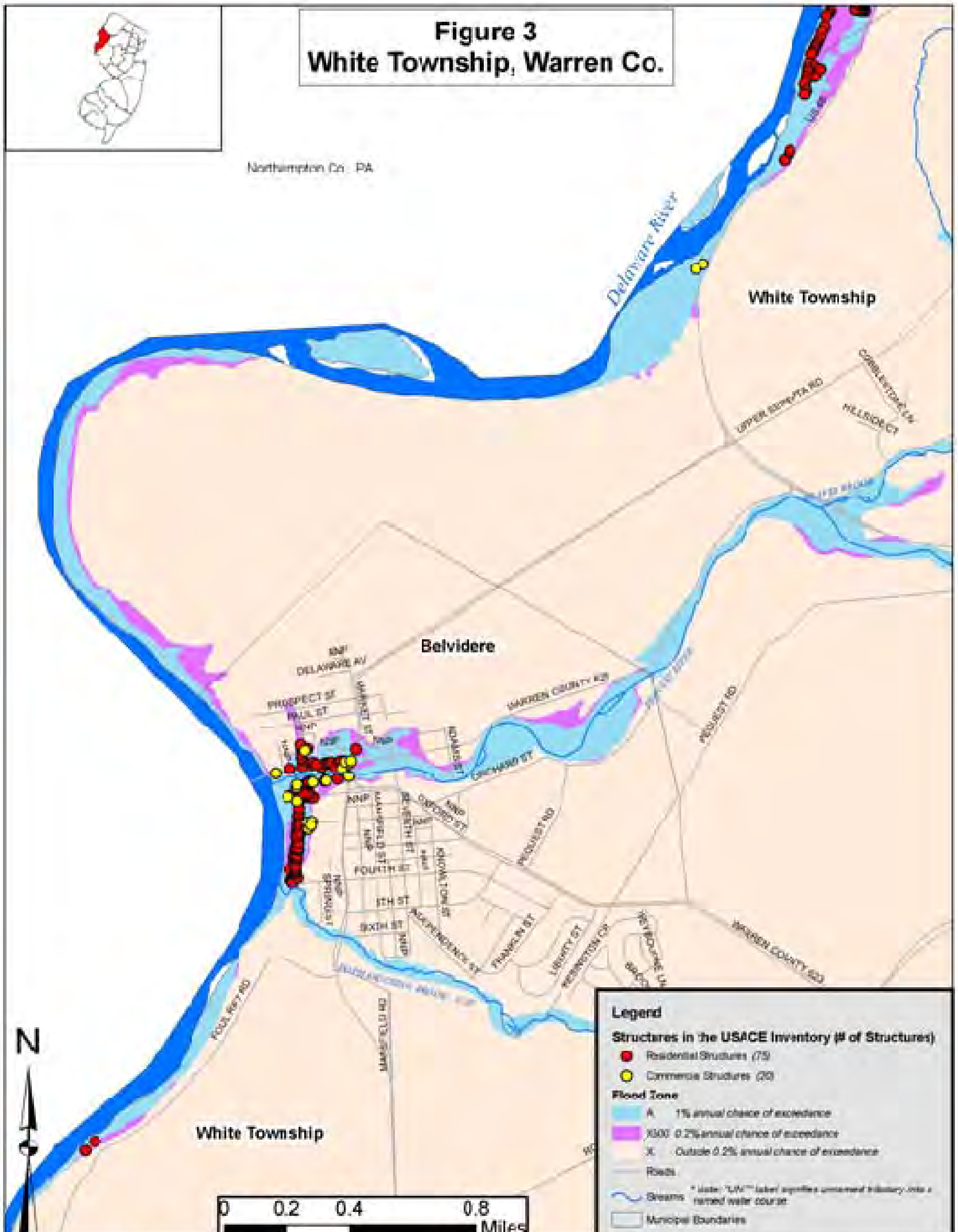
The floodplain in rural Pohatcong is occupied by residential structures, located on the bank of the Delaware River or, in fewer numbers, on the banks of the various tributaries, including Lopatcong Creek, Pohatcong Creek, and the Musconetcong River.

Figure 2: Knowlton Township



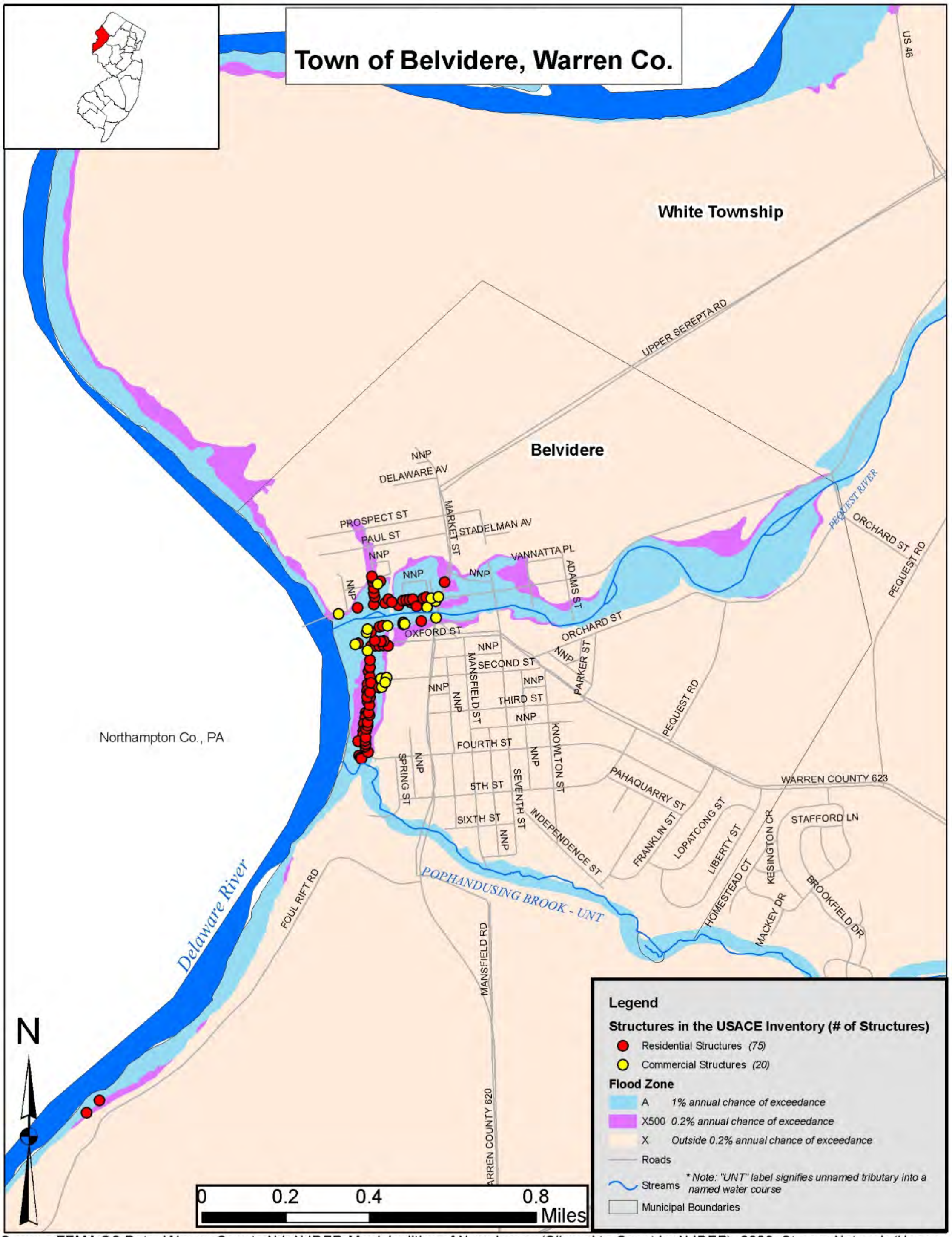
Source: FEMA Q3 Data, Warren County NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Figure 3: White Township



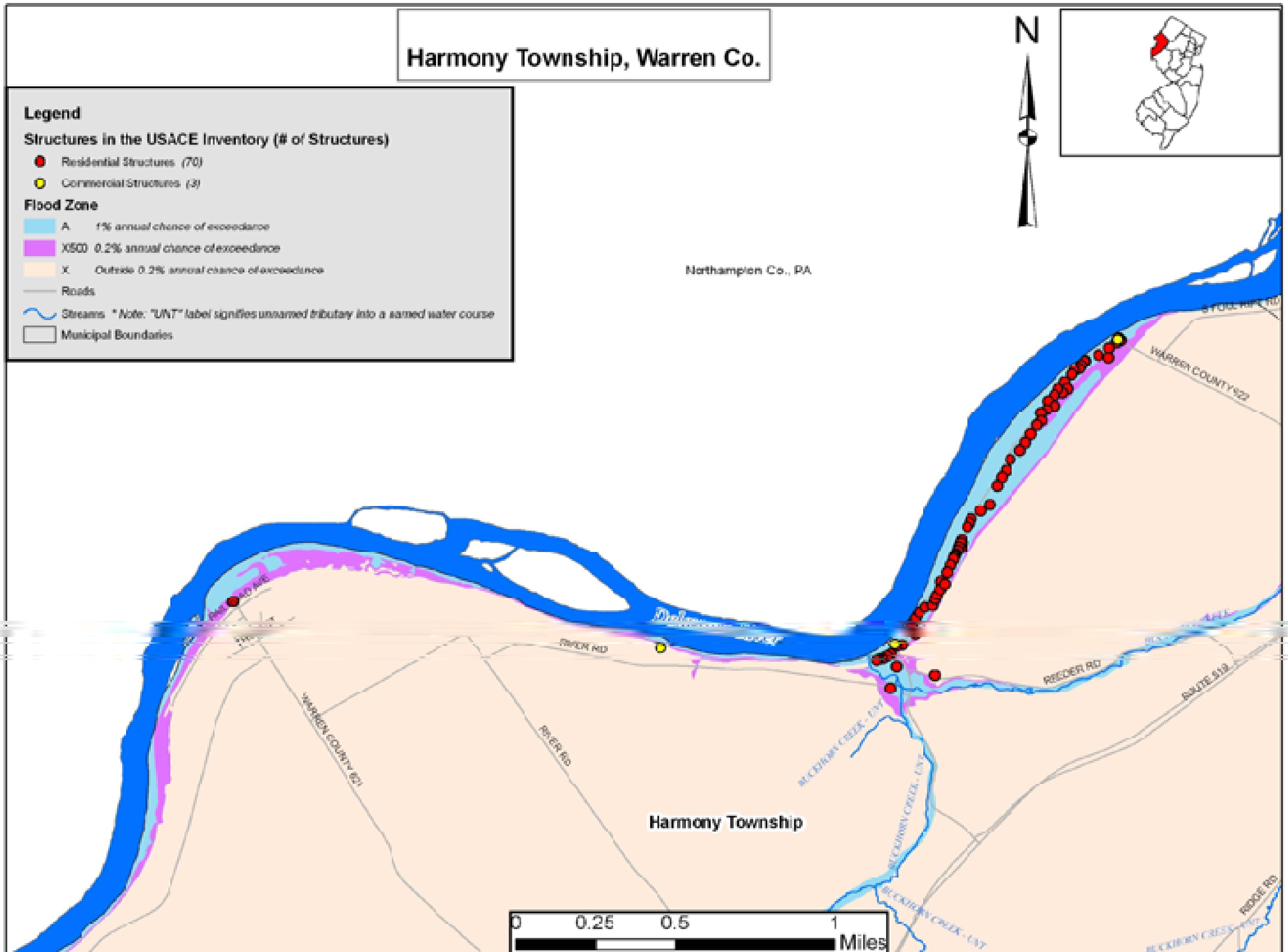
Source: FEMAQ3 Data, Warren County NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Figure 4: Town of Belvidere



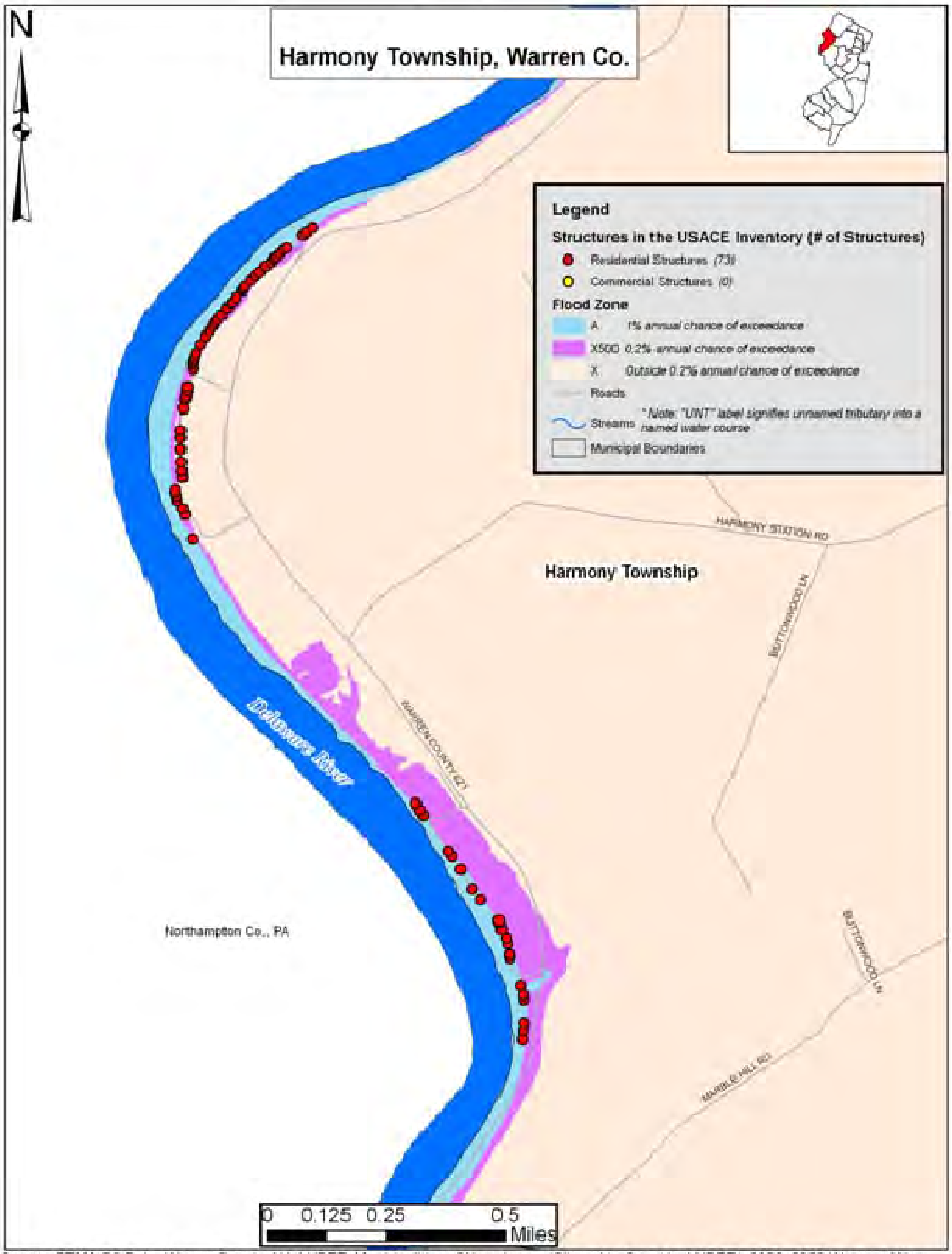
Source: FEMA Q3 Data, Warren County NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Figure 5A: Harmony Township



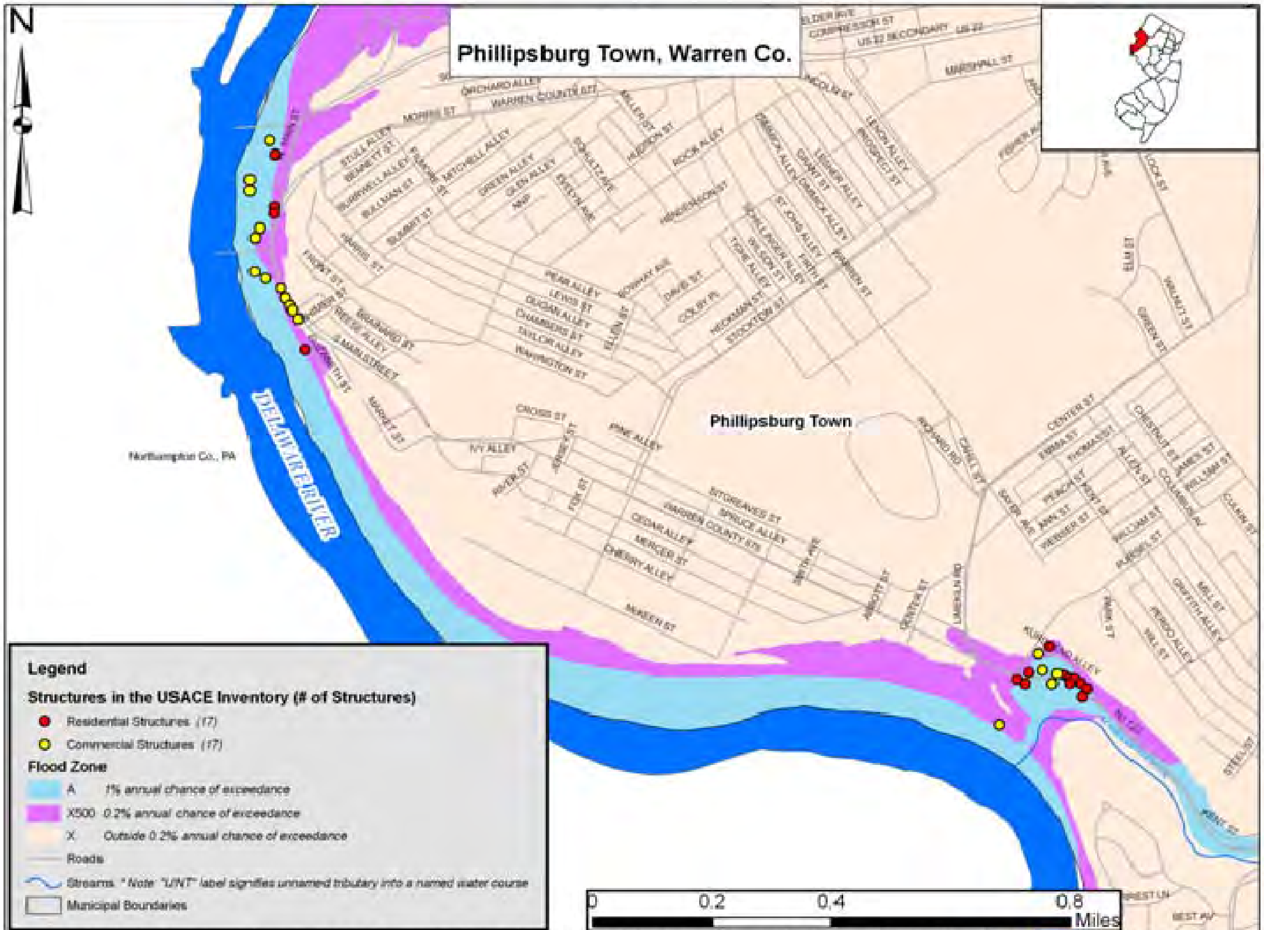
Source: FEMA Q3 Data, Warren County, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Upper Delaware Basin), 2008; 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Figure 5B: Harmony Township



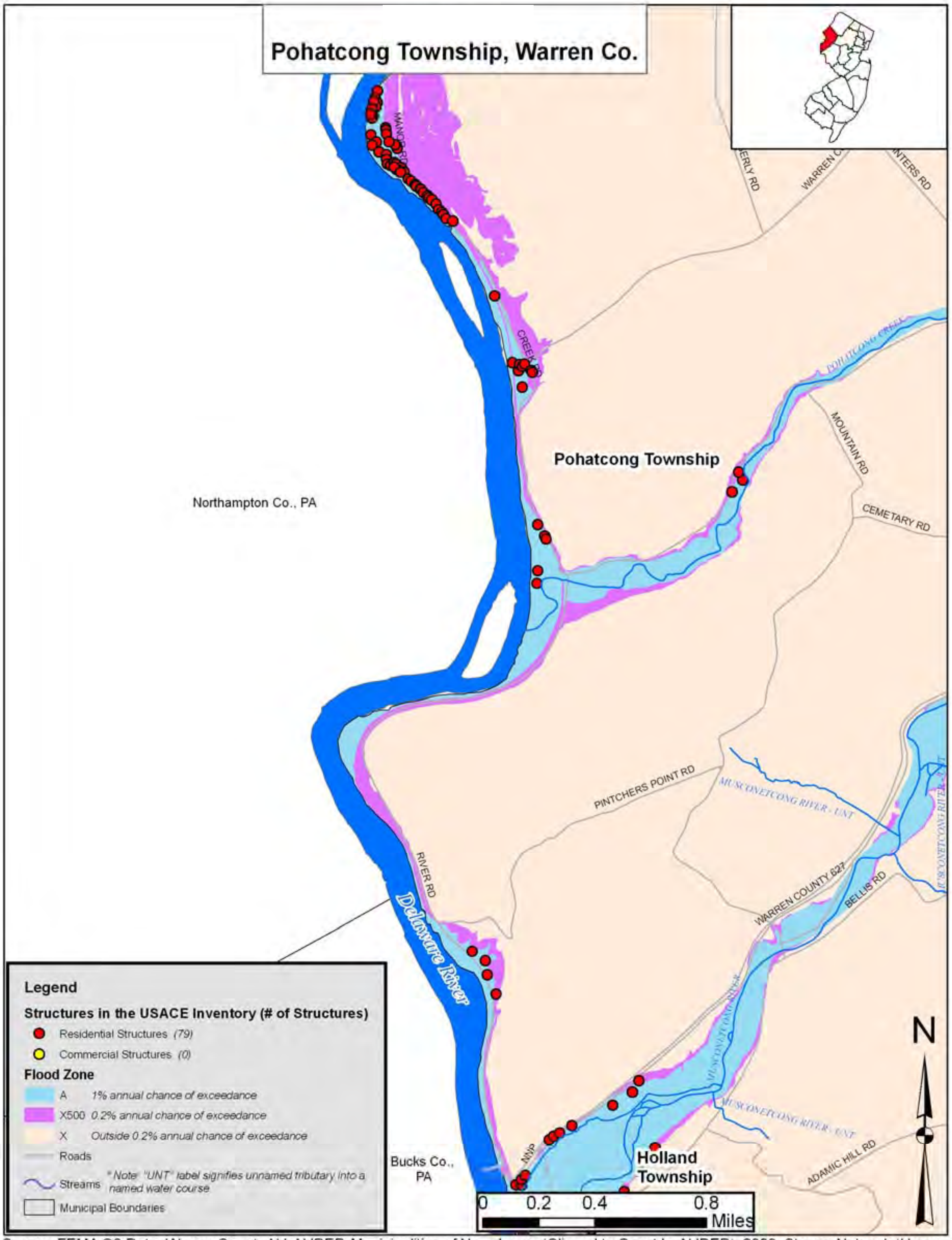
Source: FEMA Q3 Data, Warren County, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008; 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Figure 6: Town of Phillipsburg



Source: FEMA Q3 Data, Warren County, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008; Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Figure 7: Pohatcong Township



Source: FEMA Q3 Data, Warren County NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Upper Delaware River Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

C2.2. Hunterdon County

C2.2.1. *Holland Township*

Located on a bend in the Delaware River, Holland Township is a rural community with residential structures located on the riverbank. Many of these structures are older and potentially historic. In addition, two large commercial facilities are subject to flooding.

C2.2.2. *Frenchtown, Borough of*

A former manufacturing and transportation hub, this is one of the densest communities in the study area, with a downtown business core and smaller residential lots. The business district is centered on Bridge Street and the Uhlerstown-Frenchtown Bridge, which provides access to Pennsylvania. Residential areas subject to flooding extend both north and south of the bridge.

C2.2.3. *Byram (in Kingwood Township)*

This “colony association” (similar to a private homeowners association) of approximately 40 single-family homes is located in the lowest section of Kingwood Township, immediately on the banks of the Delaware. There are no commercial structures in the neighborhood. The surrounding area is rural with agricultural usage.

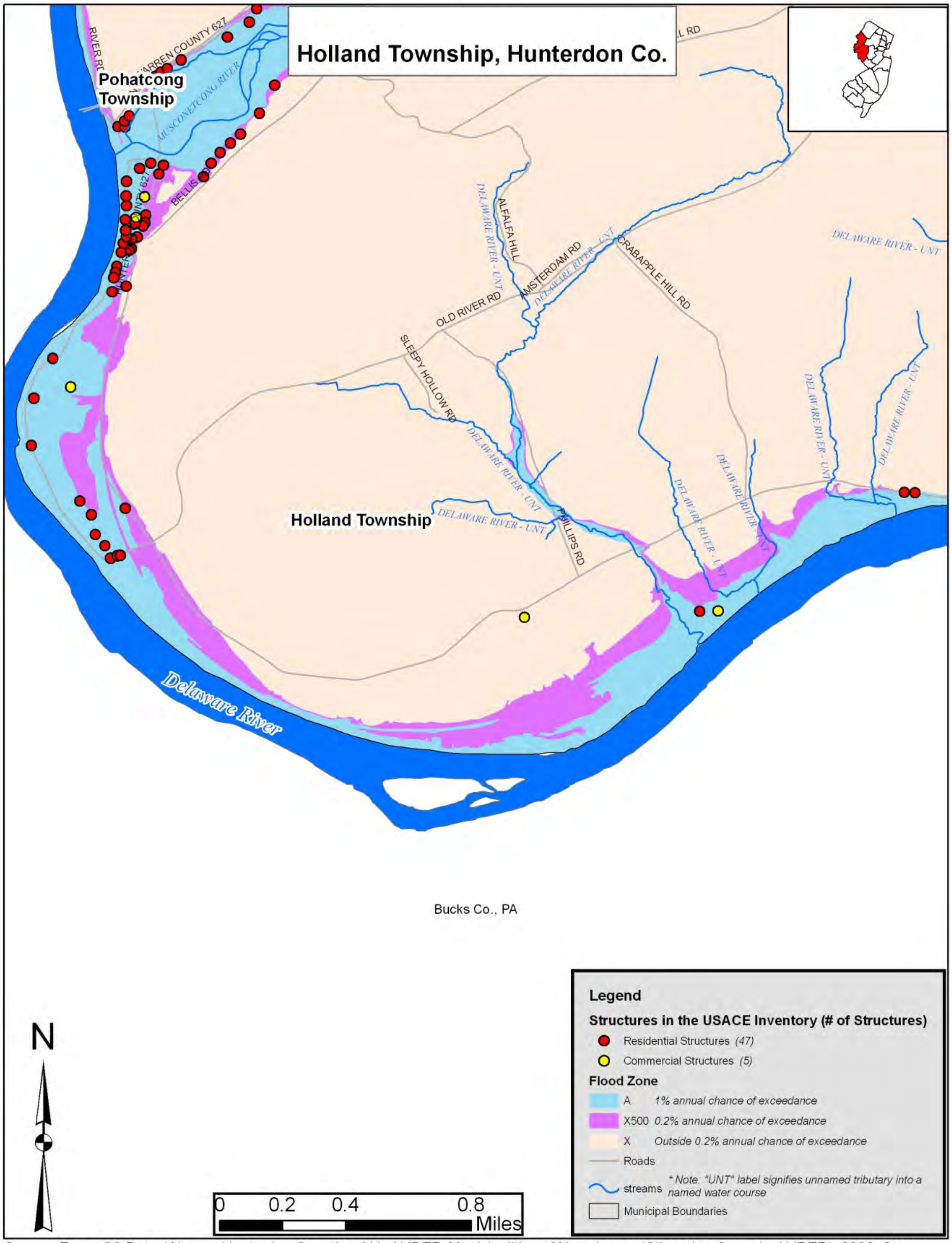
C2.2.4. *Stockton, Borough of*

The 1% ACE floodplain (100-year) extends from the Delaware River to Main St/NJ Route 29 in this small, dense historic community. Beyond Main Street, hills and bluffs rise above the flood elevation. A high percentage of Stockton’s buildings lie within the 1% ACE floodplain or the 0.2% ACE (500-year) fringe. The borough is subject to greater levels of flooding when the Delaware and Raritan (D&R) Canal embankment is breached, as occurred in 2005 and 2006.

C2.2.5. *Lambertville, City of*

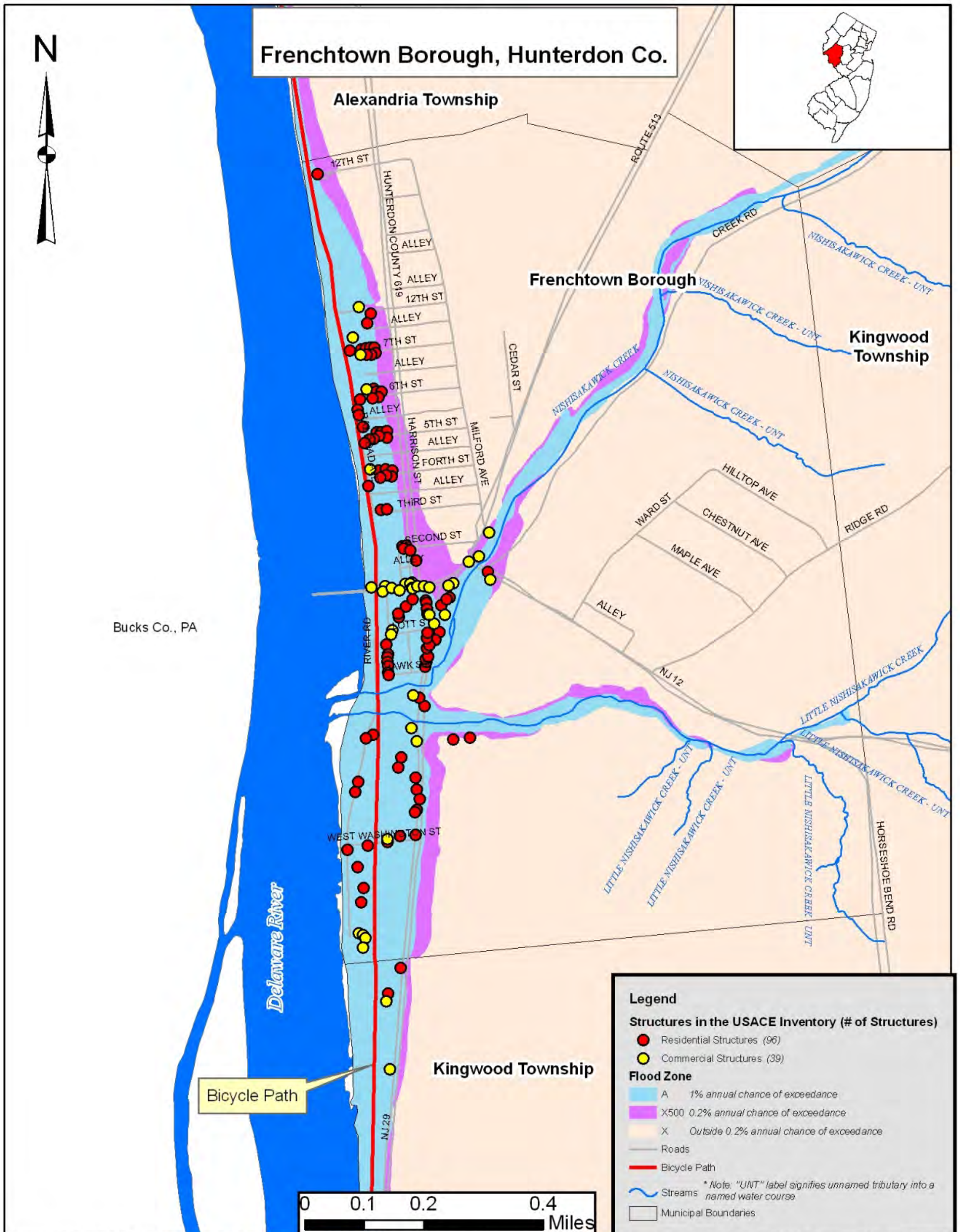
A former manufacturing and transportation community on the Delaware River with direct bridge access to Pennsylvania, Lambertville is now a travel and tourism destination for the region. The community is densely developed with a mix of commercial, multi-family, and single family dwellings. Flooding affects sizable clusters of residential and commercial structures at the northern and southern ends of the community, and along the length of the Delaware River waterfront.

Figure 8: Holland Township



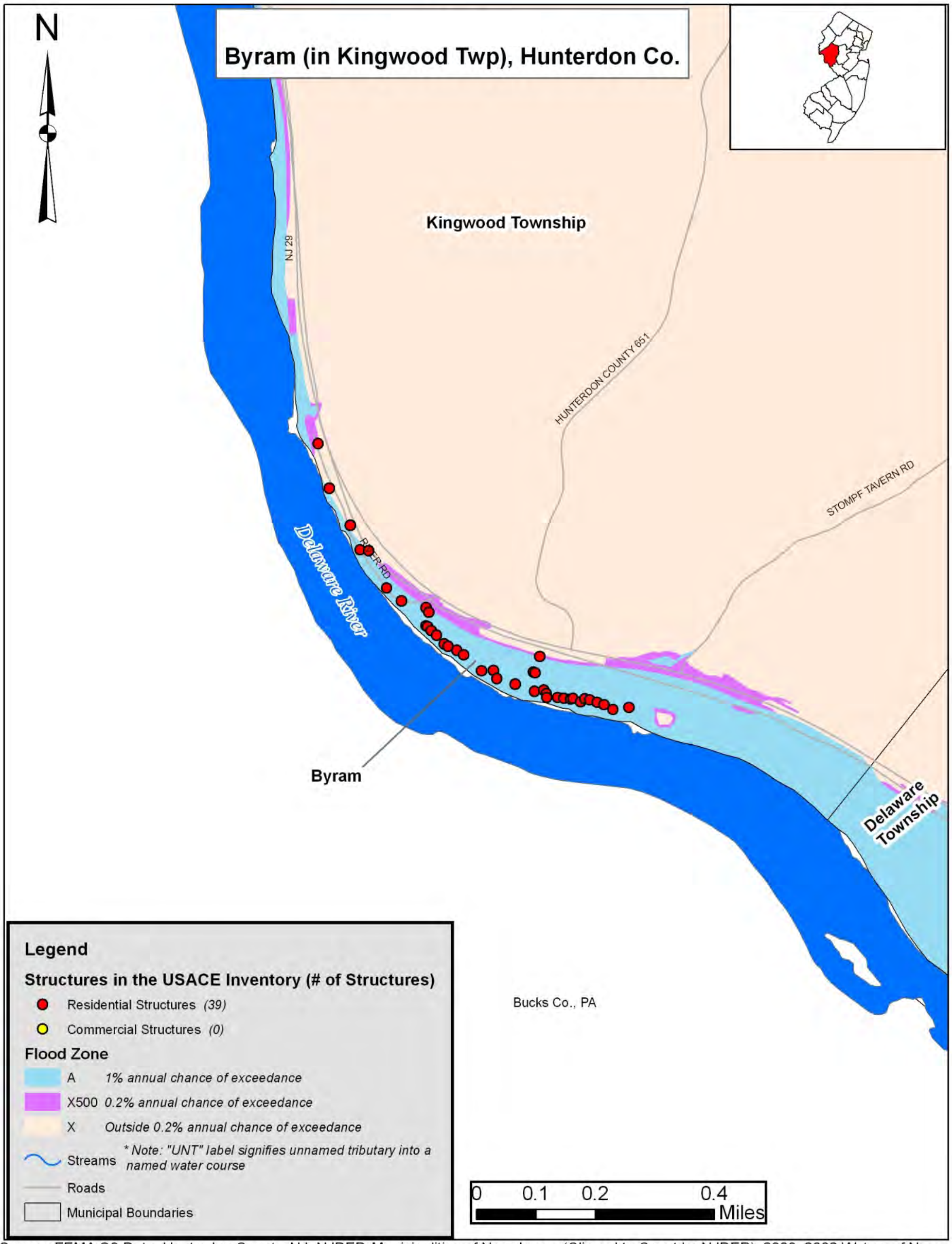
Source: Fema Q3 Data, Warren, Hunterdon Counties, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Figure 9: Frenchtown Borough



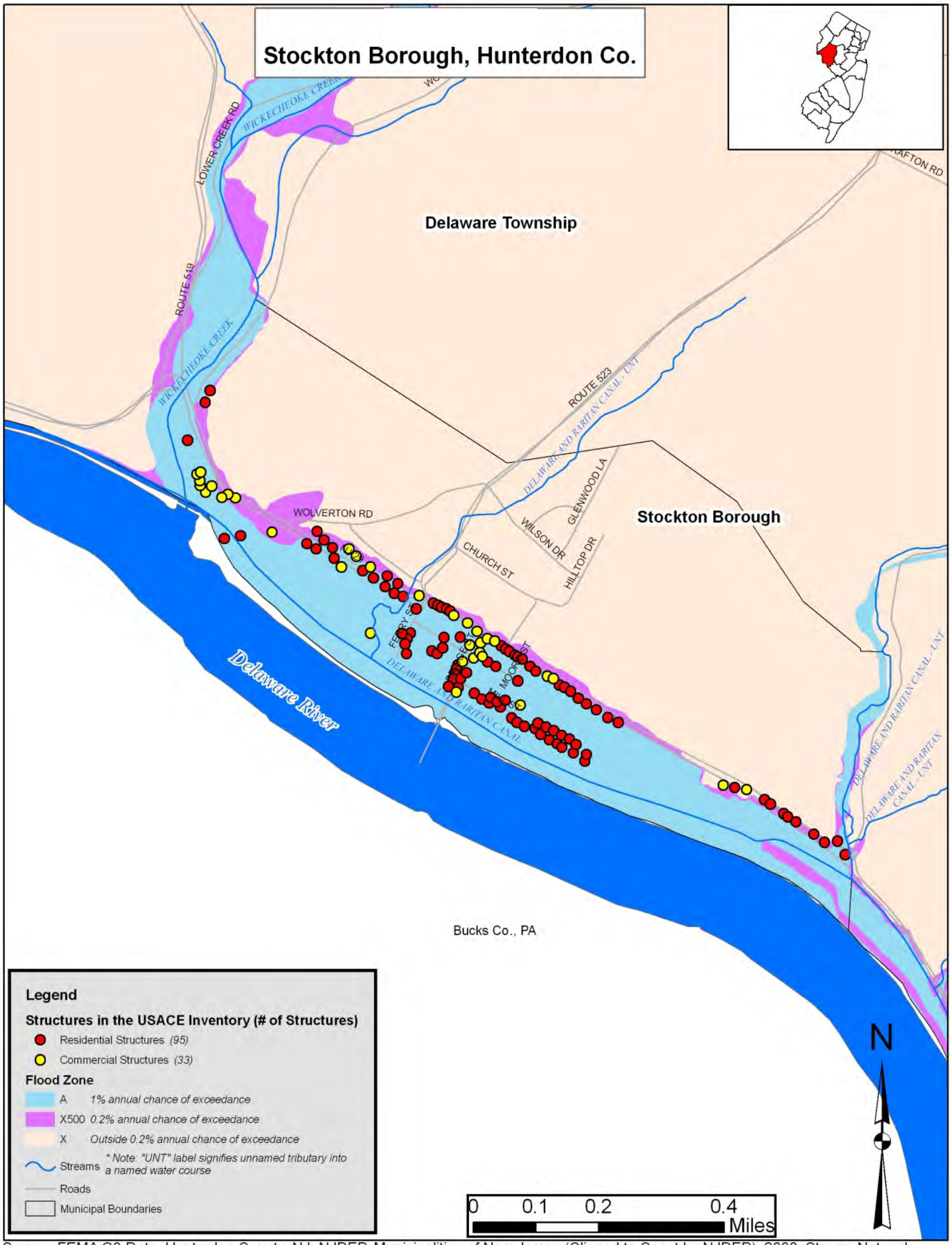
Source: FEMA Q3 Data, Hunterdon County, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Figure 10: Byram (in Kingwood Township)



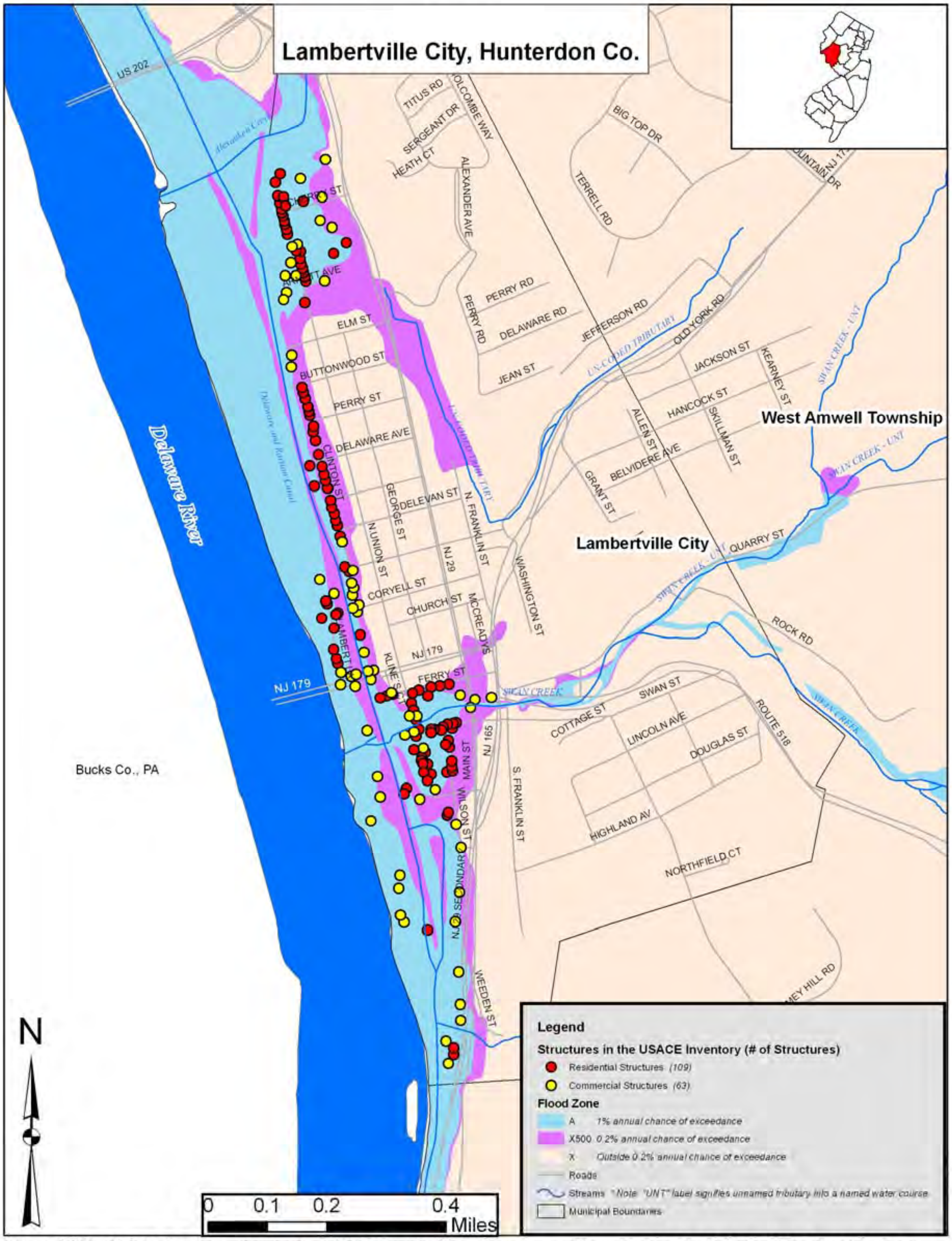
Source: FEMA Q3 Data, Hunterdon County, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008; 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Figure 11: Stockton Borough



Source: FEMA Q3 Data, Hunterdon County, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008; Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Figure 12: City of Lambertville



Source: FEMA Q3 Data, Hunterdon County, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

C2.3. Mercer County

C2.3.1. *Hopewell Township*

This is a mixed suburban/rural community, with the majority of its land area on a plateau above the Delaware River and not subject to flooding. A low-lying section of the D & R Canal embankment is subject to overtopping, which causes flooding on Route 29, to several isolated buildings, and to the water intake and pump station for the Mercer County Correctional Center. In addition, there is a residential section known as Titusville on the river side of Route 29. A low-lying section of Titusville experiences flooding from the Delaware River.

C2.3.2. *Ewing Township*

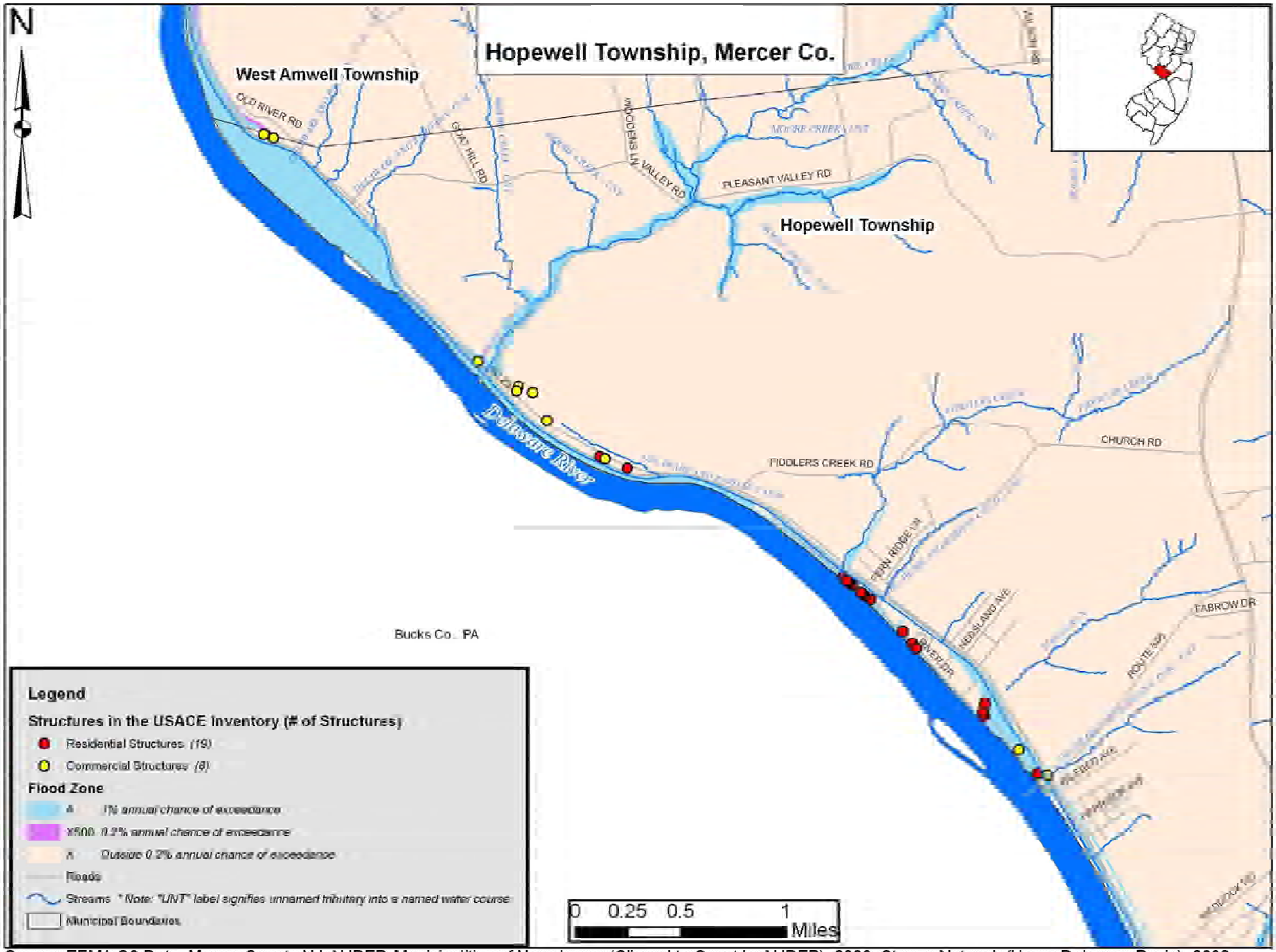
The Wilburtha neighborhood in this suburban township is located between the western embankment of the D&R Canal and the Delaware River, just south of the Scudder Falls (I-95) Bridge to Pennsylvania. It is a predominantly residential neighborhood with single-family and multi-family housing, a private girls school, and several commercial structures. The neighborhood is subject to flooding from backwater flooding through storm sewers, and overtopping of Route 29 by the Delaware River during larger flood events.

C2.3.3. *Trenton, City of*

The capital of New Jersey, Trenton is the largest community in the study area and is a densely developed city. The Island and Glen Afton neighborhoods are on the Delaware River bank, and subject to direct inundation. Glen Afton consists entirely of residential buildings; the majorities are single-family buildings, and there is a large apartment complex. More than 200 structures are subject to flooding in Glen Afton, including 100 rental units in the apartment complex. The Island neighborhood is primarily residential, with a small concentration of commercial buildings. Many of the residences in The Island are constructed of stone and masonry. Approximately 170 buildings in The Island have experienced basement flooding.

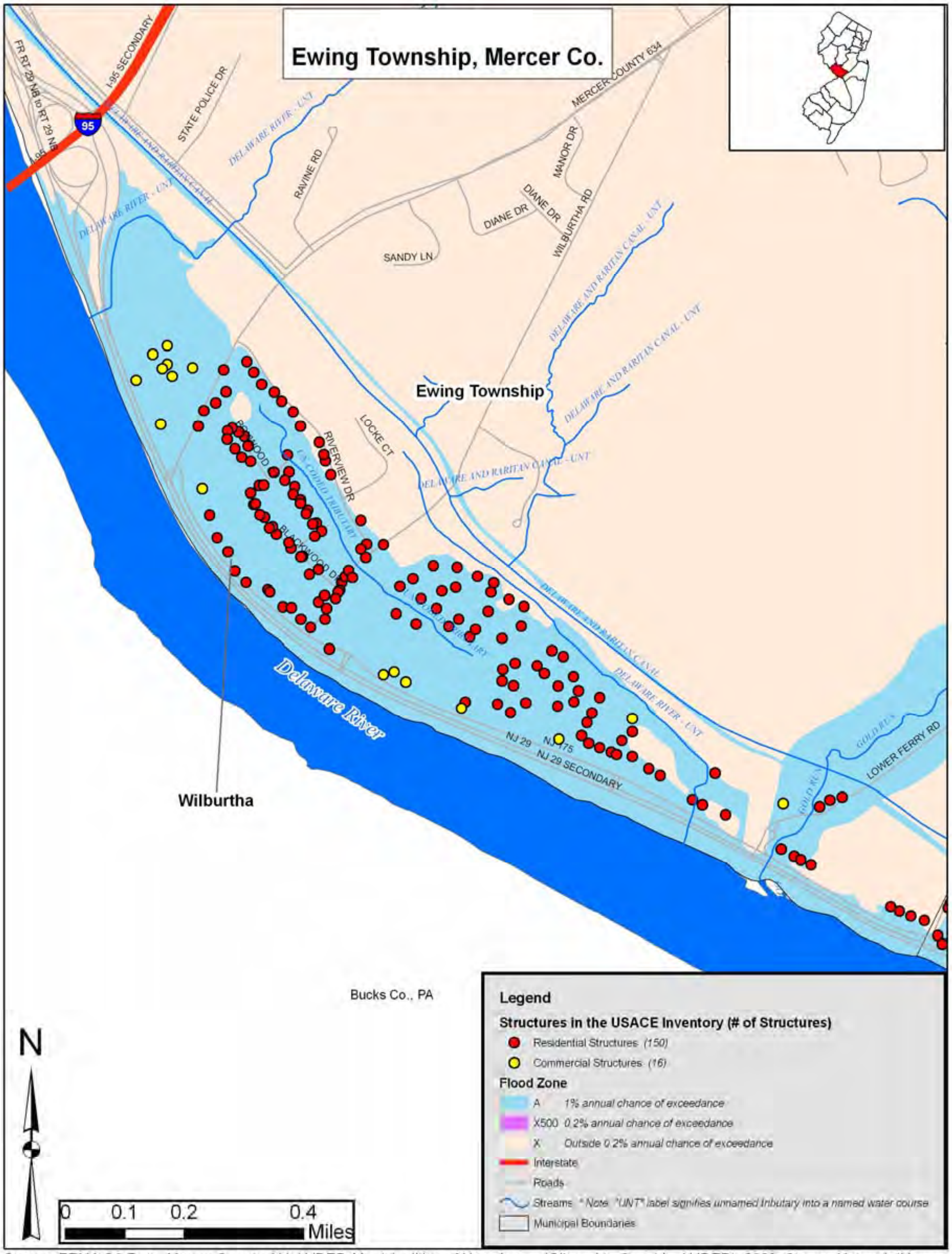
Flooding in downtown Trenton stems from the Delaware River backflowing along Route 29 and direct inundation during higher flood stages. This flooding affects commercial, governmental, and residential structures.

Figure 13: Hopewell Township



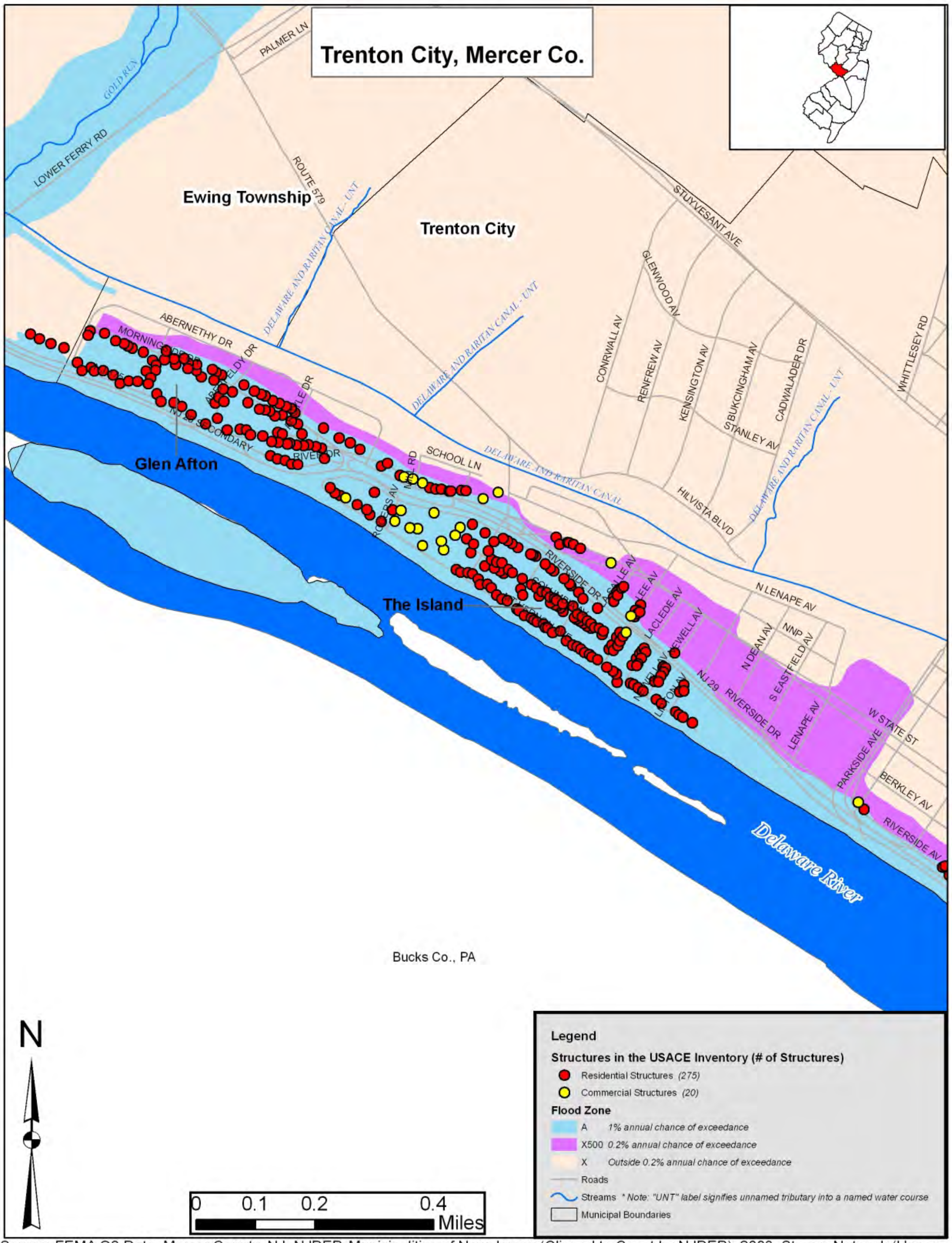
Source: FEMA Q3 Data, Mercer County NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Figure 14: Ewing Township



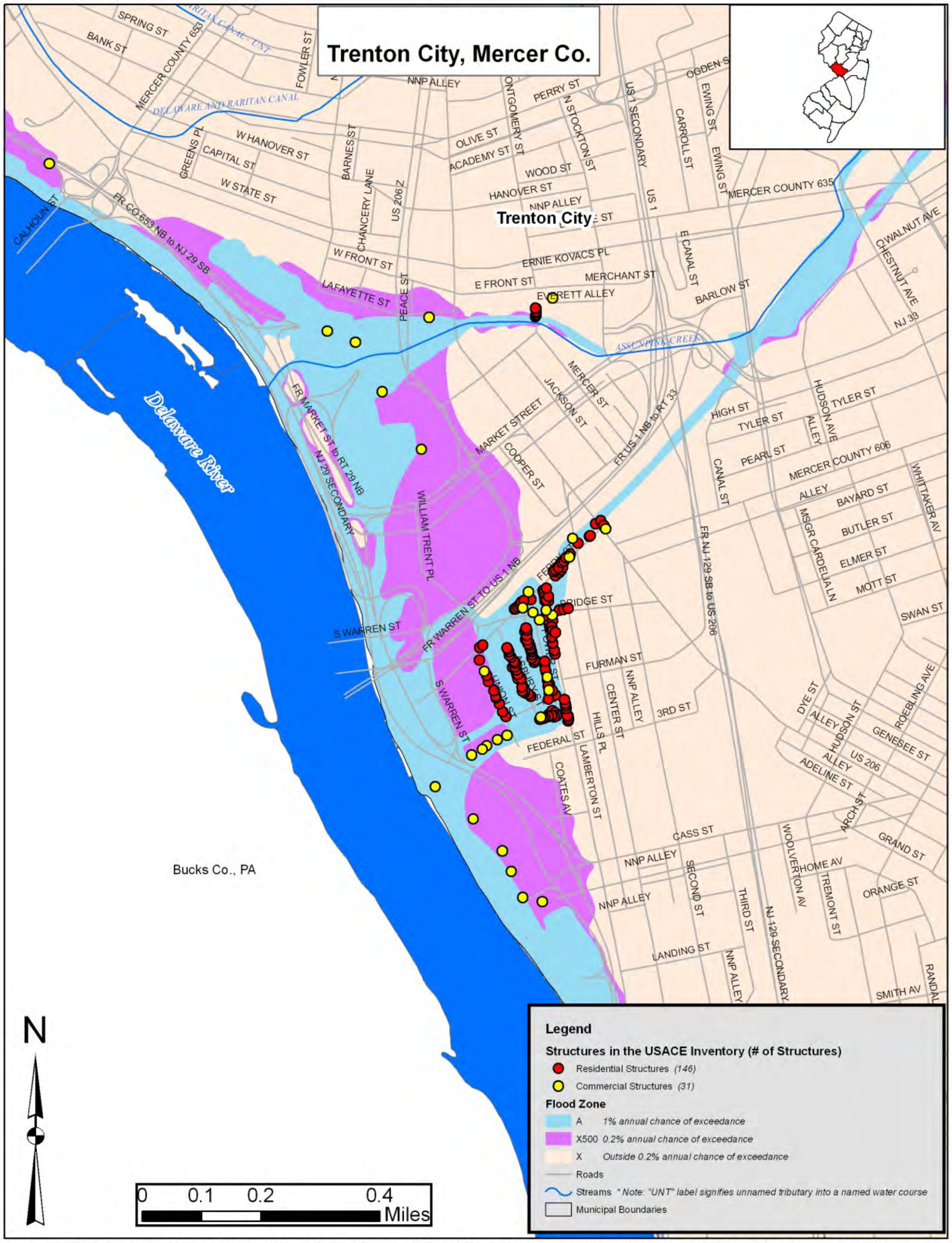
Source: FEMA Q3 Data, Mercer County, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Figure 15A: City of Trenton



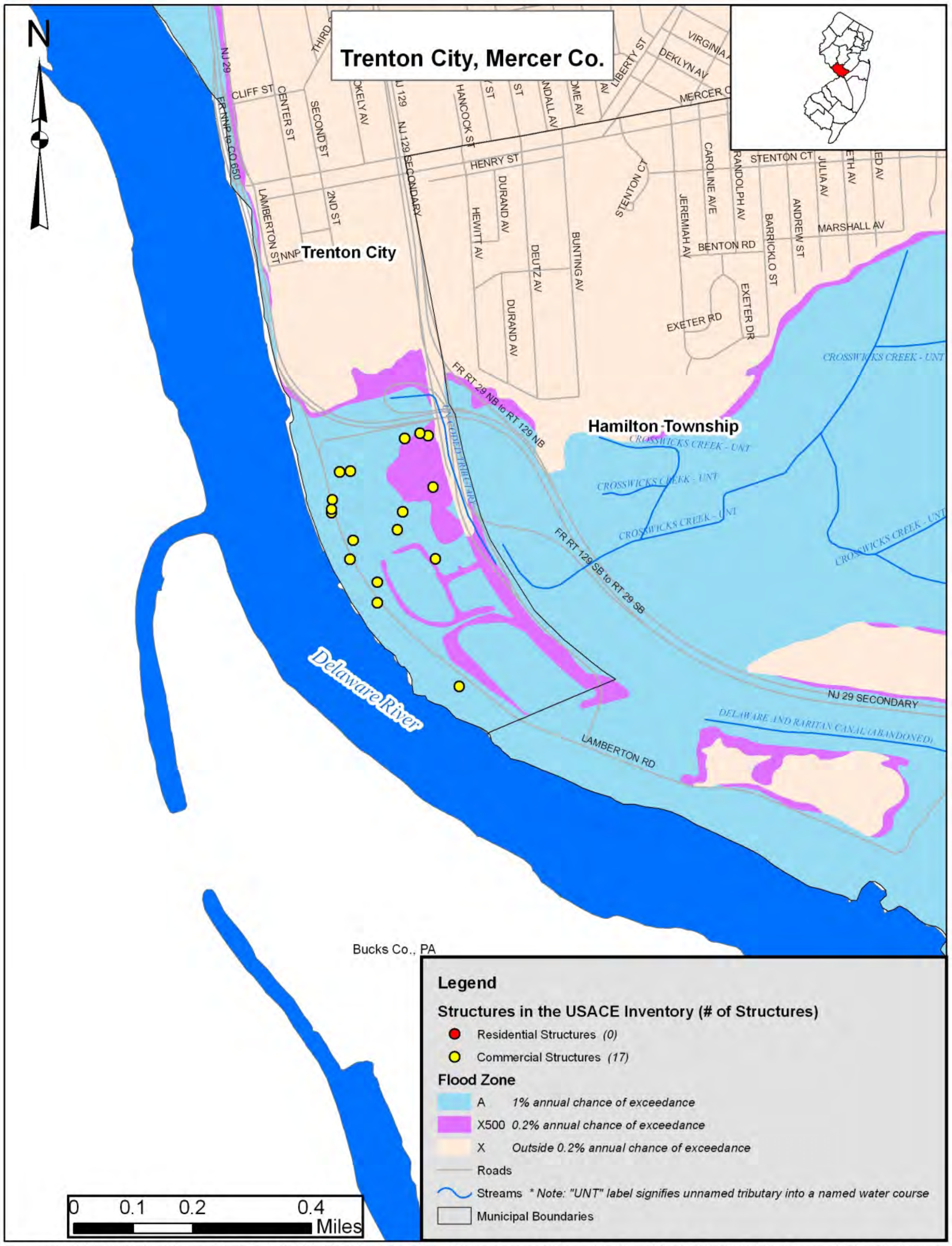
Source: FEMA Q3 Data, Mercer County, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Figure 15B: City of Trenton



Source: FEMA Q3 Data, Mercer County, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Upper Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Figure 15C: City of Trenton



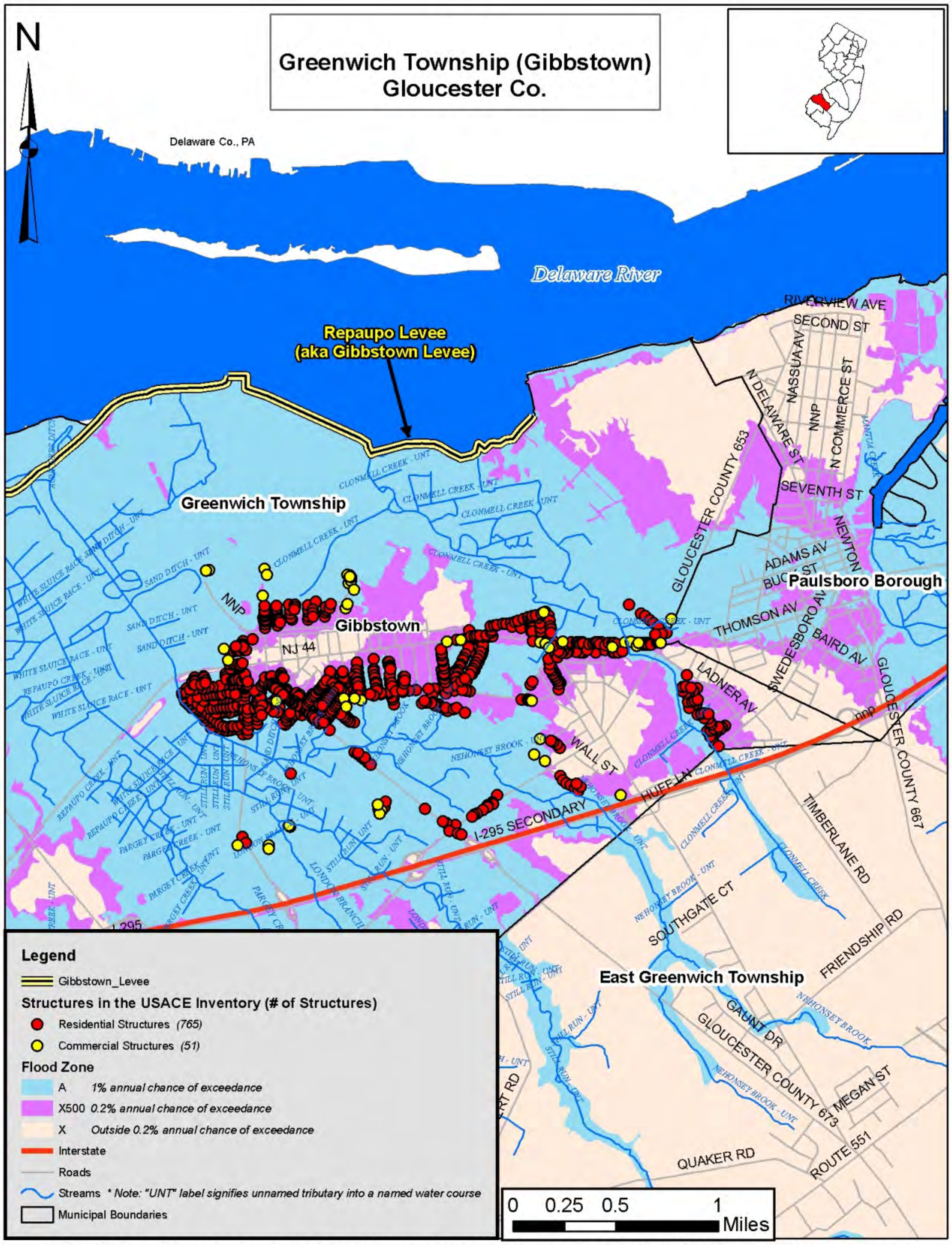
Source: FEMA Q3 Data, Mercer County, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Lower Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

C2.4. **Gloucester County**

C2.4.1. ***Greenwich Township and Logan Township***

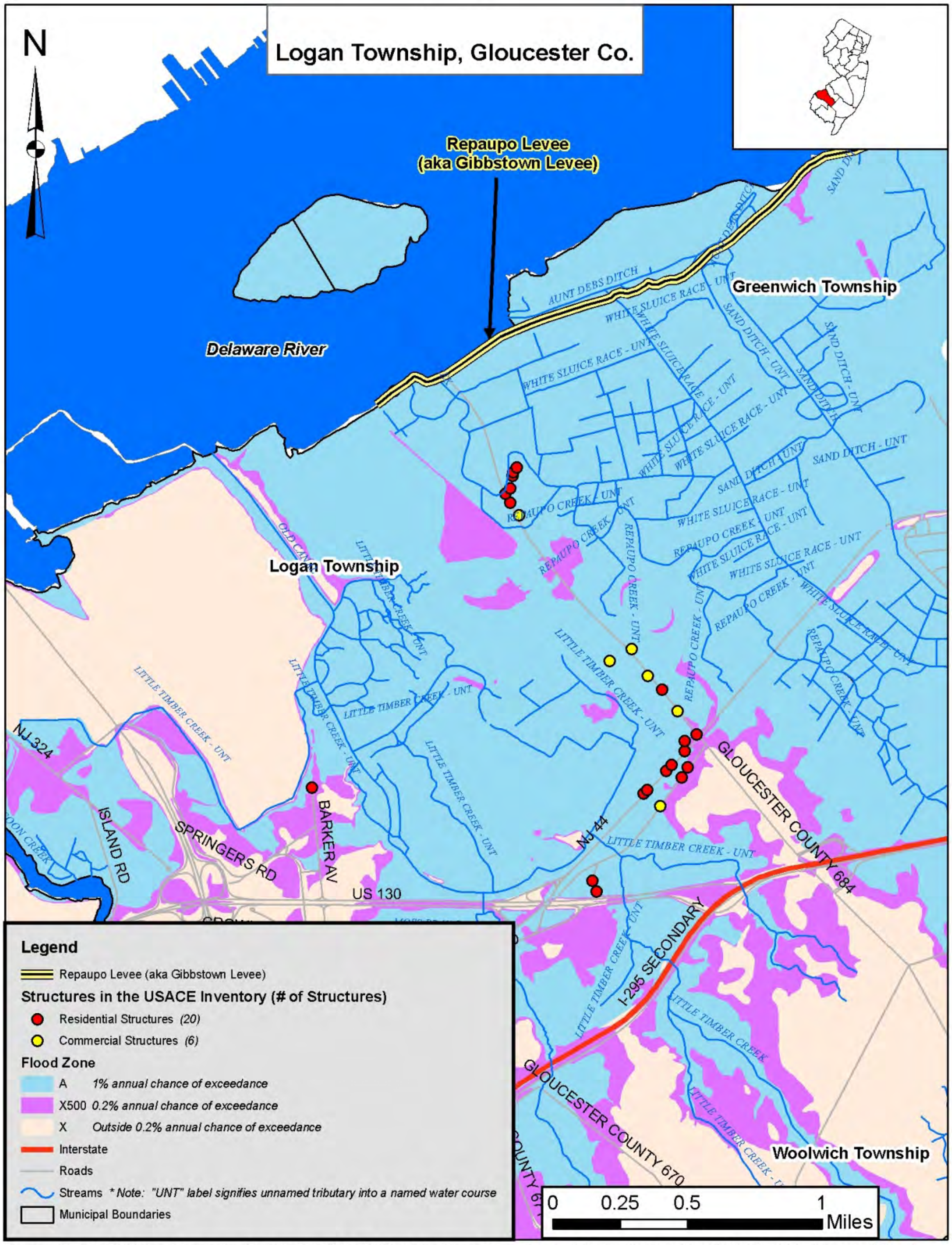
These low-lying and topographically flat communities on the bank of the Delaware River depend on being provided flood risk management against riverine flooding by an old agricultural levee. The primary land use is residential, with development clustered in Gibbstown and Paulsboro. There are other scattered residential areas, such as along Floodgate Road. Heavy industry is, or was, present at the DuPont, Ashland/Hercules, and Paulsboro Refinery facilities, and there are some light industrial manufacturing facilities in the area.

Figure 16: Greenwich Township (Gibbstown)



Source: FEMA Q3 Data, Gloucester County, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Lower Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

Figure 17: Logan Township



Source: FEMA Q3 Data, Gloucester County, NJ; NJDEP, Municipalities of New Jersey (Clipped to Coast by NJDEP), 2008, Stream Network (Lower Delaware Basin), 2008, 2002 Waters of New Jersey (Rivers, Bays, and Oceans); NJDOT, Roads 2008

C3. SOCIOECONOMICS

C3.1. Population

Population for 2010 (U.S, Bureau of Census) for the four NJ study area counties was 907,865, an increase of 7.5% over the 2000 total for the counties of 829,860. All of the study area counties saw population growth from 2000 to 2010.

The major population center within the study area is the City of Trenton in Mercer County. The city's population in 2010 was 84,913. There was a steady population decline recorded from 1950 to 2000. This decline was attributed to the reduction in the city's manufacturing base, and the larger trend of urban depopulation and suburban expansion experienced throughout New Jersey and the region. However, this trend stabilized by 2010, with population gains being forecast through 2030.

Population Projections

Population projections were available to the year 2035 for all study area municipalities. According to this data, communities in the study area can expect to see population increases in the coming decades. Table 3-1 provides population totals and estimates for the four study area counties and the state of New Jersey overall.

Table 3-1: State and County Population Totals

Location	1950	1960	1970	1980	1990	2000	2010	2020 (est.)	2030 (est.)	2035 (est.)
New Jersey	4,835,329	6,066,782	7,171,112	7,364,823	7,730,188	8,414,350	8,791,894	9,461,635	9,802,440	9,975,188
Warren County	54,374	63,220	73,960	84,429	91,607	102,437	108,692	126,798	133,422	134,204
Hunterdon County	42,736	54,107	69,718	87,361	107,776	121,989	128,349	152,889	146,546	147,825
Mercer County	229,781	266,392	304,116	307,863	325,824	350,761	366,513	370,543	384,309	388,385
Gloucester County	91,727	134,840	172,681	199,917	230,082	254,673	288,288	304,311	360,097	371,953

Source: U.S. Census Bureau, Population Estimates to year 2030, Census 2010. 2000, 1990 and 1980; Warren County Planning Department, Population Projections, 2005; Hunterdon County Planning Board Population Projections, 2002; Delaware Valley Regional Planning Commission, Mercer and Gloucester County, 2007

C3.2. **Land Use**

The majority of the floodplain areas are extensively developed, particularly in older communities such as Phillipsburg, Lambertville, Stockton, and Trenton. Because of the lack of available land for development and local adoption of floodplain management ordinances, future growth or intensification of floodplains in such areas is expected to be minimal. Rural or rural/suburban communities such as Holland, Hopewell and Ewing Townships also typically feature extensive development (at lesser densities) along the river, but have undeveloped land available in the floodplain. However, floodplain management ordinances in these communities regulate and limit intensification of floodplain development. If construction occurs on such land, the structures will be required to be in full compliance with the provisions of the NFIP. This would require the lowest level of a building to be at or above the regulated Base Flood Elevation (BFE).

In the majority of the study area communities, the floodplain is primarily occupied by residential development. In some communities such as Lambertville and Stockton, commercial uses are intermixed with the residential areas. Of particular note are the mixed commercial/residential core of Belvidere, a similarly mixed area in downtown Phillipsburg, and the governmental and commercial offices in downtown Trenton.

Residential development in the floodplain varies from single houses along the river's edge, as seen in Byram, to dense neighborhoods on smaller lots in Lambertville and The Island neighborhood in Trenton.

C3.3. **Income**

All the towns in Warren County are below the state average in per capita income. Median family income is split with Knowlton, White and Harmony being higher than the state average and Belvidere, Phillipsburg and Pohatcong below. Per capita income and mean family income in all the study towns in Hunterdon County are above the state averages, with the exception of Stockton, which fell below the average per capita income. In Mercer County, Hopewell has been historically above the state averages for per capita income and median family income, while Ewing appears to reflect the averages and Trenton has been below the state average. Greenwich and Logan in Gloucester County are below the state average in per capita income and above the state average in median family income. Phillipsburg and Trenton are the two communities that are the most below state average income levels.

The Census Bureau measures poverty using a set of money income thresholds adjusted to family size and composition. If a family's total income is below the income threshold then that family is considered below the poverty level (also known as the "poverty line"). In 2010, Trenton in Mercer County had the highest percentage of people (21.7%) living under the poverty level. The steady increase in poverty since 1980 may have influenced the steady decline in population. Alternatively, Hopewell in Mercer County has maintained very low percentages of people below the poverty line over the past thirty years, as well as Harmony in Warren County. Estimates for Ewing and Trenton demonstrate a continuing trend of an increasing percentage of the population beneath the poverty line. For consideration of environmental justice, the Gibbstown recommended plan will provide a permanent reduction in flood hazard exposure for those highly vulnerable in the study area population, including senior citizens, minorities, and the populace living in poverty.

C3.4. **Employment**

For the study area, all municipalities in Warren and Hunterdon Counties are at or below state unemployment levels. In Mercer County, Trenton has unemployment higher than the state average, while both Hopewell Township and Ewing Township are significantly below the state average. Both Greenwich and Logan in Gloucester County are below the state average for unemployment.

C3.5. **Transportation Facilities**

In the portions of the study area closest to the river (and often lying within the floodplain), various local roads provide north-south access parallel to the Delaware River. In Knowlton Township, in the northernmost section of the study area, US Route 46 begins at I-80 and parallels the river south to just north of Belvidere, NJ. From there, River Road extends along the river to just north of Phillipsburg. Within the city, local streets border the river. South of the city and Route 78, Carpentersville Road leads back to River Rd/County Rd 535. This road travels south towards Milford, and is called Reigelsville-Milford Road. It then becomes Milford-Frenchtown Road/County Road 619 en route to Frenchtown. Within Frenchtown, a short section of Old River Road is closest to the river. Route 29/River Road travels south from Frenchtown through Stockton and then on to Lambertville, and is also referred to as “Daniel Bray Highway” or “General Bray Highway”. Within Lambertville, Route 29 becomes Main Street and is several blocks inland of the river. The roadway is typically two lanes wide from Milford to Lambertville. Once south of Lambertville, Route 29 continues south through Hopewell and Ewing Townships and into the City of Trenton. The road lies inland of The Island neighborhood, and then rejoins the river as it intersects with US Route 1 (aka Trenton Freeway) and then extends through downtown Trenton. Route 29 reaches its terminus south of the city at the cloverleaf intersection with I-295 and I-195.

The regional transportation system in the study area is extensive due to the high levels of population and economic development in the area. In Warren County, State Highway Route 22 runs through the town of Phillipsburg while a section of I-80 is in the Knowlton Township area. Both Route 22 and I-80 provide transportation to Pennsylvania, with I-80 extending west across the country to California. Numerous bridges, both free and toll-charging, span the Delaware River between New Jersey and Pennsylvania. In Hunterdon County, State Highway Route 202 runs through Lambertville to Pennsylvania. The City of Trenton and Ewing Township in Mercer County, being two highly developed areas in close proximity, have the highest concentration of transportation facilities. Route 1 and I-95 span the Delaware River and offer access to Pennsylvania and points east, and Amtrak, New Jersey Transit, and the Southeastern Pennsylvania Transportation Authority have commuter rail lines in the area. Both I-295 and State Highway 130 traverse Greenwich and Logan Townships in Gloucester County. I-295 crosses the Delaware Memorial Bridge to Pennsylvania, while State Highway 130 terminates at 1-295 just east of the bridge.

C4. HISTORICAL DAMAGES

This feasibility study and economic appendix, while focusing on flooding issues along the main stem of the Delaware River, covers two distinct study areas. For the northern area or upper basin study area, from Knowlton Township to the City of Trenton, the report focuses on the flooding that occurred in 2004, 2005 and 2006. For the southern tidal areas in Logan and Greenwich Townships, the report focuses on flood risk and flooding as a result of Hurricane Sandy (October 29-30, 2012).

C4.1. Flood Events

The most widespread riverine flood event in the Delaware River Basin occurred in 1955. The National Weather Service has estimated repetition of this record flood event would cause $2.8 billion in damages. The events of 2004, 2005, and 2006 also had devastating effects on the Basin, causing a total of close to $745 million worth of damage in the states of New York, New Jersey, and Pennsylvania.

The three flood events between September 2004 and June 2006 have been analyzed by the National Weather Service (NWS). In general, the NWS determined that each of the three flood events were caused by unusually intense, long-duration rains and/or snowmelt during each event along with wet antecedent conditions leading up to each event.

Floods will be broken into individual recognizable flood events and the naming conventions simplified. Each of these events has an annual chance of exceedance (ACE) probability. The ACE probability is defined as that level of event that has a particular chance of occurring once in any year. Formerly, the 20% ACE was commonly called the 5-year event. This naming convention is a misnomer because it implies that it will only occur once in a five-year time span. In reality, the 20% ACE event is that magnitude of flooding that has a 20% chance, or 1 in 5, of happening in any year. However, it is not restricted to happening only once in a year. A table of the most recognized probabilities and their common reference is shown below followed by details about three of the most recent flood events.

Table 4-1: Probabilities of Flood Events

Probability	Common Reference
50% ACE	2-year
20% ACE	5-year
10% ACE	10-year
4% ACE	25-year
1% ACE	100-year
0.2% ACE	500-year
ACE = Annual Chance of Exceedance	

September 17-19, 2004: The remnants of Tropical Storm Ivan, interacting with a cold front that dropped into the northeastern United States late Friday, September 17, 2004, produced tremendous rainfall amounts across northeast Pennsylvania and southern New York. Most of the Delaware River Basin upstream of Trenton received three- to five-inches of rain in a 12-hour period, with some isolated areas receiving as much as seven or eight inches. Even before the rains from Ivan arrived, the Delaware River at Montague and Trenton, N.J. was flowing at 298 percent and 265 percent of normal, respectively, for the first half of September. A number of affected basin counties in Pennsylvania, New Jersey, and New York were declared as Federal disaster areas. Flood peaks along the main stem of the Delaware River were the highest since the flood of August 19, 1955.

April 2-4, 2005: Rainfall totaling as much as 5 inches, combined with wet antecedent conditions caused by more than 2 inches of rain that fell less than a week earlier, along with snow cover in the northern part of the Basin set the stage for the flooding along the main stem of the Delaware River. Along the main stem, the flood crests exceeded those reached in Tropical Storm Ivan only six-and-a-half months earlier, and again caused evacuations, bridge and road closures, and extensive damage. Rain fell mainly from the early morning hours of April 2 to the early morning hours of April 3. The heaviest rain fell across parts of northwestern New Jersey, northeastern Pennsylvania, and southeastern New York. More than 3 inches of rain was recorded by rain gages in Morris, Passaic, and Sussex Counties in New Jersey. Antecedent conditions contributed to the flooding that resulted from the April 2-4 rainfall. Above-average rainfall during the preceding 12 months and more than 2 inches of rainfall across the region on March 28-29 resulted in higher than average stream flows. Reservoirs in the upper Delaware River Basin were at capacity and spilling during the storm.

Gaging stations on the main stem of the Delaware River recorded higher frequency peaks than those recorded on any other stream in New Jersey as a result of this storm. Flood peaks along the main stem of the Delaware River were 1 to 3 feet higher than those of the September 17-19, 2004 flood and the highest since the flood of August 19, 1955. Peak flows at the six gaging stations between Port Jervis and Trenton, N. J. ranged from a 2.5% ACE to a 1.3% ACE (40- to 75-year events). Peak flows recorded by stream gages on the major tributaries to the Delaware River in New Jersey from the Musconetcong River north to Flat Brook indicated an annual chance of exceedance of 12.5% to 5% (8-year to 20-year floods).

June 24-29, 2006: Extremely heavy rainfall over the Delaware River Basin during the June 24-28 period caused flash flooding and record to near-record flood crests along many streams and rivers throughout the basin, including the main stem Delaware River. Rain fell over the Delaware River Basin every day from June 23 to June 28, 2006. Total rainfall ranged from 3 to 6.5 inches across the New Jersey part of the basin and 7 to 15 inches in northeastern Pennsylvania. Heavy rainfall during June 24-26 saturated the ground and produced bank full and minor flooding conditions by early Tuesday, June 27. Most flooding in New Jersey occurred along the main stem of the Delaware River. Peak stages at the Montague and Delaware Water Gap gages averaged 0.5 foot higher than the April 2005 peaks. At the Belvidere, Riegelsville, and Trenton gages, the peak stages were slightly lower than the April 2005 peaks.

Gibbstown (Greenwich/Logan Townships): This area is vulnerable to flooding since there is no confidence of any protection being afforded the study area from the existing Federally Uncertified Landform (FUL). A direct hit of a Hurricane Sandy-type storm event, with the full brunt of the storm affecting the Gibbstown area (making the area susceptible to significant damage impacts as experienced by north and central NJ coastal and bay communities in October 2012) would be expected to overwhelm the existing FUL. For the study area, the number of structures at risk in the base year range from 236 at a 50% ACE, to 392 at a 2% ACE, to 457 at a 1% ACE (100-year event). Applying the Census estimate for 2015 of an average of 2.63 people per structure, the Population at Risk for these three potential events is estimated at 620, 1,031, and 1,202 respectively. Future year sea level change conditions for the most likely scenario would increase the Population at Risk estimates by 14-18%. In total, Greenwich Township has a population of 4,899 (Gibbstown as a sub-aggregate has 3,739 people). Logan Township also has 10-21 additional structures potentially impacted by flooding. The population below the poverty level is 8.9% in Greenwich Township, so environmental justice is a factor in recommending a plan of improvement to reduce any adverse flooding impacts, particularly to afford protection to this segment of the populace that is lower on the economic scale. Health concerns such as infectious disease from contaminated flood waters and a storm event aftermath of mold development would also adversely impact the community. Infrastructure impacts could encompass transportation (roads, bridges) electricity, gas supplies, water and phone services. Mental trauma and adverse physical health impacts from stress and anxiety during extended post-flood recovery could also be significant.

The major flood events had a tremendous impact on homeowners, businesses, and municipalities in the Delaware River basin. Millions of dollars in public funds and insurance claims resulted from these damaging flood events. The following section gives a brief description of the damage which occurred in the most flood prone areas of the basin.

C4.2. **Damages in Flood Prone Areas – Upper Basin**

Insurance claims from the National Flood Insurance Program (NFIP) administered by FEMA were analyzed for the general picture of flood damages within the Delaware River Basin. The Delaware River Basin Commission (DRBC) performed a comparative analysis of FEMA-designated repetitive and severe repetitive loss properties in the Delaware River Basin from the three flood events of September 2004, April 2005 and June 2006 from the NFIP (see Exhibit C-F). The analysis conducted by the DRBC combined both repetitive and severe repetitive loss properties and included maps and tables that show the number and dollar amounts of loss properties per municipality and county. FEMA declares a property as a repetitive loss when there are two or more losses reported which were paid more than $1,000 for each loss and the two losses must be within 10 years of each other and be at least 10 days apart. FEMA declares a property as a severe repetitive loss when there are at least four losses, each exceeding $5,000, or when there are two or more losses where the building payments exceeded the property value. A limitation of this analysis is that it only considered closed NFIP claims, and not uninsured flood damages. Uninsured flood damages include such things as roads, bridges, and public utilities. This analysis also does not consider damages to residential property that is not insured by owners and it does not distinguish the source of flooding as either from streams or stormwater backups. DRBC's web page that summarizes the complete analysis is at:

http://www.state.nj.us/drbc/Flood_Website/floodclaims_home.htm

As shown in Table 4-2, Harmony Township had the highest combined payout from the NFIP of $11.5 million for the three flood events in 2004, 2005, and 2006. The City of Trenton had more submitted claims than any other municipality, but the average payout per claim of just over $11,430 was significantly less than the average payout of $53,151 and $49,474 for Harmony Township and Kingwood Township, respectively. A total of 58 municipalities in 11 counties in the State of New Jersey had at least one NFIP claim from the three events. In total, 1,715 claims were filed for these three events, with a total combined payout of over $45 million. The April 2005 event had the largest total payout of just under $20 million.

Table 4-2: FEMA NFIP Claims for 2004-2006 Flood Events

Municipality	County	Claims (#)	Total Payouts ($) Sept. 2004 Event	Total Payouts ($) April 2005 Event	Total Payouts ($) June 2006 Event	Total Combined Payouts ($)	Average Payout ($)
Harmony Township	Warren	217	$2,629,899	$4,943,502	$3,960,431	$11,533,832	$53,151
Trenton City	Mercer	472	$729,998	$2,343,196	$2,321,539	$5,394,733	$11,430
Kingwood Township	Hunterdon	82	$798,144	$1,830,589	$1,428,140	$4,056,873	$49,474
Lambertville City	Hunterdon	203	$668,685	$1,458,963	$1,560,286	$3,687,934	$18,167
Knowlton Township	Warren	100	$594,143	$1,611,031	$1,432,277	$3,637,451	$36,375
Pohatcong Township	Warren	94	$671,797	$1,407,282	$1,314,567	$3,393,646	$36,103
Stockton Boro	Hunterdon	84	$25,468	$1,393,410	$923,258	$2,342,136	$27,883
Phillipsburg Town	Warren	49	$925,753	$795,953	$430,102	$2,151,808	$43,914
Belvidere Town	Warren	114	$293,843	$964,465	$877,253	$2,135,561	$18,733
Frenchtown Boro	Hunterdon	70	$305,555	$677,665	$986,035	$1,969,255	$28,132
Holland Township	Hunterdon	30	$288,959	$410,532	$441,358	$1,140,849	$38,028
Delaware Township	Hunterdon	34	$134,161	$509,524	$396,291	$1,039,976	$30,588
Blairstown Township	Warren	27	$288,810	$418,996	$276,150	$983,956	$36,443
Hopewell Township	Mercer	17	$63,499	$149,914	$211,244	$424,657	$24,980
Lopatcong Township	Warren	7	$37,394	$104,828	$56,056	$198,278	$28,325
Ewing Township	Mercer	31	$31,649	$92,308	$73,349	$197,306	$6,365
Montague Township	Sussex	7	$6,962	$25,773	$121,728	$154,463	$22,066
Sandyston Township	Sussex	2		$95,850	$37,765	$133,615	$66,808
Cinnaminson Township	Burlington	8		$108,574	$935	$109,509	$13,689
White Township	Warren	5	$33,572	$27,017	$33,365	$93,954	$18,791
Mantua Township	Gloucester	1		$59,387		$59,387	$59,387
West Amwell Township	Hunterdon	5	$31,812	$17,416	$7,627	$56,855	$11,371
Hope Township	Warren	2	$51,411			$51,411	$25,706
Camden City	Camden	5		$32,652	$2,399	$35,051	$7,010
Hopatcong Boro	Sussex	1			$26,558	$26,558	$26,558
Hackettstown	Warren	4	$14,994	$6,456		$21,450	$5,363
Downe Township	Cumberlan	3		$20,695		$20,695	$6,898
West Deptford Township	Gloucester	3		$19,448		$19,448	$6,483
Palmyra Boro	Burlington	2		$19,301		$19,301	$9,651
Alexandria Township	Hunterdon	1			$16,026	$16,026	$16,026

Table 4-2: FEMA NFIP Claims for 2004-2006 Flood Events (continued)

Municipality	County	Claims (#)	Total Payouts ($) Sept. 2004 Event	Total Payouts ($) April 2005 Event	Total Payouts ($) June 2006 Event	Total Combined Payouts ($)	Average Payout ($)
Netcong Boro	Morris	1		$14,505		$14,505	$14,505
Mount Ephraim Boro	Camden	1		$14,136		$14,136	$14,136
Frankford Township	Sussex	2		$6,838	$7,089	$13,927	$6,964
Lebanon Township	Hunterdon	1		$13,011		$13,011	$13,011
Branchville Boro	Sussex	1	$12,419			$12,419	$12,419
New Hanover Township	Burlington	1		$10,518		$10,518	$10,518
East Greenwich Township	Gloucester	1		$10,517		$10,517	$10,517
National Park Boro	Gloucester	2		$9,699		$9,699	$4,850
Pennsville Township	Salem	2		$9,535		$9,535	$4,768
Jefferson Township	Morris	1		$9,228		$9,228	$9,228
Delran Township	Burlington	3		$9,146		$9,146	$3,049
Woodlynne Boro	Camden	2		$5,508	$3,284	$8,792	$4,396
Salem City	Salem	1			$8,276	$8,276	$8,276
Brooklawn Boro	Camden	1		$7,962		$7,962	$7,962
Hamilton Township	Mercer	1		$5,876		$5,876	$5,876
Bordentown City	Burlington	1		$3,768		$3,768	$3,768
Sparta Township	Sussex	1		$3,700		$3,700	$3,700
Lower Township	Cape May	1		$3,510		$3,510	$3,510
Delanco Township	Burlington	1		$3,353		$3,353	$3,353
Carneys Point Township	Salem	1		$3,136		$3,136	$3,136
Mansfield Township	Warren	2	$516	$2,443		$2,959	$1,480
Burlington City	Burlington	1		$2,447		$2,447	$2,447
Franklin Township	Warren	1	$2,264			$2,264	$2,264
Washington Township	Mercer	1		$1,855		$1,855	$1,855
Collingswood Boro	Camden	1		$1,534		$1,534	$1,534
Medford Township	Burlington	1		$1,059		$1,059	$1,059
Riverside Township	Burlington	1		$783		$783	$783
Mount Laurel Township	Burlington	1		$538		$538	$538
TOTALS		**1715**	**$8,641,707**	**$19,699,332**	**$16,953,388**	**$45,294,427**	**$26,411**

C4.3. Flood Risk in Tidal Area, Greenwich and Logan Townships (Gibbstown)

In the 1800's, in the southern area or lower basin in Greenwich and Logan Townships, a 4.5 mile long privately owned levee (referred to the Gibbstown Levee) was built to keep out waters from the Delaware River and five tide gates were constructed on five interior to drain the meadows at low tide. Salt hay was then harvested as a commercial product and some development, including industry, occurred behind the levee. Salt hay was an agricultural product used for subsidence farming in the 1800's, providing bedding for farm animals. By the early 20th century, however, as the area industrialized and the market for salt hay became obsolete, the Repaupo Meadow Company, which originally constructed the dike and floodgates to reclaim marshlands in Greenwich and Logan Townships, became little more than an entity on paper, and the infrastructure fell into disrepair. Sundry stop-gap repairs have been made over the years, but the structural decay has not been addressed in a comprehensive fashion.

In 2000, Greenwich Township requested flood-fight assistance from the Corps after almost 5 inches of rain fell in 12 hours. Six 12-inch pumps were deployed to the Gibbstown Floodgates. The Township requested DuPont, which owned the adjoining Repaupo chemical plant and maintained the structure, to remove debris and clean the trash racks on the other floodgates along the levee, principally, the White Sluice Floodgates.

In 2003, surge from Hurricane Isabel brought the Delaware River level to within 1 foot of the crest of the Gibbstown Floodgate Structure. In advance of the approaching hurricane, sandbag walls were placed across both the Gibbstown Floodgate Structure, which is lower than the levee crest, and a low spot in the levee crest where the access road ramps up to the levee. In addition, when the river was at its highest range, a leak developed near the top of the Repaupo Floodgate Structure where there had been apparent differential settlement between two monoliths of the concrete structure. This was reported to have happened during similar high water events in the past. No evacuation was ordered, and the levee and floodgate structure held.

In 2006, the Corps performed emergency repairs to the floodgate under the auspices of PL 84-99. Then, in 2008, the Gloucester County Improvement Authority announced that it had secured funding and permits necessary to replace the floodgates and repair 900 feet of levee adjacent to the floodgates, raising it seven to eleven feet in height from its existing elevation. In 2009, work on the levee was undertaken, consisting of floodgate repairs and raising a 900-foot long section of the levee. Even, with these stopgap repairs, the lack of protective capability that can be expected for the existing Federally Uncertified Landform leaves the Gibbstown area susceptible to significant flood damages.

The Gibbstown area has been fortuitous in not being impacted to the extent of the NJ Upper Basin from the 2004, 2005, and 2006 flood events. A direct hit of a Hurricane Sandy-type storm event, with the full brunt of the storm affecting the Gibbstown area (making the area susceptible to significant monetary damage impacts to structures, infrastructure and people as experienced by north and central NJ coastal and bay communities in October 2012) would be expected to overwhelm the existing FUL. For the study area, the number of structures at risk in the base year range from 236 at a 50% ACE, to 392 at a 2% ACE, to 457 at a 1% ACE (100-year event). Applying the Census estimate for 2015 of an average of 2.63 people per structure, the Population at Risk for these three potential events is estimated at 620, 1,031, and 1,202 respectively. Future year sea level change conditions for the most likely scenario would increase the Population at Risk estimates by 14-18%. Additional discussion is provided in Section C.4.1 Gibbstown (Greenwich/Logan Townships) above.

C5. DAMAGE ANALYSIS METHODOLOGY

An economic flood damage analysis model for the existing without project condition was developed for the 1% ACE (100-year) floodplain in the 14 communities in the upper project study area from Trenton northward along the New Jersey bank of the Delaware River, as well as for the 2 communities in the downriver Gibbstown Levee study area in Gloucester County. Interface with hydrologic modeling resulted in the estimation of average annual damages disaggregated by reach for the study area for the existing without project condition. Results of these analyses, together with the future without project conditions, if different from existing, served as a baseline for determining estimated reductions in damages from various structural and non-structural alternative plans.

The extent of floodplain investment is majorly important to determining the estimated flood damages. Therefore, surveys were conducted to identify each residential and habitable commercial structure within the study area. Both the locations and elevations of structures and their entryways were identified to determine potential impact by flood waters.

C5.1. Reach Delineation (H&H and/or Economic Interface)

A reach is a stretch of river or land between topographic points. Reaches were the primary geographic unit used during the planning process. Reaches are defined by hydrologic considerations and stream stations, with stream size, slope, and uniformity of shape being taken into account. For purposes of relating flood damage at structures to predicted flood levels, a stream stationing value was assigned to each of the structures that is consistent with the stationing used in the Delaware River Hydrologic Engineering Center (HEC) River Analysis Software (HEC-RAS) hydraulic model for the Interim Feasibility Study for New Jersey. Since the model utilizes HEC-GeoRAS utilities, both the stream centerline and the cross sections could be exported from the model as georeferenced Geographic Information Systems (GIS) shapefiles. Stream stationing was then determined at individual structures by measuring offsets from hydraulic model cross sections in a GIS environment. Stationing provided in feet was converted to miles for consistency with the HEC Flood Damage Analysis (HEC-FDA) requirements. The existing without project condition economic analysis delineated structures by considering H&H reaches and municipalities. For example, Trenton has been divided into seven reach units. Also, for each reach, tabular information was developed that presents expected damages for a range of recurrence interval storm events. An exceedance probability-damage function curve was also developed for each damage reach.

Structures were assigned a station value based on the furthest upstream extent of the structure. This methodology was also applied to structures large enough to span several HEC-RAS cross sections. Structures identified in the supplied data as demolished, accessory, missing, etc. were not assigned stream stationing and not included in the model. The stations for each structure were entered into the HEC-FDA model, with the other required structure data obtained in field inventories.

Stationing in the lower basin study area (Gibbstown) was determined similarly, by measuring offsets from Delaware River Basin Commission's data for the quarter mile marks of the Delaware River. Stationing was determined in miles and structures were assigned a station value based on the furthest upstream extent of the structure. Structures identified in the supplied data as demolished, accessory, missing, etc. were not assigned stream stationing. The stations for each structure were entered into the HEC-FDA model, with the other required structure data obtained in field inventories. The lower basin study area uses a stage frequency curve (available in Exhibit C-D) to estimate water surface elevations for different storm recurrence intervals. The stage frequency curve is at 0.5 mile increments based upon the interpolation from NOAA's long term tide stations at Philadelphia, PA and Lewes, DE and the length of record for the data. This gage data was used to establish the river profile for an area that is tidally influenced. The river miles used in the model are from a shapefile from the DRBC. Interior flooding for the lower basin study area was not considered in this model. In the following table, damage reaches without any impacted structures are shown as blank in the Municipality column.

Table 5-1: Reach Delineation - Upper Basin Study Area

Municipality	Reach Name	Station (mi)		
		Downstream	Upstream	Index
	DR-1	127.8409	130.9693	129.5330
Trenton	DR-2	130.9693	131.8202	131.5340
Trenton	DR-3	131.8202	132.3842	132.0960
Trenton	DR-4	132.3842	133.2854	132.6830
Trenton	DR-5	133.2854	134.1139	133.5220
Trenton	DR-6	134.1139	135.2281	134.9435
Trenton	DR-7	135.2281	136.6580	135.7960
Ewing	DR-8	136.6580	137.0195	136.7990
Ewing	DR-9	137.0195	138.8104	138.0660
Ewing	DR-10	138.8104	140.1799	140.0530
Hopewell	DR-11	140.1799	141.5323	140.3440
Hopewell	DR-12	141.5323	143.1879	142.3360
Hopewell	DR-13	143.1879	144.0322	143.7590
Hopewell	DR-14	144.0322	145.1685	144.6020
Hopewell	DR-15	145.1685	146.2979	145.7390
Hopewell	DR-16	146.2979	146.7380	146.6030
	DR-17	146.7378	147.7548	147.1620
Lambertville	DR-18	147.7550	148.3899	148.1890
Lambertville	DR-19	148.3899	149.2920	148.8670
Lambertville	*DR-19A**	*149.0200*	*149.2920*	*149.1960*
	DR-20	149.2922	150.9624	149.9960
Stockton	DR-21	150.9620	151.6406	151.4630
Stockton	DR-22	151.6406	152.2657	151.8250
	DR-23	152.2657	155.6038	153.9720
Kingwood	DR-24	155.6038	156.2490	155.9740
Kingwood	DR-25	156.2490	156.8275	156.5430
Kingwood	DR-26	156.8275	163.0646	159.0970
Kingwood	DR-27	163.0646	163.4700	163.3580
Frenchtown	DR-28	163.4700	164.0665	164.0660
Frenchtown	DR-29	164.0665	164.8270	164.4010
Holland	DR-30	164.8265	169.6087	167.6730
Holland	DR-31	169.6087	171.3069	170.4520
Holland	DR-32	171.3069	172.7305	172.1610
Holland	DR-33	172.7305	173.8514	173.0100
Holland	DR-34	173.8514	174.4429	174.1430
Pohatcong	DR-35	174.4429	174.6093	174.5910

*Reach DR-19A: sub-reach of DR-19 created to cover area of Lambertville affected by the focused array of plans and analyzed separately.

Table 5-1: Reach Delineation - Upper Basin Study Area (continued)

Municipality	Reach Name	Station (mi)		
		Downstream	Upstream	Index
Pohatcong	DR-36	174.6093	175.5646	175.2870
Pohatcong	DR-37	175.5646	177.2842	176.4210
Pohatcong	DR-38	177.2842	178.4216	178.1240
Pohatcong	DR-39	178.4216	179.5509	178.9790
Pohatcong	DR-40	179.5509	181.4570	180.4010
Phillipsburg	DR-41	181.4570	182.0940	181.8070
Phillipsburg	DR-42	182.0940	183.1928	182.6720
Phillipsburg	DR-43	183.1928	183.5281	183.4240
Phillipsburg	DR-44	183.5281	183.7820	183.7080
	DR-45	183.7820	186.3621	184.9580
Harmony	DR-46	186.3621	187.2147	186.9310
Harmony	DR-47	187.2147	187.8118	187.5070
Harmony	DR-48	187.8118	188.9203	188.3530
Harmony	DR-49	188.9203	190.4513	189.7760
Harmony	DR-50	190.4513	190.9228	190.5960
Harmony	DR-51	190.9228	192.0188	191.4760
Harmony	DR-52	192.0188	194.1531	193.4700
White	DR-53	194.1531	196.0232	195.1620
	DR-54	196.0232	196.5926	196.2950
	DR-55	196.5926	197.3141	196.8760
Belvidere	DR-56	197.3141	197.6495	197.4910
	DR-57	197.6495	197.8931	197.7880
White	DR-58	197.8931	201.1289	199.7160
	DR-59	201.1289	202.0052	201.7040
Knowlton	DR-60	202.0052	202.8400	202.5610
Knowlton	DR-61	202.8400	203.9889	203.6890
Knowlton	DR-62	203.9889	204.8267	204.5460
Knowlton	DR-63	204.8267	205.3479	205.1750
Knowlton	DR-64	205.3479	205.9652	205.6770
Knowlton	DR-65	205.9652	206.9918	206.5330
Knowlton	DR-66	206.9918	208.4054	207.4730
	DR-67	208.4054	215.9147	213.0680
	DR-68	215.9147	253.6720	245.7290

Table 5-2: Reach Delineation - Lower Basin (Repaupo) Study Area

Municipality	Reach Name	Station (mi)		
		Downstream	Upstream	Index
Logan	RL-1	82.00	83.50	82.50
Logan/Greenwich	RL-2	83.50	86.00	85.00
Greenwich	RL-3	86.00	88.50	87.50

C5.2. **Structure Inventory**

Structure data was obtained from a field inventory. Structures were assigned a unique structure identification number. The following information was obtained during the field inventory:

Structure ID #	Property Type	Condition	First Floor Elevation
Street	Style (Stories)	Exterior Walls	Zero Damage Elevation
City	Footprint	Roof	Benchmark Used
Zip Code	Square Footage	Garage	Tax Parcel Number
Photo ID	Quality	Basement	Map Sheet
Owner	Year Built	Structure Maps	Photos

For the majority of the structure elevations in the Delaware River Basin the methodology used to derive the values was as follows:

- For communities where LiDAR was available (the majority), the structure was visited and information was collected relating the 1st floor and 0 damage from the ground. These were hand measurements and were recorded as deltas, rather than elevations.
- Hand measurements were used to calculate the elevations by adding or subtracting the deltas from a point elevation derived from the LiDAR.
- For example, if a structure's first floor was measured to be 5 feet above grade by the field crew, and the ground elevation from the LiDAR was found to be 125ft NAVD, the 1st floor elevation was entered as 130ft NAVD.
- While the LiDAR methodology was preferred because of the reduced cost, in some cases throughout the basin it was not possible. In those situations, direct survey was used to "shoot" the elevations for each structure.

C5.3. **Depreciated Replacement Value**

Data for each structure was entered into the Marshall and Swift (M&S) Residential or Commercial Software Programs to obtain the depreciated replacement cost. Depreciated replacement cost, as opposed to market value, is applied in the damage estimation process, since it measures directly damageable assets from flooding events and the cost to replace these assets. Market value includes additional factors such as the value of land, which are not included in the assessment of damageable structure and content assets from flooding. Depreciated replacement cost was estimated by the Marshall and Swift Software using the Life Cycle method. This method was used to assign a representative effective age, based on the M&S typical life cycle chart for a property and assumes that a structure can have a lower effective age regardless of an increasing chronological age if improvements typically made through the life cycle of a structure are completed. By consolidating the effective age, the Life-Cycle Method normalizes extremes and appropriately accounts for the effects condition has on effective age.

C5.4. **Content – to – Structure Value**

Residential structures utilized a content to structure ratio. The residential ratio was selected to best represent the wide range of incomes in the basin as well as external costs such as landscaping and automobile damage. This ratio was applied for initial formulation screening purposes to try to reflect the cumulative damage potential for both internal and external factors for the properties. Fine-tuned content percentage(s) will be applied in the next phase of the formulation effort. A standard deviation of 0.25 was used based on the documented studies showing this level of relationship. The relationship is assumed to be normally distributed and the uncertainty parameter for this ratio was set at 25%.

Commercial structures used a content-to-structure ratio. This ratio is the average documented ratio in the Corps' Institute of Water Resources (IWR) Analysis of Nonresidential Content Value and Depth-Damage Data for Flood Damage Reduction Studies. This average has a standard deviation of 18.09. Due to lack of data, the relationship is assumed to be normally distributed. This ratio was chosen because of the discrepancies in commercial structures that exist in the basin. Convenience stores and restaurants may have slightly lower ratios, while manufacturing or warehouse facilities may have higher ratios. A large ratio may be due to a situation where a warehouse is constructed with inexpensive materials, but may contain an expensive inventory of products comparatively. The uncertainty parameter for this ratio was set.

C5.5. **Stage-Damage Functions**

Structure and content stage damage curves were assigned to each residential structure using the Corps Institute of Water Resources Economic Guidance Memorandum 04-01 Generic Depth-Damage Relationships for Residential Structures. Structure and Content Stage- Damage Curves were assigned to each commercial structure using the Corps Institute of Water Resources Analysis of Nonresidential Content Value and Depth (Stage)-Damage Data for Flood Damage Reduction Studies as a guide. The residential structure curves used a supplied standard deviation and the commercial curves had no supplied standard deviation. Structure curves were assigned based on the total number of stories and whether or not the structure has a basement. Content of the structures was assumed to be a proportion of the replacement cost of the structure.

C5.6. **Flood Damage Modeling**

Upon completion of damage reach assignment, hydrologic and hydraulic modeling data was entered into HEC-FCA models. Water surface profile elevations were exported from HEC-RAS and imported to HEC-FDA as a discharge-probability table for the upper portion of the study area. This table contained all eight water surface profiles provided within the model. These profiles were the 0.50, 0.20, 0.10, 0.04, 0.02, 0.01, 0.004, and 0.002 exceedence probability flood events. For the southern portion of the study area tidal elevations for the 0.50, 0.20, 0.10, 0.04, 0.02, 0.01, 0.004, and 0.002 exceedence probability events were imported into HEC-FDA from a stage frequency analysis done at nearby NOAA tidal stations.

From this data, discharge-probability functions with uncertainty were determined for each reach using HEC-FDA for the upper portion of the study area. HEC-FDA was utilized to perform an analytical process by which Log Pearson III statistics were used along with the length of record for the data to compute the uncertainty associated with the gages. Length of record was based on the stream flow data collected from United States Geological Survey's (USGS) National Weather Information System (NWIS) website from five USGS stream gages. For the upstream area of the study, the stream gages were the following: Gage 01463500 at Trenton, NJ, Gage 01457500 at Riegelsville, NJ, Gage 01446500 at Belvidere, NJ, Gage 0140200 at Delaware Water Gap, NJ, and Gage 01438500 at Montague, NJ. For the lower portion of the study area at Greenwich and Logan Townships, HEC-FDA was used to perform an analytical analysis to compute synthetic statistics from the given stage frequencies at 0.5 mile increments along the Gibbstown Levee alignment.

Stage-discharge functions with uncertainty were then determined for each reach for the upper portion of the study area. Stage-discharge functions were not needed for the tidally-influenced lower portion of the study area since stage frequency curves were directly entered into the HEC-FDA model from nearby tidal stations. Derivation of the stage uncertainty for the upper portion of the study area was computed from several factors. They included: natural variability of the Delaware River, hydraulic model calibration against surveyed high-water-marks (HWMs), and hydraulic model inaccuracies. Guidance from EM 1110-2-1619 was used to quantify stage-discharge uncertainty. Refer to section 4.4.6 for further explanation of the derivation of the functions. The stage-discharge functions were determined at the index location for each reach. The index location is defined between the beginning and ending station values and where data is normally deemed most reliable. Using these functions, along with the structure information, HEC-FDA was used to compute reach stage-damage functions.

Lastly, reach stage-damage functions were used to run an evaluation of the plan by analysis years and an equivalent annual damage (EAD) assessment was completed. The EAD is the predicted average aggregate dollar amount per year for fifty years of flood damage. This dollar value was divided by the number of surveyed structures in each damage reach to estimate the predicted damage value per surveyed structure per damage reach segment.

The EAD results quantify the damage that can be expected on an annual basis for the studied areas along the Delaware River under existing conditions for the without project scenario. These numbers were calculated through a Monte Carlo statistical simulation. With high probability storms, damages will be relatively low due to lower flood elevations and limited structure and content damage. When the storm flood levels rise, structures are further inundated and higher levels of damage will occur, but at a lower probability in the EAD model calculation. This is evident in damage per surveyed structure being relatively high for communities susceptible to higher frequency storms and higher depreciated replacement costs.

The economic model for the upper portion of the study area from Trenton northward predicted the highest annual damage at the City of Lambertville. It also predicted some of the higher values for damage per structure in Lambertville. Lambertville's EAD is higher than most communities since high probability events cause relatively large amounts of damage.

An examination of a sample area in the Lambertville municipality for damage reach 18 determined an estimated damage for high frequency storms [less than 10% ACE (10-year)] ranging from $400,000 to $800,000. When the events become less frequent than a 10% ACE (10-year) event, damages begin to build at much higher rates in Lambertville (for example, a 2.5% ACE (40-year) event produces more than $2.5 million of damage). This trend is similar in other communities, but Lambertville's high initial damage estimates lead to a higher relative EAD for the community. Higher relative depreciated replacement cost and vulnerability to flooding are two of the numerous reasons that can contribute to the higher initial damage modeled for Lambertville versus other municipalities.

The Gibbstown section of the study area is located in the tidally influenced portion of the Delaware. This part of the study area was modeled without consideration of any flood risk management by the levee, defined as a federally uncertified landform (hereafter referred to as FUL). Since the landform does not satisfy Federal certification standards it is assumed for a Corps planning analysis to provide no certifiable risk management and is not included in the modeling process as providing protective capability (see report Section C9 for more detail). The residential and commercial structures in this area have initial damage elevations close to or below base flow conditions of the Delaware River.

Once all models were finalized, the study team tried to compare the HEC-FDA model results to National Flood Insurance Program (NFIP) claims data for a sample area (the City of Trenton). Based on the USGS gage data for a sample, Gage 01463500, at Trenton, NJ, the storm recurrence intervals were determined for the April 2005 and June 2006 events. The NFIP documented $2,343,000 of closed claims for the April 2005 event, and $2,322,000 of NFIP closed claims for the June 2006 event. The existing without project condition model results show total damages more than reported by the NFIP claims. This is an expected result for two reasons. The model does not take into account any local high grounds or flood risk management that may be in place that structures may have utilized. Also, NFIP claims data may contain errors, and the data may be unreliable with regard to locations of claims. The data used is also only the closed data, or only the claims that have been paid by the insurance companies, and do not represent total damages incurred. Knowing the limitations of the data and of the model, the modeled results could reflect a conservative assessment. In total, with consideration of the NFIP claims, the model results appear reasonable for the municipalities.

C6. EXISTING WITHOUT PROJECT CONDITIONS

C6.1. Upper Basin Study Area – Trenton to Knowlton

Depending on magnitude or severity, flood events will cause a different amount of flood damage. HEC-FDA models, incorporating structure inventory database information, were modified to include future projections for the hydrologic and hydraulic conditions of the Delaware River. An Expected Annual Damage for each damage reach was calculated. Expected Annual Damage is the amount of damage that is predicted during a specific year. The expected annual damage dollar value was divided by the number of surveyed structures in each damage reach to estimate the predicted damage value per surveyed structure per damage reach segment. The results of the calculation may be used to quantify the damage that can be expected within that analysis year for the studied areas along the Delaware River assuming no current flood protection. The Upper Basin portion of the study (Mercer, Hunterdon, and Warren Counties) results in an expected annual damage of $7.5 million for the 2015 base year.

The existing without project condition economic analysis has delineated structures by reaches and municipalities For each reach, tabular information was developed that presents expected damages for a range of storm events. An exceedance probability-damage function curve was also developed for each damage reach.

Table 6-1 displays a summary of the number of structures by municipality impacted by different probabilities of exceedance, and Table 6-2 displays a breakdown of expected average annual damages by damage reach for analysis year 2015 (the estimated base year for any constructed plans of improvement to be operable). Likewise, Table 6-3 displays a breakdown of expected average annual damages by damage reach for analysis year 2065 (the final year of the standard 50-year planning horizon). N/A in the tables denotes Not Applicable.

Table 6-1: Total Number of Structures by Municipality and Exceedance Probability for the Without Project Condition (Base Year)

Location	50% ACE (2-year)	20% ACE (5-year)	10% ACE (10-year)	4% ACE (25-year)	2% ACE (50-year)	1% ACE (100-year)	0.4% ACE (250-year)	0.2% ACE (500-year)
Trenton	0	20	100	153	195	255	313	344
Ewing	0	0	9	66	98	127	153	164
Hopewell	0	1	6	12	20	25	27	28
Lambertville	3	8	18	50	83	100	130	154
Stockton	0	1	2	51	71	98	115	121
Kingwood	1	8	15	30	33	36	40	41
Frenchtown	0	1	7	20	32	45	72	100
Holland	0	1	2	7	13	17	23	28
Pohatcong	1	9	20	32	48	65	74	76
Phillipsburg	0	0	2	2	11	14	17	19
Harmony	2	10	33	62	105	133	144	144
Belvidere	0	1	4	18	50	74	89	93
White	0	0	4	4	7	7	8	8
Knowlton	0	2	8	34	47	69	92	106
Greenwich	207	250	274	331	351	385	427	460
Logan	10	10	11	11	11	11	12	12
TOTAL	**224**	**322**	**515**	**883**	**1175**	**1461**	**1736**	**1898**

Table 6-2: Expected Annual Damage by Damage Categories and Damage Reaches for the Existing Without Project Condition in the Upper Basin, Year 2015

Rounded to the Nearest Thousand (December 2010 Price Level)

Municipality	Damage Reach	No. of Structures	Commercial (USD)	Residential (USD)	Total (USD)	Total/Structure (USD)
	DR-1	0	$0	$0	$0	$0
Trenton	DR-2	17	$266,000	$0	$266,000	$15,647
Trenton	DR-3	0	$0	$0	$0	$0
Trenton	DR-4	164	$341,000	$1,000	$342,000	$2,085
Trenton	DR-5	12	$388,000	$2,000	$390,000	$32,500
Trenton	DR-6	23	$43,000	$9,000	$52,000	$2,261
Trenton	DR-7	287	$477,000	$979,000	$1,456,000	$5,073
Ewing	DR-8	12	$2,000	$11,000	$13,000	$1,083
Ewing	DR-9	154	$162,000	$579,000	$741,000	$4,812
Ewing	DR-10	8	$0	$1,000	$1,000	$125
Hopewell	DR-11	3	$0	$2,000	$2,000	$667
Hopewell	DR-12	19	$0	$18,000	$18,000	$947
Hopewell	DR-13	0	$0	$0	$0	$0
Hopewell	DR-14	8	$34,000	$13,000	$47,000	$5,875
Hopewell	DR-15	0	$0	$0	$0	$0
Hopewell	DR-16	2	$6,000	$0	$6,000	$3,000
	DR-17	0	$0	$0	$0	$0
Lambertville	DR-18	78	$318,000	$138,000	$456,000	$5,846
Lambertville	DR-19	94	$787,000	$495,000	$1,282,000	$13,638
Lambertville	*DR-19A**	*60*	*$819,000*	*$135,000*	*$953,000*	*$15,885*
	DR-20	0	$0	$0	$0	$0
Stockton	DR-21	63	$71,000	$95,000	$166,000	$2,635
Stockton	DR-22	65	$173,000	$102,000	$275,000	$4,231
	DR-23	0	$0	$0	$0	$0
Kingwood	DR-24	25	$0	$126,000	$126,000	$5,040
Kingwood	DR-25	14	$0	$58,000	$58,000	$4,143
Kingwood	DR-26	0	$0	$0	$0	$0
Kingwood	DR-27	4	$3,000	$2,000	$5,000	$1,250
Frenchtown	DR-28	60	$101,000	$57,000	$158,000	$2,633
Frenchtown	DR-29	71	$84,000	$14,000	$98,000	$1,380
Holland	DR-30	0	$0	$0	$0	$0
Holland	DR-31	5	$225,000	$1,000	$226,000	$45,200
Holland	DR-32	0	$0	$0	$0	$0
Holland	DR-33	12	$27,000	$19,000	$46,000	$3,833
Holland	DR-34	31	$0	$25,000	$25,000	$806
Pohatcong	DR-35	15	$0	$13,000	$13,000	$867
Pohatcong	DR-36	4	$0	$2,000	$2,000	$500
Pohatcong	DR-37	0	$0	$0	$0	$0
Pohatcong	DR-38	17	$0	$17,000	$17,000	$1,000
Pohatcong	DR-39	47	$0	$76,000	$76,000	$1,617
Pohatcong	DR-40	0	$0	$0	$0	$0
Phillipsburg	DR-41	16	$13,000	$5,000	$18,000	$1,125
Phillipsburg	DR-42	0	$0	$0	$0	$0
Phillipsburg	DR-43	9	$2,000	$0	$2,000	$222
Phillipsburg	DR-44	8	$35,000	$7,000	$42,000	$5,250
	DR-45	0	$0	$0	$0	$0
Harmony	DR-46	22	$0	$101,000	$101,000	$4,591
Harmony	DR-47	0	$0	$0	$0	$0
Harmony	DR-48	51	$0	$161,000	$161,000	$3,157

Table 6-2 con't: Expected Annual Damage by Damage Categories and Damage Reaches for the Existing Without Project Condition in the Upper Basin

Rounded to Nearest Thousand (December 2010 Price Level) Year: 2015

Municipality	Damage Reach	No. of Structures	Commercial (USD)	Residential (USD)	Total (USD)	Total/Structure (USD)
Harmony	DR-49	0	$0	$0	$0	$0
Harmony	DR-50	2	$0	$4,000	$4,000	$2,000
Harmony	DR-51	0	$0	$0	$0	$0
Harmony	DR-52	71	$50,000	$295,000	$345,000	$4,859
White	DR-53	0	$0	$0	$0	$0
White	DR-54	3	$0	$8,000	$8,000	$2,667
White	DR-55	0	$0	$0	$0	$0
Belvidere	DR-56	86	$143,000	$108,000	$251,000	$2,919
Belvidere	DR-57	7	$3,000	$7,000	$10,000	$1,429
White	DR-58	0	$0	$0	$0	$0
White	DR-59	5	$103,000	$5,000	$108,000	$21,600
Knowlton	DR-60	58	$0	$41,000	$41,000	$707
Knowlton	DR-61	14	$0	$8,000	$8,000	$571
Knowlton	DR-62	0	$0	$0	$0	$0
Knowlton	DR-63	4	$2,000	$7,000	$9,000	$2,250
Knowlton	DR-64	0	$0	$0	$0	$0
Knowlton	DR-65	31	$19,000	$38,000	$57,000	$1,839
Knowlton	DR-66	10	$0	$0	$0	$0
	DR-67	0	$0	$0	$0	$0
	DR-68	0	$0	$0	$0	$0
TOTAL		**1,711**	**$3,878,000**	**$3,650,000**	**$7,528,000**	**N/A**

**Reach DR-19A is a separately updated and analyzed subset of Reach DR-19 and has been excluded from the totals above.*

Table 6-3: Expected Annual Damage by Damage Categories and Damage Reaches for the Existing Without Project Condition in the Upper Basin, Year 2065

Rounded to Nearest Thousand (December 2010 Price Level)

Municipality	Damage Reach	No. of Structures	Commercial (USD)	Residential (USD)	Total (USD)	Total/Structure (USD)
	DR-1	0	$0	$0	$0	$0
Trenton	DR-2	17	$573,000	$0	$573,000	$33,706
Trenton	DR-3	0	$0	$0	$0	$0
Trenton	DR-4	164	$626,000	$4,000	$630,000	$3,841
Trenton	DR-5	12	$694,000	$3,000	$697,000	$58,083
Trenton	DR-6	23	$91,000	$17,000	$108,000	$4,696
Trenton	DR-7	287	$747,000	$1,416,000	$2,163,000	$7,537
Ewing	DR-8	12	$5,000	$18,000	$23,000	$1,917
Ewing	DR-9	154	$280,000	$892,000	$1,172,000	$7,610
Ewing	DR-10	8	$0	$1,000	$1,000	$125
Hopewell	DR-11	3	$0	$3,000	$3,000	$1,000
Hopewell	DR-12	19	$0	$28,000	$28,000	$1,474
Hopewell	DR-13	0	$0	$0	$0	$0
Hopewell	DR-14	8	$48,000	$19,000	$67,000	$8,375
Hopewell	DR-15	0	$0	$0	$0	$0
Hopewell	DR-16	2	$13,000	$0	$13,000	$6,500
	DR-17	0	$0	$0	$0	$0
Lambertville	DR-18	78	$524,000	$208,000	$732,000	$9,385
Lambertville	DR-19	94	$1,263,000	$656,000	$1,919,000	$20,415
Lambertville	*DR-19A**	*60*	*$1,288,000*	*$215,000*	*$1,503,000*	*$25,045*
	DR-20	0	$0	$0	$0	$0
Stockton	DR-21	63	$117,000	$148,000	$265,000	$4,206
Stockton	DR-22	65	$278,000	$160,000	$438,000	$6,738
	DR-23	0	$0	$0	$0	$0
Kingwood	DR-24	25	$0	$176,000	$176,000	$7,040
Kingwood	DR-25	14	$0	$85,000	$85,000	$6,071
Kingwood	DR-26	0	$0	$0	$0	$0
Kingwood	DR-27	4	$5,000	$4,000	$9,000	$2,250
Frenchtown	DR-28	60	$164,000	$88,000	$252,000	$4,200
Frenchtown	DR-29	71	$168,000	$26,000	$194,000	$2,732
Holland	DR-30	0	$0	$0	$0	$0
Holland	DR-31	5	$361,000	$2,000	$363,000	$72,600
Holland	DR-32	0	$0	$0	$0	$0
Holland	DR-33	12	$57,000	$32,000	$89,000	$7,417
Holland	DR-34	31	$2,000	$39,000	$41,000	$1,323
Pohatcong	DR-35	15	$0	$20,000	$20,000	$1,333
Pohatcong	DR-36	4	$0	$5,000	$5,000	$1,250
Pohatcong	DR-37	0	$0	$0	$0	$0
Pohatcong	DR-38	17	$0	$30,000	$30,000	$1,765
Pohatcong	DR-39	47	$0	$124,000	$124,000	$2,638
Pohatcong	DR-40	0	$0	$0	$0	$0
Phillipsburg	DR-41	16	$24,000	$10,000	$34,000	$2,125
Phillipsburg	DR-42	0	$0	$0	$0	$0
Phillipsburg	DR-43	9	$6,000	$0	$6,000	$667
Phillipsburg	DR-44	8	$61,000	$13,000	$74,000	$9,250
	DR-45	0	$0	$0	$0	$0
Harmony	DR-46	22	$0	$155,000	$155,000	$7,045
Harmony	DR-47	0	$0	$0	$0	$0
Harmony	DR-48	51	$0	$260,000	$260,000	$5,098

Table 6-3 con't: Expected Annual Damage by Damage Categories and Damage Reaches for the Existing Without Project Condition in the Upper Basin

Rounded to Nearest Thousand (December 2010 Price Level) Year: 2065

Municipality	Damage Reach	No. of Structures	Commercial (USD)	Residential (USD)	Total (USD)	Total/Structure (USD)
Harmony	DR-49	0	$0	$0	$0	$0
Harmony	DR-50	2	$0	$8,000	$8,000	$4,000
Harmony	DR-51	0	$0	$0	$0	$0
Harmony	DR-52	71	$71,000	$437,000	$508,000	$7,155
White	DR-53	0	$0	$0	$0	$0
White	DR-54	3	$0	$14,000	$14,000	$4,667
White	DR-55	0	$0	$0	$0	$0
Belvidere	DR-56	86	$211,000	$160,000	$371,000	$4,314
Belvidere	DR-57	7	$4,000	$11,000	$15,000	$2,143
White	DR-58	0	$0	$0	$0	$0
White	DR-59	5	$136,000	$7,000	$143,000	$28,600
Knowlton	DR-60	58	$0	$61,000	$61,000	$1,052
Knowlton	DR-61	14	$1,000	$11,000	$12,000	$857
Knowlton	DR-62	0	$0	$0	$0	$0
Knowlton	DR-63	4	$3,000	$10,000	$13,000	$3,250
Knowlton	DR-64	0	$0	$0	$0	$0
Knowlton	DR-65	31	$30,000	$55,000	$85,000	$2,742
Knowlton	DR-66	10	$0	$1,000	$1,000	$100
	DR-67	0	$0	$0	$0	$0
	DR-68	0	$0	$0	$0	$0
TOTAL		**1,711**	**$6,563,000**	**$5,417,000**	**$11,980,000**	**N/A**

**Reach DR-19A is a separately updated and analyzed subset of Reach DR-19 and has been excluded from the totals above.*

C6.2. Lower Basin Study Area – Logan and Greenwich

Tables 6-4 and 6-5 display a breakdown of expected average annual damages by municipality and damage reach for analysis years 2015 and 2065, respectively, for the lower basin study area.

Table 6-4: Expected Annual Damage by Damage Categories and Damage Reaches for the Existing Without Project Condition in the Lower Basin, Year 2015

Rounded to Nearest Thousand (December 2010 Price Level)

Municipality	Damage Reach	No. of Structures	Commercial (USD)	Residential (USD)	Total (USD)	Total/Structure (USD)
Logan	RL-1	3	$0	$21,000	$21,000	$6,885
Logan/Greenwich	RL-2	30	$164,000	$629,000	$793,000	$26,417
Greenwich	RL-3	809	$4,330,000	$8,675,000	$13,005,000	$16,075
Total			**$4,493,000**	**$9,325,000**	**$13,818,000**	**$16,411**

Table 6-5: Expected Annual Damage by Damage Categories and Damage Reaches for the Existing Without Project Condition in the Lower Basin, Year 2065

Rounded to Nearest Thousand (December 2010 Price Level)

Municipality	Damage Reach	No. of Structures	Commercial (USD)	Residential (USD)	Total (USD)	Total/Structure (USD)
Logan	RL-1	3	$0	$23,000	$23,000	$7,761
Logan/Greenwich	RL-2	30	$322,000	$720,000	$1,042,000	$34,737
Greenwich	RL-3	809	$5,714,000	$11,055,000	$16,769,000	$20,728
Total			**$6,036,000**	**$11,798,000**	**$17,835,000**	**$21,181**

C7. FUTURE WITHOUT PROJECT CONDITIONS

The future conditions modeling effort utilized Hydrologic Engineering Center's Flood Damage Analysis (HEC-FDA) models. This previous effort developed the base year conditions and the structure inventory data that was used in conjunction with the future year condition. The future conditions assume that the structure inventory remains the same for the entire analysis period.

The model prepared for this study includes the full structure inventory, the base year hydrology and hydraulics for year 2015, and the future year hydrology and hydraulics for year 2065. The FDA program has been upgraded by HEC, from HEC-FDA 1.2.4 to HEC-FDA 1.2.5a. The newest model release incorporates two model changes that HEC has made, and this model has produced slightly lower damage estimates that align closer to real reported damages. These minor calculation differences guided the decision to use HEC-FDA 1.2.5a for this study.

The study covers the study area from Trenton, NJ through Knowlton Township, NJ in the upper basin and Greenwich and Logan Townships in the lower basin area. The HEC-FDA model utilized hydrologic data from five USGS gages along this corridor: Gage at Trenton, NJ, Gage at Riegelsville, NJ, Gage at Belvidere, NJ, Gage at Delaware Water Gap, NJ, and Gage at Montague, NJ. For the lower basin, gages at Lewes, De and Philadelphia were applied. Water surface profile elevations were provided from the HEC-RAS models for the upper portion of the study area of the Delaware River for base year and future conditions. Future conditions for year 2065 assumed a 10% increase in flows.

C7.1. **Upper Basin Study Area**

HEC-FDA models, previously developed, incorporating structure inventory database information, were modified to include future projections for the hydrologic and hydraulic conditions of the Delaware River. An Expected Annual Damage for each damage reach was calculated which is the amount of damage that is predicted during a specific year, in this case 2065. The results of the calculation may be used to quantify the damage that can be expected within future year 2065 for the study area assuming no implementation of risk management measures. The northern part of the study area (Trenton and North) result in an expected annual damage of $12 million for the future condition in 2065.

Equivalent annual damage is the predicted aggregate dollar amount per year over a 50-year period of analysis and discounted by the federal discount rate (FY14 = 3.5%). Equivalent Annual Damage for the without project condition is estimated to be above $9 million. Table 7-1 displays a summary of the number of structures by municipality impacted by different probabilities of exceedance for the future without project condition, Table 7-2 displays a breakdown of equivalent annual damages by damage reach, and Table 7-3 aggregates the equivalent annual damages by municipality.

Table 7-1: Total Number of Structures by Municipality and Exceedance Probability for the Without Project Condition (Future Year)

Location	50% ACE (2-year)	20% ACE (5-year)	10% ACE (10-year)	4% ACE (25-year)	2% ACE (50-year)	1% ACE (100-year)	0.4% ACE (250-year)	0.2% ACE (500-year)
Trenton	1	61	118	177	236	289	334	379
Ewing	0	1	32	88	118	144	164	166
Hopewell	0	3	7	18	23	26	27	30
Lambertville	4	11	27	70	95	114	149	161
Stockton	0	2	22	62	87	112	120	125
Kingwood	1	14	25	32	36	39	41	42
Frenchtown	0	2	13	26	43	60	93	115
Holland	0	2	6	12	17	19	28	32
Pohatcong	1	17	26	42	64	69	76	77
Phillipsburg	0	1	2	8	13	14	19	21
Harmony	2	15	41	96	127	142	144	144
Belvidere	0	1	5	33	64	84	93	93
White	0	2	4	5	7	7	8	8
Knowlton	0	4	15	40	60	82	102	114
Greenwich	236	287	331	369	392	457	589	700
Logan	10	11	11	11	11	12	19	21
TOTAL	**255**	**434**	**685**	**1089**	**1393**	**1670**	**2006**	**2228**

Table 7-2: Equivalent Annual Damage by Damage Categories and Damage Reaches for the Without Project Condition in the Upper Basin

Rounded to Nearest Thousand (December 2010 Price Level)

Municipality	Damage Reach	No. of Structures	Commercial (USD)	Residential (USD)	Total (USD)	Total/Structure (USD)
	DR-1	0	$0	$0	$0	$0
Trenton	DR-2	17	$372,000	$0	$372,000	$21,872
Trenton	DR-3	0	$0	$0	$0	$0
Trenton	DR-4	164	$439,000	$2,000	$441,000	$2,690
Trenton	DR-5	12	$493,000	$2,000	$495,000	$41,261
Trenton	DR-6	23	$60,000	$12,000	$72,000	$3,104
Trenton	DR-7	287	$569,000	$1,132,000	$1,701,000	$5,927
Ewing	DR-8	12	$3,000	$13,000	$16,000	$1,350
Ewing	DR-9	154	$203,000	$687,000	$890,000	$5,777
Ewing	DR-10	8	$0	$1,000	$1,000	$83
Hopewell	DR-11	3	$0	$2,000	$2,000	$825
Hopewell	DR-12	19	$0	$22,000	$22,000	$1,151
Hopewell	DR-13	0	$0	$0	$0	$0
Hopewell	DR-14	8	$38,000	$15,000	$53,000	$6,715
Hopewell	DR-15	0	$0	$0	$0	$0
Hopewell	DR-16	2	$8,000	$0	$8,000	$4,131
	DR-17	0	$0	$0	$0	$0
Lambertville	DR-18	78	$389,000	$162,000	$551,000	$7,075
Lambertville	DR-19	94	$954,000	$548,000	$1,502,000	$15,976
Lambertville	*DR-19A**	*60*	*$985,000*	*$163,000*	*$1,147,000*	*$19,117*
	DR-20	0	$0	$0	$0	$0
Stockton	DR-21	63	$87,000	$113,000	$200,000	$3,180
Stockton	DR-22	65	$209,000	$122,000	$331,000	$5,103
	DR-23	0	$0	$0	$0	$0
Kingwood	DR-24	25	$0	$143,000	$143,000	$5,725
Kingwood	DR-25	14	$0	$67,000	$67,000	$4,816
Kingwood	DR-26	0	$0	$0	$0	$0
Kingwood	DR-27	4	$4,000	$3,000	$7,000	$1,601
Frenchtown	DR-28	60	$122,000	$68,000	$190,000	$3,169
Frenchtown	DR-29	71	$113,000	$18,000	$131,000	$1,845
Holland	DR-30	0	$0	$0	$0	$0
Holland	DR-31	5	$272,000	$2,000	$274,000	$54,711
Holland	DR-32	0	$0	$0	$0	$0
Holland	DR-33	12	$37,000	$24,000	$61,000	$5,050
Holland	DR-34	31	$1,000	$30,000	$31,000	$996
Pohatcong	DR-35	15	$0	$16,000	$16,000	$1,039
Pohatcong	DR-36	4	$0	$3,000	$3,000	$783
Pohatcong	DR-37	0	$0	$0	$0	$0
Pohatcong	DR-38	17	$0	$22,000	$22,000	$1,280
Pohatcong	DR-39	47	$0	$92,000	$92,000	$1,967
Pohatcong	DR-40	0	$0	$0	$0	$0
Phillipsburg	DR-41	16	$16,000	$7,000	$23,000	$1,446
Phillipsburg	DR-42	0	$0	$0	$0	$0
Phillipsburg	DR-43	9	$3,000	$0	$3,000	$382
Phillipsburg	DR-44	8	$44,000	$9,000	$53,000	$6,585
	DR-45	0	$0	$0	$0	$0
Harmony	DR-46	22	$0	$119,000	$119,000	$5,430
Harmony	DR-47	0	$0	$0	$0	$0
Harmony	DR-48	51	$0	$195,000	$195,000	$3,825

Table 7-2 con't: Equivalent Annual Damage by Damage Categories and Damage Reaches for the Without Project Condition in the Upper Basin

Rounded to Nearest Thousand (December 2010 Price Level)

Municipality	Damage Reach	No. of Structures	Commercial (USD)	Residential (USD)	Total (USD)	Total/Structure (USD)
Harmony	DR-49	0	$0	$0	$0	$0
Harmony	DR-50	2	$0	$6,000	$6,000	$2,821
Harmony	DR-51	0	$0	$0	$0	$0
Harmony	DR-52	71	$57,000	$344,000	$401,000	$5,644
White	DR-53	0	$0	$0	$0	$0
White	DR-54	3	$0	$10,000	$10,000	$3,308
White	DR-55	0	$0	$0	$0	$0
Belvidere	DR-56	86	$166,000	$126,000	$292,000	$3,400
Belvidere	DR-57	7	$3,000	$9,000	$12,000	$1,726
White	DR-58	0	$0	$0	$0	$0
White	DR-59	5	$114,000	$6,000	$120,000	$23,997
Knowlton	DR-60	58	$0	$48,000	$48,000	$827
Knowlton	DR-61	14	$0	$9,000	$9,000	$646
Knowlton	DR-62	0	$0	$0	$0	$0
Knowlton	DR-63	4	$2,000	$8,000	$10,000	$2,500
Knowlton	DR-64	0	$0	$0	$0	$0
Knowlton	DR-65	31	$23,000	$44,000	$67,000	$2,145
Knowlton	DR-66	10	$0	$1,000	$1,000	$54
	DR-67	0	$0	$0	$0	$0
	DR-68	0	$0	$0	$0	$0
TOTAL		**1,711**	**$4,801,000**	**$4,262,000**	**$9,063,000**	**$5,297**

**Reach DR-19A is a separately updated and analyzed subset of Reach DR-19 and has been excluded from the totals above.*

Table 7-3: Equivalent Annual Damage by Damage Categories and Municipalities for the Without Project Condition in the Upper Basin

Rounded to Nearest Thousand (December 2010 Price Level)

Municipality (Total)	No. of Structures	Commercial (USD)	Residential (USD)	Total (USD)	Total/Structure (USD)
Trenton	503	$1,933,000	$1,148,000	$3,080,000	$6,123
Ewing	174	$206,000	$701,000	$907,000	$5,213
Hopewell	32	$47,000	$39,000	$86,000	$2,688
Lambertville*	172	$1,343,000	$711,000	$2,054,000	$11,942
Stockton	128	$296,000	$236,000	$532,000	$4,156
Kingwood	43	$4,000	$213,000	$217,000	$5,047
Frenchtown	131	$235,000	$86,000	$321,000	$2,450
Holland	48	$310,000	$55,000	$365,000	$7,604
Pohatcong	83	$0	$133,000	$133,000	$1,602
Phillipsburg	33	$64,000	$16,000	$79,000	$2,394
Harmony	146	$57,000	$664,000	$721,000	$4,938
White	8	$170,000	$135,000	$305,000	$38,125
Belvidere	93	$114,000	$16,000	$130,000	$1,398
Knowlton	117	$25,000	$109,000	$134,000	$1,145
TOTAL	**1,711**	**$4,801,000**	**$4,262,000**	**$9,063,000**	**$5,297**

C7.2. **Lower Basin Study Area**

The Lower Basin (Gibbstown) portion of the study area (in Gloucester County) was modified with three different projections for the future condition. The three projections included a Low trend, an Intermediate trend, and a High trend. The Lower Basin model results in an EAD of $13.8 million for the base year (2015), $17.8 million under Low trends, $21.7 million under Intermediate trends, and $35.7 million under High trends. Equivalent annual damage is estimated to equal $15.2 million assuming the Low, $16.6 million assuming Intermediate, and $21.5 million assuming High.

Expected annual damages for the Lower Basin study area are tabulated below for the base year and the three future year scenarios:

Table 7-4: Expected Annual Damages for the Base Year and Future Year Scenarios for Lower Basin Study Area

Damage Category	Dollars ($1,000's)			
	Base Year	Low	Intermediate	High
Commercial	$4,493	$6,036	$7,504	$12,412
Residential	$9,325	$11,798	$14,158	$23,246
TOTAL	$13,818	$17,835	$21,662	$35,657

The EAD shows an increase of 29% between the base year and the historically trended future conditions. Assuming Intermediate, the increase over the base year is 57%, and the increase assuming High is 158%.

The equivalent annual damage is computed by discounting future expected annual damage values given the discount rate of 3.50% and the analysis period of 50 years. The equivalent annual damage for the three scenarios is listed below:

Table 7-5: Equivalent Annual Damages for the Future Year Scenarios for Lower Basin Study Area

Damage Category	Dollars ($1,000's)		
	Future – Low	Future – Intermediate	Future – High
Commercial	$5,038	$5,557	$7,291
Residential	$10,199	$11,033	$14,244
TOTAL	$15,237	$16,589	$21,535

C8. ALTERNATIVE SCREENING

C8.1. **Structural Measures**

During Phase 1 of the alternative screening process, structural alternatives including levees and floodwalls, backflow prevention structures, channel modifications, dams or flow detention, and dam removal were considered. For potential implementation by a Corps improvement plan, levees and floodwalls (with associated interior drainage features) were carried forward from the Phase 1 through Phase 2 screening. The screening for the set of Concept-Level Alternatives is displayed in Table 8-1, below.

In Phase 3, the general plan identified for the communities of Logan and Greenwich was a line of protection including 13,788 LF of floodwall and 7,386 LF of levee, extending northward from high ground near Floodgate Road, along the west side of Gibbstown, until reaching high ground in Paulsboro. Alternative combinations of levees and floodwalls were evaluated as part of the final array. The plan included acquisition of 17 structures and nonstructural treatment (ringwall) of 3 properties outside the alignment. Alternative features to address interior drainage behind the levees and floodwalls were evaluated to develop a comprehensive plan. For Lambertville, the end plan from the Phase 3 process was to construct 516 LF levee with a maximum height of 12 feet high to protect against backwater at Alexauken Creek, in combination with a 1,409 LF floodwall segment along the Delaware & Raritan Canal with a maximum height of 7 feet, one property buy-out, and the construction of a 54 inch diameter gravity outlet in the area of Ely Creek

The Tentatively Selected Plan TSP includes the above two hydrologically separate areas. The northern area is located in Lambertville while the southern area is located in Greenwich and Logan Townships (Gibbstown area). Details for the above process and ultimate plan recommendations are provided in Section 5 (Plan Selection Process) and Section 6 (The Selected Plan) of the Main Report.

Table 8-1: Concept Level Alternatives - Initial Economic Evaluation for Lines of Protection

Town	Site#[1]	Structural Alternative	Height Above Grade [2]	Figure # in Community Evaluations	Estimated LOP Construction Cost (rounded)	Estimated Annual Cost of Lop (rounded)[4]	HEC-FDA Reach and (# of Bldgs.)	# of Buildings Behind LOP	Equivalent Annual Damage [5][6]	Initial Screening Benefit/Cost Ratio (BCR)	Notes/Assessment on Cost-Effectiveness
Knowlton	1	4,000 LF T-wall floodwall with levee tie-off	9 feet	Fig 3.4	$ 19,197,000	$910,000	DR-65 (31)	31	$57,000	<0.1	Unlikely to be cost-effective. No further evaluation recommended.
Phillipsburg	2a	700 LF T-wall floodwall at Lopatcong Creek	>15 feet	Fig. 3.15	$ 7,194,000	$340,000	DR-41 (16)	16	$18,000	<0.1	Unlikely to be cost-effective. No further evaluation recommended.
	2b	1,725 LF ringwall (T-wall floodwall) at Wastewater Treatment Plant (WWTP)	> 10 feet	Fig. 3.15	$ 13,234,000	$630,000	DR-41 (1)	1	--	--	A flood event at the plant would not affect water supply in the Delaware and Raritan Canal
Frenchtown (all reaches)	3	7,000 LF floodwall along bike path (sheetpile-supported I-wall)	6 feet	Fig. 3.22	$ 17,044,000	$810,000	131	117	$141,000	0.2	Unlikely to be cost-effective. No further evaluation recommended.
Reach DR-28		--	--	--	--	--	DR-28 (60)	47	$87,284		
Reach DR-29		--	--	--	--	--	DR-29 (71)	69	$53,252		
Stockton (all reaches)	4	Reinforce canal bank along 5,400 LF - Elevate bank height; assume 50% of a new levee	9 feet above existing	Fig. 3.27	$7,318,000	$350,000		115	$359,000	1.03	Potentially cost-effective. Refine damage/benefit assessment for concept-level Line of Protection (LOP) layout and costs. Refine damages to reflect impacts of D&R Canal embankment.
Reach DR-21		--	--	--	--	--	DR-21 (63)	63	$168,000		
Reach DR-22		--	--	--	--	--	DR-22 (65)	52	$191,000		
Lambertville	5	(a) 590 LF levee at Alexauken Creek (b) 810 LF floodwall along D&R Canal	(a) 12 feet (b) 5 feet	Fig. 3.30	$4,427,000	$210,000	DR-19 (94)	38	$610,000	2.9	Likely to be cost-effective. Refine damage/benefit assessment for LOP layout and costs.
		Floodgates and tie-back structure for floodgates at Swan Creek		--	--	$189,000	DR-18A	55	$283,000	0.81	Possibly cost effective, The addition of a tie-back structure for the floodgates may prevent the project from having a BCR above 1.
Ewing	6	7,700 LF T-wall floodwall with levee tie-off	9 feet	Fig. 3.35	$30,519,000	$1,450,000	DR-9 (154)	146	$640,000	0.4	Unlikely to be cost-effective. No further evaluation recommended.

Price Level: October 2009, Discount Rate (FY2011): 4.125%, Period of Analysis: 50 years

Table 8-1 (Continued): Concept-Level Alternatives—Initial Economic Evaluation for Lines of Protection

Town	Site#(1)	Structural Alternative	Height Above Grade (2)	Figure # in Community Evaluations	Estimated LOP Construction Cost (rounded)	Estimated Annual Cost of Lop (rounded)(4)	HEC-FDA Reach and (# of Bldgs.)	# of Buildings Behind LOP	Equivalent Annual Damage (5)(6)	Initial Screening Benefit/Cost Ratio (BCR)	Notes/Assessment on Cost-Effectiveness
Trenton (Glen Afton/The Island)	7a.1	7,280 LF T-wall floodwall	13 feet	Fig. 3.40	$59,233,000	$2,820,000	DR-7 (287)	287	$1,463,000	0.5	Summary: Refine damage/benefit assessment and concept layout/costs. LOP is assumed to be less for 5 foot barrier vs. 13 foot barrier. The 13-foot high barrier with vehicle-load coating option (7a.5) is not likely to be cost-effective.
	7a.2	7,280 LF T-wall floodwall (includes removable sections)	13 feet	Fig. 3.40	$88,788,000	$4,220,000	DR-7 (287)	287	$1,463,000	0.3	
	7a.3(3)	7,280 LF 5 ft. high deployable FloodBreak barrier; vehicle-load coating	5 feet	Fig. 3.40	$29,000,000	$1,380,000	DR-7 (287)	287	$1,463,000	1.06	These 5-ft high barriers would likely have high residual damages.
	7a.4(3)	7,280 LF 5 ft. high deployable FloodBreak barrier; pedestrian-load coating	5 feet	Fig. 3.40	$17,000,000	$810,000	DR-7 (287)	287	$1,463,000	1.8	These 5-ft high barriers would likely have high residual damages.
	7a.5(3)	7,280 LF 13 ft. high deployable FloodBreak barrier; vehicle-load coating	13 feet	Fig. 3.40	$75,000,000	$3,570,000	DR-7 (287)	287	$1,463,000	0.4	
Trenton, cont.(6)- Downtown: Bridge St. at US Route 1 and Rt. 29/South Warren St.	7b.1	150 LF portable flood barrier along Route 1 and 375 LF portable flood barrier along Rt. 29/South Warren St.	6 feet	Fig. 3.41	$2,451,000	$120,000	DR-4 (158)	158	$2,400	<0.1	Summary: Unlikely to be cost-effective. Few buildings in downtown Trenton are below 100-year floodplain elevation. LOP layout was based on Q3 mapping; the updated extent of flooding using the DFIRM model shows a smaller 1% ACE floodplain. Majority of damage in reach occurs to buildings immediately on riverfront.
Downtown: Bridge St. at US Route 1 only(3)	7b.2(3)	150 LF deployable FloodBreak barrier; vehicle-load coating	6 feet	Fig. 3.41	$1,000,000	$50,000	DR-4 (158)	158	$2,400	<0.1	
Downtown: Rt. 29/South Warren St.(3)	7c.1	400 LF single-section deployable FloodBreak barrier, vehicle-load coating	6 feet	Fig. 3.41	$2,300,000	$110,000	DR-4 (158)	158	$2,400	<0.1	

Price Level: October 2009, Discount Rate (FY2011): 4.125%, Period of Analysis: 50 years

Table 8-1 (Continued): Concept-Level Alternatives—Initial Economic Evaluation for Lines of Protection

Town	Site #[1]	Structural Alternative	Height Above Grade [2]	Figure # in Community Evaluations	Estimated LOP Construction Cost (rounded)	Estimated Annual Cost of LOP (rounded)	HEC-FDA Reach and (# of Bldgs.)	# of Buildings Behind LOP	Selected EAD Amount for Comparison [5]	Initial Screening Benefit/Cost Ratio (BCR)	Notes/Assessment on Cost-Effectiveness
Trenton, cont.[6]- Downtown: Rt. 29/South Warren St.[3]	7c.2	Two section (130 and 120 LF) deployable FloodBreak barrier, with berm in between; vehicle-load coating	6 feet	Fig. 3.41	$1,300,000	$60,000	DR-4 (158)	158	$2,400	<0.1	
Greenwich and Logan Townships (Gibbstown)	8	25,000 LF Levee/floodwall; 40% T-wall floodwall	9 feet	Fig. 3.46	$78,432,000	$3,730,000	RL-3 (809)	805	$12,582,000	3.4	Likely to be cost-effective. Refine damages to reflect protection from existing levee.

Price Level: October 2009, Discount Rate (FY2011): 4.125%, Period of Analysis: 50 years

(1) Different design options (materials, height above grade) are presented for sites 7a and 7c. A number is added to the site designation to indicate the design option.
(2) Includes 3 feet freeboard. A risk and uncertainty analysis for actual additional design allowances has not been conducted at this stage.
(3) Estimated costs provided by FloodBreak, Inc. (www.floodbreak.com) These estimates do not include costs for lands and easements.
(4) Both the Probability-Weighted (PW) and Risk and Uncertainty (R&U) EAD estimation do not consider **protection** from existing uncertified features such as embankments or levees.
(5) PW EAD is shown for specific protected buildings; however, if all buildings in a given reach would be protected by LOP, the EAD including R&U from HEC-FDA model is shown.
(6) In downtown Trenton, if alt. 7b.1 is not chosen, then 7b.2 and either 7c.1 or 7c.2 would be selected.

C8.2. **Nonstructural Measures**

Details for the Nonstructural measures screening process can be found in Section 5 of the main report and in Appendix H: Plan Formulation: Details of Phases 1&2. Nonstructural measures are those activities that can be undertaken to move what is being damaged out of harm's way, rather than attempting to alter the movement of water. Nonstructural measures include a variety of techniques, including land-use controls to limit future development in the flood hazard areas, acquisition or relocation of flood-prone development, and retrofit of existing structures. The following is a brief summary of the alternative screening process for nonstructural measures through each of the three Phases.

For Phase 1, the following measures were evaluated for consideration based on the criteria of completeness, effectiveness, efficiency, and acceptability: Land Use and Regulatory Measures, Building Retrofit Measures, and Land Acquisition Measures. A summary of the screening and results for each community is presented, in downstream order from Knowlton Township to Greenwich and Logan Townships, in Table 8-2. This provides a summary of potential Federal interest for additional investigation of nonstructural measures.

For Phase 2, viable measures were combined as a system to create location specific Alternatives. The subsections and tables in Section 5.8 of the Main Report present a quantitative and qualitative comparison of the Alternatives created by using the measures described in Phase 1. Potentially cost-effective treatments (equal to or greater than 0.7 BCR) for at least the 50% ACE (2-year) floodplain were identified in the following communities: White Township, Belvidere, Harmony Township, Phillipsburg, Pohatcong Township, Byram (in Kingwood Twp.), Stockton, Lambertville, Hopewell Township, and Trenton. However, the Corps cannot participate in the nonstructural retrofit of single private structures which was the case for Pohatcong Township and Stockton.

Phase 3 eliminated the viability of nonstructural measures (see Section 5.9.3 in the Main Feasibility Report), except as described below, and concluded with levee and floodwall systems remaining viable in the Alexauken Creek area of Lambertville and in the Gibbstown area of Greenwich and Logan Townships. Both areas also include nonstructural features and interior drainage measures. Together, these flood risk management measures constitute the Tentatively Selected Plan, which is described in more detail in Section 5.10 of the Main Report.

Table 8-2: Potential Federal Interest for Additional Investigation of Nonstructural Measures

Town	Suitable for Additional Corps Investigation	Initial Screening Benefit-Cost Ratio (BCR)	Notes/Assessment
Knowlton Township	No	0.3	Unlikely to be cost-effective. No further evaluation recommended.
White Township	Yes	1.2	7 structures in the 1% ACE (100-year) floodplain.
Town of Belvidere	Yes	0.8	9 structures in the 10% ACE (10-year) floodplain.
Harmony Township	Yes	0.8	32 structures in the 20% ACE (5-year) floodplain.
Town of Phillipsburg	Yes	0.9	3 structures in the 4% ACE (25-year) floodplain.
Pohatcong Township	No	0.9	Only 1 structure in the 50% ACE (2-year) floodplain meets the BCR threshold of 0.7. The Corps cannot modify single private structures.
Holland Township	No	0.6	Unlikely to be cost-effective. No further evaluation recommended.
Frenchtown Borough	No	0.4	Unlikely to be cost-effective. No further evaluation recommended.
Byram (in Kingwood Twp.)	Yes	0.8	12 structures in the 20% ACE (5-year) floodplain.
Stockton Borough	No	1.6	Only a single structure in the 50% ACE (2-year) floodplain has a positive BCR. Corps cannot modify single private structures.
City of Lambertville	Yes	0.8	25 structures in the 10% ACE (10-year) floodplain.
Hopewell Township	Yes	1.3	2 structures in the 20% ACE (5-year) floodplain.
Ewing Township	No	0.3	Unlikely to be cost-effective. No further evaluation recommended.
City of Trenton (Glen Afton/The Island)	Yes	0.8	46 structures in the 20% ACE (5-year) floodplain (in Glen Afton/The Island). Not recommended for further evaluation in downtown Trenton.
Greenwich and Logan Twps. (Gibbstown)	Yes	2.6	420 buildings in the 1% ACE (100-year) floodplain.

(*) Details shown for plan with greatest number of structures at or above 0.7 BCR threshold being applied in the screening process to determine if suitable for additional Corps investigation

C9. ECONOMIC ANALYSIS AUGMENTATION

C9.1. Economic/Flood Damage Analysis

An economic flood damage analysis model for the "existing without project" condition was developed for the 1% ACE (100-year) floodplain in the 14 communities in the upper project study area from Trenton northward, as well as the Gibbstown study area in Gloucester County. The damage analysis interfaced with the hydrologic modeling resulted in the estimation of average annual damages disaggregated by reach for the study area for the "existing without-project condition". Results of these analyses, together with the future without project conditions, serve as a baseline for determining estimated reductions in damages.

C9.1.1. *Structure Inventory*

Surveys were conducted to identify each residential and habitable commercial structure within the study area. Both the locations and elevations of structures and their entryways were identified to determine potential impact by flood waters. A field update of the inventory was conducted in 2014 to ensure that the data was current.

The inventory of structures contributing to storm damages in areas covered by the focused array of alternative plans was revised to reflect the current (Post-2012 Hurricane Sandy) conditions. The update was conducted via a review of publicly available aerial photographs and other pertinent information and via a field survey of a randomly selected sample of structures for the purposes of developing an overall value update factor to be applied to the full inventory.

The sample set of structures for the field survey in Gibbstown was developed by randomly selecting 21 seed structures from the full inventory and adding the next nine structures following each seed to give a sample set of 210 structures in 21 clusters of 10, representing 25% of the overall inventory. In Lambertville the inventory update included all 60 structures that could possibly benefit from a levee or floodwall at the northern section of the City

On completion of the field survey, depreciated structure replacement values at a July 2014 price level were calculated for all surveyed structures using RS Means Square Foot Costs 2014. Structure values from the prior inventory were compared to the values calculated at the 2014 price level to compute an overall value update factor of 1.45 for the Gibbstown inventory. This factor was then applied to all structures in the revised Gibbstown inventory which were not included in the field survey. An update factor was not developed for the applicable portion of the inventory in Lambertville (Reach DR-19A), which was revised using structure values calculated directly using RS Means for all 60 structures surveyed.

C9.1.2. *Benefit Determination Involving Existing Levees for Gibbstown Study Area*

The purpose of this section of the feasibility report Economic Appendix is to provide information as to the current status of the existing Gibbstown Levee/Federally Uncertified Landform and provide clarity as to what level of protection the existing structure provides, consistent with Policy Guidance Letter 26: Benefit Determination Involving Existing Levees (CECW-PR/CECW-E, 23 December 1991) .

The structure was constructed in the early 1800s by the Repaupo Meadow Company (RMC), a public corporation of landowners, and consisted of approximately five miles of earthen levees and floodgate structures. Its original purpose was to enhance agricultural resources; however, residential and industrial development in Greenwich and Logan Townships, Gloucester County, changed the focus of the project to flood damage reduction. Despite the RMC being a state-sanctioned entity, by the 1960s it was unable to maintain the structure on its own, and was eventually assisted by the local municipalities and the DuPont Company, which had operated a large industrial plant behind the landform. (DuPont no longer operates there, but leases the site as an industrial park and maintains caretaker status.)

In March 1962, a major storm event coupled with high tides severely damaged the structure, and dozens of residences behind the landform were inundated. The portion of the structure from Thompson Point to the downriver end of the structure was restored to pre-storm conditions later the same year by the U.S. Army Corps of Engineers (USACE) under Public Law 84-99 authority. The restoration authorization included wording to the effect that the local interests would operate and maintain the structure. Concurrently, the US Department of Agriculture Soil Conservation Service [now Natural Resources Conservation Service (NRCS)] constructed a floodgate at White Sluice Race under Public Law 83-566 authority. Since the 1960s, the levee has continued to suffer sporadic damage, and the floodgate at the confluence of Repaupo Creek with the Delaware River was determined to be structurally inadequate by USACE during inspections in 1997. The RMC became operationally defunct during the 1970s. The townships, DuPont, and Hercules have since performed levee repairs as necessary, and USACE performed a temporary rehabilitation of the Repaupo Creek Floodgate in 2000 under the Advance Measures authority of PL 84-99, Rehabilitation Inspection Program. USACE has studied the structure under the Continuing Authorities Program; however, no current study is ongoing due to lack of sponsor participation.

Further anecdotal evidence from conversations with local emergency management officials indicated that seepage has been observed periodically throughout the levee history during high water events.

In 2007, a Continuing Eligibility Inspection was performed on the site and it was determined to be Unacceptable for eligibility in the PL 84-99 Program primarily due to a lack of a public sponsor, but also due to other deferred maintenance issues. Since that time, the project has been inactive in PL 84-99. Using county and state funding, Gloucester County replaced the Repaupo Creek Floodgate in 2009, and made improvements to the adjacent portions of the levee. Gloucester County also performed repairs to levee damage due to Hurricane Sandy in 2012.

The project currently is depended on to protect the residential areas, industrial areas, railroad tracks, and roads upriver along Repaupo Creek, White Sluice Race, Sand Ditch, and Clonmell Creek from flooding due to high levels of the Delaware River.

The levee was last inspected by USACE personnel in 2012 while performing an Initial Eligibility Inspection for the PL 84-99 Rehabilitation and Inspection Program. The DuPont Levee Segment was not inspected, therefore no observations are listed.

In the Logan Township section, unwanted vegetation covered both the landside and riverside slopes of the levee near the downriver tieback. Before Hurricane Sandy, Gloucester County Officials removed excessive vegetation, added riprap and slushed concrete into the riprap on the riverside slope to armor it against wave erosion. Sod is missing on the levee and creating potential erosion pathways. There are also encroachments to the levee in this segment. Including debris, there is a house that has additions built up the landside slope of the levee to its crest. The 15 foot vegetation free zone on the landside of the levee also has small woody vegetation growing in it.

In the Greenwich Township section, unwanted vegetation and trees encroaching on the levee were observed throughout the section. Two locations were also noted to have sloughing occurring on the riverside. These areas are threatening the integrity of the levee. A few small ruts and depressions related to vehicular traffic were also observed. With the Repaupo Meadow Company no longer managing the levee system, the numerous entities involved degrade assurances that overall maintenance of the project is performed.

To better understand the nature of the levee embankment and foundation, USACE personnel obtained borings from a 2007 Melick-Tully Study on repairing the floodgates. The report provided several borings on and around the embankment. The borings indicated that the levee is composed of sands and gravel and the foundation has layers of organic clays, peats and silt. Both drilling areas, upstream and downstream of the Repaupo tide gate, had low blow counts in the borings, indicating that it is susceptible to uneven settlement, cracking, embankment through seepage and underseepage. The report only pertained to the southern end of the embankment on the Logan and Greenwich Township sections and no further information was available. Due to a high level of uncertainty and risk with the embankment and foundation, these ratings were found to be Unacceptable according to the PL 84-99 categorization of levees. There is no further boring data on the embankment, but the observations of sloughing, settlement, and sand boils would indicate that the remainder of the levee is composed of similar materials.

Given the levee's history, previous damages, and the current state of disrepair, it is believed that the levee offers little or no protection from storm events. The 2007 Melick Tully report detailing the poor composition of the embankment and the foundation should also be considered as further evidence that the competency of the levee should be questioned. Due to the great amount of uncertainty in the entire levee embankment and considering the visual evidence of settlement, bank caving, unwanted vegetation growing on the levee, and the previous failures throughout the history of the embankment, no Probable Failure or Non-Failure points were able to be determined.

To further address Policy Guidance Letter 26, sensitivity analysis of the H&H and economic modeling for the proposed levee and floodwall system was conducted assuming the unlikely reliability performance scenarios that two, five, or ten-year ACE protection could actually be provided by the exiting FUL. BCR's for the proposed levee and floodwall system ranged from 0.51-0.74 for the 2-year ACE to a BCR range of 0.05-0.08 for the 10 –year ACE assumed protection level. An extensive boring program and geotechnical analysis of the existing levee structure could be conducted and then a more refined determination of benefits could be defined; however, a study at this level could be cost prohibitive considering the levee's physical length and location on two hazardous waste sites.

Therefore, given the levee's history, previous damages and current state of disrepair, it was determined prudent to assume that the Gibbstown Levee System/Federally Uncertified Landform (FUL) is offering zero protection. As a result, the most likely without project condition scenario in the study has assessed no level of reasonable protection by the existing FUL.

C9.1.3. *Average Annual Damage Summary*

Depending on the magnitude (or severity), different flood events will cause different amounts of flood damage. The Equivalent Annual Damage (EAD), as previously mentioned, is the average flood damage in dollars per year (based on the depreciated replacement values established from the structure inventory) that would occur in a designated area from potential flooding over the 50 year planning horizon of this study, taking into account any changes in hydrologic conditions anticipated to occur during the 50-year period. Estimation of the EAD provides the basis for comparing the effectiveness of different flood risk management measures (i.e., the reduction in the EAD), to determine project benefits.

Table 9-1: Annual Damage: Without Project Condition

Municipality	Base Year Average Annual Damage	Future Year Average Annual Damage	Equivalent Annual Damage
Trenton and North			
Trenton	$2,506,725	$4,171,218	$3,080,453
Ewing	$754,374	$1,195,766	$906,516
Hopewell	$72,970	$111,710	$86,323
Lambertville	$1,738,000	$2,651,000	$2,053,659
Stockton	$442,269	$702,870	$532,094
Kingwood	$188,938	$270,226	$216,956
Frenchtown	$255,528	$445,925	$321,155
Holland	$297,883	$492,740	$365,047
Pohatcong	$108,512	$179,285	$132,906
Phillipsburg	$60,803	$114,338	$79,255
Harmony	$610,852	$930,138	$720,906
Belvidere	$261,462	$386,329	$304,501
White	$115,736	$156,855	$129,909
Knowlton	$114,337	$171,542	$134,054
Subtotal	**$7,528,389**	**$11,979,942**	**$9,063,734**
Tidal Area, Greenwich and Logan (Gibbstown)			
Greenwich/Logan (Gibbstown)	**$10,260,911**	**$13,328,752**	**$11,318,349**
Combined			
Total	**$17,789,300**	**$25,308,694**	**$20,382,083**

Table 9-1 represents the EAD for each municipality included in this study. The EAD figures in the table were generated using by HEC-FDA version 1.2.5a, a computer model developed by the Hydrologic Engineering Center of the US Army Corps of Engineers. The EAD values were updated to reflect newly released stage frequency data in the tidal areas (Gibbstown) and the structural inventory revised in 2014 for Gibbstown and Lambertville. Note that the EADs in Lambertville are significantly less than the initial EAD calculation because the inventory update only included the 60 structures that could possibly benefit from a levee or floodwall at the northern section of the City.

The EAD results quantify the damage that can be expected on an annual basis for the studied areas along the Delaware River under existing economic conditions for the without project scenario. The Lower Basin (Gibbstown Levee) portion of the study area (in Gloucester County) was analyzed with three different projections for future sea level change conditions. The three projections included the historic trend (low projection), a medium projection, and a high projection. The Lower Basin model results in an expected annual damage of $13.8 million for the base year (2015), $17.8 million under historic future trends, $21.7 million under the medium projection, and $35.7 million under the high projection. Equivalent annual damage is estimated to equal $15.2 million assuming the historic trend, $16.5 million assuming the medium projection, and $21.5 million assuming the high projection.

The expected annual damage shows an increase of almost 30% between the base year and the historically trended future conditions. Assuming the medium projection, the increase over the base year is over 50%, and the increase assuming the high projection, is about 160%. While the portion of the study area from Trenton northward has an EAD of about $9.0 million, it is far upstream of the tidal limit and therefore assumed not to be subject to the impact of future sea level change.

The economic model for the upper portion of the study area from Trenton northward predicted the highest annual damage per community at the City of Lambertville. It also predicted some of the higher values for damage per structure in Lambertville. Lambertville's EAD is higher than most communities since high probability events cause relatively large amounts of damage.

The Gibbstown Levee section of the lower study area is located in the tidally influenced portion of the Delaware. This part of the study area was modeled without consideration of any flood risk management by the Federally Uncertified Landform (FUL). As the landform does not satisfy Federal certification standards, this Corps planning analysis considers the landform to provide no certifiable risk and damage reduction and is not included in the modeling process. The residential and commercial structures in this area have initial damage elevations close to or below base flow conditions of the Delaware River, and without the uncertified risk management of the FUL, they would experience damage during high frequency events, and therefore be expected to be flooded on a relatively frequent basis under modeled conditions.

C9.1.4. *Summary of Evaluation Measures*

Potential solutions to frequent flooding problems were evaluated for selected New Jersey communities within the Delaware River Basin. An array of potential solutions is available for consideration to address flooding issues. Most of these options were addressed by the Corps in the August 1984 *Delaware River Basin Study Survey* Report. The current study revisits the previously identified options, using updated information, including surveys, mapping and modeling in the assessment, as well as considering new or modified alternatives.

For each community, the identified flood problems were described and compared to a series of evaluation criteria addressing the technical, economic, environmental, and social aspects of the problems and potential flood risk management and environmental restoration plans. Where possible, the estimated annual costs of concept-level structural measures were compared to AAD of protected development to help guide assessments of cost effectiveness and economic efficiency and determine initial screening BCRs. For nonstructural measures, a screening algorithm was applied to the building inventory of floodplain buildings for identification of suitability for nonstructural retrofit. The algorithm determined the most suitable, least-cost retrofit method for each building based on its structure type, method of construction, size, and elevation.

Structural Measures

In Stockton, the initial assessment indicated the proposed measure (enhancements to the existing embankment of the D&R Canal) was potentially cost-effective. Cost and benefit assessments when further refined determined the plan was not viable

In Lambertville, a levee along Alexauken Creek combined with a floodwall segment along the D&R Canal appeared to possibly be an effective solution to flooding in the northern section of the community and was continued for evaluation in the later study phase.

In the Glen Afton and The Island neighborhoods of Trenton, a range of structural alternatives were evaluated including floodwalls, floodwalls with removable sections, and deployable flood barriers. Further evaluation of the risk management these measures would provide and the level of residual damages was undertaken and found to not have a viable plan.

In Greenwich and Logan Townships, an extensive levee/floodwall line of protection was likely to provide cost-effective protection to structures in Gibbstown, plus unquantified benefits to the community of Paulsboro. Nonstructural protection would be included for a number of residences outside the LOP, as well as a ringwall for a light industrial manufacturing facility. This measure was further evaluated for Federal participation in the later study phase.

The structural measures evaluated for Knowlton Township, along the Lopatcong Creek in Phillipsburg, Frenchtown, Ewing Township, and downtown Trenton were not determined to be cost-effective, and no further evaluation for Corps participation was recommended.

Nonstructural Measures

The following nonstructural measures were evaluated and found to meet the evaluation criteria: elevation, wet floodproofing, dry floodproofing, ringwalls, rebuilding, and acquisition. A screening algorithm was used to evaluate each building in the 1% ACE (100-year) floodplain, to assign appropriate retrofit measures, and to calculate their likely costs.

As with the structural screening, the calculation of AAD assumed no protection from existing features such as levees, railroad beds, or canal embankments. The annual costs were compared to the AAD to determine the initial screening BCRs, assuming all flood risks are mitigated. From

Knowlton Township to Trenton, potentially cost-effective treatments (equal to or greater than 0.7 BCR) for at least the 50% ACE (2-year) floodplain were identified in the following upper basin communities: White Township, Belvidere, Harmony Township, Phillipsburg, Pohatcong Township, Byram (in Kingwood Twp.), Stockton, Lambertville, Hopewell Township, and Trenton. Further evaluation of Federal participation in nonstructural retrofit in these communities is warranted, with the exception of Pohatcong Township and Stockton, where only single private structures met the BCR threshold. The Corps cannot participate in the nonstructural retrofit of single private structures. Based on initial screening BCRs below the 0.7 threshold, further evaluation of nonstructural measures in Knowlton Township, Holland Township, Frenchtown, and Ewing Township was not recommended.

For the upper basin as a whole, the nonstructural treatment of 28 buildings in the 50% ACE (2-year) floodplain had an initial screening BCR of 1.3, while the treatment of 136 buildings in the 20% ACE (5-year) floodplain had an initial screening BCR of 0.8. Optimization of costs and benefits would be required to identify a recommended plan.

In Greenwich and Logan Townships, nonstructural treatments were also evaluated and assigned to buildings. The initial screening BCR of 3.9 was seen in the treatment of 254 buildings in the 50% ACE (2-year) floodplain. The treatment of the suitable buildings in the 1% ACE (100-year) floodplain would include 420 buildings with an initial screening BCR of 2.6.

C10. FOCUSED ARRAY OF ALTERNATIVE PLANS

After further analysis of the evaluation array of alternative plans it became apparent that cost effective options were not available in Stockton and Trenton and any nonstructural plans were not viable. Structural plans for Gibbstown and Lambertville remained feasible and more detailed alternatives for design and implementation were considered.

C10.1. **Gibbstown (Logan and Greenwich Townships)**

The general plan identified for the communities of Logan and Greenwich was identified as a 21,339 foot long line of protection including 7,386 LF of levee with a maximum height of 12 feet and 13,788 LF of floodwall with a maximum height of 10 feet-concrete (primarily T-wall with piles) and two swing closure gates. Alternative combinations of levees and floodwalls were evaluated as part of the final array. The TSP plan included acquisition of 17 structures and nonstructural protection of 3 properties outside the alignment, and interior drainage features.

In response to items identified in the project Risk Register, as well as to address the need to identify mitigation requirements, refinements were performed for the structural plan in the Gibbstown area. These updates included incorporating recently completed storm surge modeling results into the storm damage analysis and into the selection of a preliminary structure design elevation. The plan layouts were significantly revised using more detailed topographic mapping, detailed parcel mapping and current aerial photography. The new topo identified several locations where existing grade elevations are sufficient to meet the structure crests, providing an opportunity to reduce structure lengths. The alignments were also revised to avoid properties owned by DuPont and Hercules. Some properties owned by both companies have been identified as having significant HTRW concerns and are listed as RCRA or CERCLA sites. In addition, the alignment was revised to avoid piping systems at the Paulsboro Refinery.

One of the major technical concerns was the potential for poor soil conditions along the potential line of protection at Gibbstown. A limited geotechnical investigation was undertaken to identify the general nature of the soils and to develop more reliable design criteria. Based on this information the design sections and cost estimates have been updated to include additional excavation and disposal of poor quality material, geogrids, wick drains and surcharging to enhance levee stability, and additional pile length (50 ft) for stability of the flood wall sections.

The opportunities for alternative alignments or design features to provide enhanced risk management, to reduce impacts, or to reduce costs were also considered. The possibility of building a levee at the bank of the Delaware River was rejected due the presence of contamination at the DuPont and Hercules properties. An alternative to use a ring levee around Gibbstown to reduce wetland impacts was rejected due to concerns associated with the lack of safe evacuation routes during a storm. As seen in Table 10-1 screening, these options proved to be more costly even after incorporating the reduction in mitigation requirements.

Table 10-1: Economics - Gibbstown

Scenario	Alternative 1 Lowest Construction Cost Plan	Alternative 2 Maximum Wetland Avoidance Plan	Alternative 3 Intermediate Wetland Avoidance Plan
Annual Without Project Damage			
CSRM Damage	$15,237,000	$15,237,000	$15,237,000
Total Damage	$15,237,000	$15,237,000	$15,237,000
Annual With Project Damage			
CSRM Damage	$317,000	$317,000	$317,000
Total Damage	$317,000	$317,000	$317,000
Annual Benefits			
CSRM Damage	$14,920,000	$14,920,000	$14,920,000
Qualitative *	$0	$0	$0
Total Benefit	**$14,920,000**	**$14,920,000**	**$14,920,000**
First Costs			
Line of Protection	$177,173,000	$204,215,000	$186,859,000
Mitigation Costs	$4,753,000	$3,645,000	$4,011,000
Total	$181,926,000	$207,860,000	$190,870,000
Interest & Investment Cost			
Interest During Construction (IDC) **	$7,780,000	$8,889,000	$8,163,000
Total Investment	$189,706,000	$216,749,000	$199,033,000
Annual Costs			
Annualized Investment **	$8,088,000	$9,241,000	$8,486,000
O&M Cost	$198,000	$198,000	$198,000
Total Cost	**$8,286,000**	**$9,439,000**	**$8,684,000**

Benefit-to-Cost Comparison			
Net Benefits	**$6,634,000**	**$5,481,000**	**$6,236,000**
BCR	**1.8**	**1.6**	**1.7**

*Additional Qualitative Potential Benefits (Emergency/Miscellaneous Damages)

The flood damage potential for these categories of non-physical costs was considered. The emergency/miscellaneous damages for a significant flood event could result in damages for this category up to a 5% addition to total CSRM physical damages. Because of uncertainty, though, these relatively small potential annualized damages are treated qualitatively in the table.

** At FY 14 Discount Rate of 3.5%, 50 Year Period of Analysis, 30 Month Construction Period; as sensitivity, FY 15 Discount Rate of 3.375% shows slight increase in net benefits with a BCR of 1.8 for Highest Net Benefit Plan (Alternative 1).

C10.1.1. ***Interior Drainage***

Areas landward of the levee/floodwall will have minimal risk of exterior river floods or storm surge (Gibbstown) but are still subject to interior flooding from stormwater runoff. Thus, interior drainage facilities are required to safely store and discharge the runoff to limit interior residual flooding. The interior areas were studied to determine the specific nature of flooding and to formulate drainage alternatives to maximize National Economic Development (NED) benefits.

C10.2. **Lambertville**

The TSP identified for Lambertville is to construct a 516 LF levee segment, with a maximum height of 12 feet, to protect against Delaware River backwater at Alexauken Creek, in combination with an 1409 LF floodwall segment along the Delaware & Raritan Canal, with a maximum height of 7 feet, 1 property buy-out and demolition, and the construction of a 54 inch diameter gravity outlet in the area of Ely Creek.

Refinements were also made to the structural features for Lambertville. These refinements utilized more detailed topography to slightly alter the structure layout. This update identified an area where existing grade elevations along an embankment were at or above the proposed structure crest elevation. New geotechnical borings however indicate that the embankment may not provide a sufficient level of stability to meet safety standards. The borings also revealed that bedrock is approximately 13 ft below the surface and that there are some areas of soft or pervious soils. The floodwall design and costs were therefore modified to incorporate a sheetpile cutoff wall extending to bedrock, even where the current embankment grades exceed the top of floodwall elevation. The revisions address several concerns identified a potential risks to accurate selection of the TSP.

The flood risk management benefits for this plan were refined to reflect an update of the structure inventory and a more detailed delineation of economic reaches and the identification of the structures affected by the levee/floodwall plan. The refinements modified the HEC-FDA model to accurately reflect the extent of protection. These revisions resulted in an increase to the estimated BCR and net benefits.

Table 10-2: Economics - Lambertville

Annual Without Project Damage	
Flood Damage	$1,147,000
Interior Flood Damage	$
Total Damage	$1,147,000
Annual With Project Damage	
Flood Damage	$290,000
Interior Flood Damage	$52,000
Total Damage	$342,000
Annual Benefits	
Flood Damage	$805,000
Qualitative Benefits *	$0
Total Benefit	**$805,000**
First Costs	
Total	$8,911,000
Interest & Investment Cost	
Interest During Construction (IDC)**	$381,000
Total Investment	$9,292,000
Annual Costs	
Annualized Investment*	$396,000
O&M Cost	$36,000
Total Annual Cost	**$432,000**
Benefit to Cost Comparison	
Net Benefits	**$373,000**
BCR	**1.9**

*Additional Qualitative Potential Benefits (Emergency/Miscellaneous Damages)
**Interest Rate 3.5%, 50 Year Period of Analysis, 30 Month Construction Period

The flood damage potential for these categories of non-physical costs (emergency and miscellaneous) was initially considered for damages for large, infrequent events. Referencing studies, the emergency/miscellaneous damages for a large flood event could result in damages for this category up to 5% addition to total CSRM physical damages. Because of uncertainty, these relatively small potential damages (and subsequent benefits to be provided by the selected plans) are being treated qualitatively.

C10.2.1. *Interior Drainage*

There are two drainage areas landward of the levee/floodwall being considered for Lambertville. Drainage to the north through the propose levee to Alexauken Creek is a small area of about 50 acres. To the south is a much larger area that forms the existing Ely Creek. This area has a complex drainage system including several existing diversion structures that direct the majority of flow to the south, around the existing Ely Creek outlet that runs under the D&R Canal. A recent photograph of the diversion structure at Delaware Avenue is provided in Figure 5.6 of the Main Report. Using funds from a FEMA mitigation grant, the Ely Creek outlet was recently modified to include a sluice gate to prevent backflow from the Delaware River

The USACE's HEC-HMS (Hydrologic Modeling System) was used to analyze the runoff and interior drainage features' performance. The model incorporates the existing drainage features. Based on the hydrologic analysis it was determined that the existing outlet at Ely Creek was sufficient to meet Minimum Facility requirements and that a 48 inch diameter pipe would meet the minimum facility requirements for the northern drainage area.

The impacts and annual damages associated with interior flooding were evaluated and it was determined that the interior damages in the northern area are negligible. Given the lack of damages to support additional improvements the Minimum Facility was identified as the most cost effective interior plan.

A total of 5 Interior Drainage Alternatives were identified for Ely Creek as potential plans to reduce the interior damages which were estimated to average at $196,000 per year. Table 10-2 provides a summary of the costs, NED benefits, BCR, and net benefits for each of the alternatives. The three alternatives that provide additional outlet capacity are each cost effective with BCRs ranging from 2.0 to 2.3. Both of the pump station alternatives considered have annual costs that exceed the reduction in annual damages. Table 10-2 presents a combined summary of damages, benefits and costs for the Lambertville line of protection and interior drainage analyses.

For the Repaupo/White Sluice Interior Ponding area, six 6-foot high by 10-foot wide box culverts convey the flows of the 3 creeks through the levee were sufficient to meet minimum facility requirements. The size of these minimum facility outlets were chose based on the size of the existing creeks and the peak flows at the sites.

For the Clonmell Creek Interior Ponding area, three 4-foot high by 10-foot wide box culverts conveying the flows of the creek through the levee were sufficient to meet minimum facility requirements.

For the main town center interior ponding area ,three 3-foot high by 4-foot wide box culverts conveying the flows of the local runoff through the levee were sufficient to meet minimum facility requirements. For the smaller town center interior ponding area, a 3-foot diameter culvert draining the local runoff through the levee was sufficient to meet minimum facility requirements.

Various alternatives that could potentially improve interior drainage to enhance the established minimum facilities were evaluated for each interior ponding area to determine their viability and cost effectiveness. The alternatives considered were:

- Increased capacity of gravity outlets.
- Pump stations to draw down interior ponding levels.
- Excavated detention areas adjacent to the line-of-protection.
- Construction of interior levees.

Economic and hydraulic analyses indicated that the interior flood levels will result in relatively low levels of annual flood damages and that none of the alternatives considered are cost effective.

C11. Tentatively Selected Plans (TSP) - Benefits; Compared to Costs

Benefit estimates for the implementation of the Tentatively Selected Plans in the two areas are summarized in Table 10-3.

In Gibbstown, the TSP, with a BCR of 1.8 and net benefits of $6,634,000, includes 7,386 LF of levee with a maximum height of 12 feet, 13,788 feet of floodwall with a maximum height of 10 feet (primarily concrete T-wall with piles), the construction of two swing closure gates, acquisition of 17 structures and nonstructural protection (ringwall) for 3 commercial properties outside line of protection, and interior drainage features. Approximately 11.5 acres of wetlands will be impacted by the Gibbstown levee/floodwall system and ringwalls. Approximately 12.5 acres of mitigation is planned. The flood risk management system will also have an impact on movement of fish in the Repaupo Creek watershed. The impact will be mitigated with “fish friendly” flood gates at the two largest creeks.

In Lambertville, the TSP, with a BCR of 1.9 and net benefits of $373,000, is 516 LF of levee along Alexauken Creek with a maximum height of 12 feet, 1,409 LF of floodwall along D&R Canal with a maximum height of 7 feet, 1 property buy-out and demolition, and the construction of a 54 inch diameter gravity outlet in the area of Ely Creek.

Table 11-1: Benefits Summary

Scenario	Gibbstown Alternative 1	Lambertville Levee/Floodwall
Annual Without Project Damage		
Flood Damage (Coastal)	$15,237,000	$0
Flood Damage (Riverine)	$0	$1,147,000
Total Damage	$15,237,000	$1,147,000
Annual With Project Damage		
Flood Damage (Coastal)	$317,000	$0
Flood Damage (Riverine)	$0	$290,000
Interior Flood Damage	$0	$52,000
Total Damage	$317,000	$342,000
Annual Benefits		
Total Flood Damage Reduction	**$14,920,000**	**$805,000**

Summary of Tentatively Selected Plan Benefit-Cost Ratios

	Gibbstown	Lambertville
Annual Benefits	$14,920,000	$805,000
Annual Costs	$8,286,000	$432,000
Net Benefits	$6,634,000	$373,000
BCR	1.8	1.9
Selected as Plan	✓	✓

Interest Rate 3.5%, 50 Year Period of Analysis, 30 Month Construction Period

Applying the FY 15 discount rate of 3 3/8% has a negligible impact on the BCR results, with the above BCRs, rounded to the nearest tenth, of 1.8 for Gibbstown and 1.9 for Lambertville.

C12. Risk and Uncertainty

The Line of Protection will be the first line of defense against flooding or coastal storm surge

ER 1105-2-101, "Risk Analysis for Flood Damage Reduction Studies (USACE, January 3, 2006) stipulates that the risk analysis for a flood protection project should quantify the performance of the plan and evaluate the residual risk, including the consequences of exceedance of the project's capacity. The guidance specifically stipulates, along with the basic economic performance of a project, the engineering performance of the project is to be reported in terms of:

- The annual exceedance probability
- The long-term risk of exceedance
- The conditional non-exceedance probability

The overall economic performance of the line of protection plans for Gibbstown and Lambertville have been computed by HEC-FDA. The annual exceedance probability of a project is the likelihood that a target stage is exceeded by flood waters in any year and can be considered as an indication of the level of risk management provided by the NED Plan. The target stage is the point at which significant damage is incurred in the with-project condition, the significant damage elevation was defined as the water surface elevation which results in damages equal to 5% of damages incurred by the 1% annual chance exceedance event ("100-year" event) in the without-project condition.

C12.1.1. *Economic Sensitivity to Sea Level Trends*

The tidal part of the Study Area (Gibbstown) was analyzed with three different projections for future sea level change conditions. The three projections included the historic trend (low projection), a modified intermediate projection, and a high projection. Equivalent Annual Damage was estimated to be $17.8 million under historic future trends, $21.7 million under the medium projection, and $35.7 million under the high projection.

The expected annual damage shows an increase of almost 30% between the base year and the historically trended future conditions. Assuming the medium projection, the increase over the base year is over 50%, and the increase assuming the high projection is about 160%.

Figure 6.8, shown in the Main Report, presents the Gibbstown Line of Protection design elevation superimposed on the three anticipated rates of sea level change for the 10-yr, 100-yr, and 500-yr storm events.