PASSAIC TIDAL PROTECTION AREA
ESSEX AND HUDSON COUNTIES, NEW JERSEY

GENERAL REEVAULATION STUDY

Draft Economic Appendix

US Army Corps of Engineers
New York District

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DISCLAIMER

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is not to be used as the basis for final design, construction,
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decisions. Please be advised that this document
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Your comments, together with AECOM
comments, will be incorporated into future submissions.

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*Figures are not included in this Draft Submittal. All Figures will be provided in the Final Report

INTRODUCTION

Purpose and Scope

1. This report documents procedures and results of the economic storm damage analysis for the Tidal Protection Area of the Passaic River in Hudson and Essex Counties, New Jersey, General Reevaluation Study. The purpose of the Passaic Tidal Protection Area General Reevaluation Study is to determine if the project as currently authorized remains economically justifiable and environmentally acceptable. The Passaic Tidal project is an authorized but unconstructed (ABU) project, as identified in the May 2013 Post-Hurricane Sandy Second Interim Report to Congress.

2. This document presents the findings of economic assessments for the without-project conditions, as well as analysis results for structural coastal risk management alternatives. Economic analyses include development of stage versus damage relationships and annual damages over a 50-year analysis period. Damage assessments include damages due to tidal

flood inundation along the shoreline and damages caused by residual flooding due to ponding of runoff behind the Line of Protection. Benefits that were evaluated for the alternatives are:

- Reduced inundation damage to structures and contents
- Reduced inundation damage to motor vehicles associated with residences
- Reduced costs of removal and disposal of storm damage debris

3. Estimates of damages are based on February 2015 price levels and a 50-year analysis period. Damages have been annualized over the 50-year period using the fiscal year 2016 discount rate of 3.125%.

4. The Economic Appendix:

    - Provides an overview of the problems and opportunities
    - Describes the without-project future conditions
    - Summarizes the analysis methodologies
    - Evaluates storm damage reduction benefits
    - Evaluates net benefits and benefit-to-cost ratios for structural alternatives
    - Evaluates the impact on the net benefits for a range of sea level rise scenarios
    - Evaluates the performance of the plan and residual risk (Sub Appendix A)

Study Authority

5. The Passaic Tidal Protection Area is part of the larger Passaic River Main Stem project, which was authorized for construction by Section 101(a)(18) of the Water Resources Development Act (WRDA) of 1990, as amended by Section 101(a)(18)(ii) of WRDA 1992, Section 102(p) of WRDA 1992, and Section 327(i) of WRDA 2000:

    In general. The project for flood control, Passaic River Main Stem, New Jersey and New York: Report of the Chief of Engineers, dated February 3, 1989, except that the main diversion tunnel shall be extended to include the outlet to Newark Bay, New Jersey, at a total cost of $1,200,000,000, with an estimated first Federal cost of $890,000,000 and an estimated first non–Federal cost of $310,000,000.

Pre-engineering design work was underway until the non-federal sponsor, the New Jersey Department of Environmental Protection (NJDEP), withdrew support for the project in 1995. Work was halted until March 2011, when the non-Federal sponsor requested a reevaluation of the Passaic River Main Stem project. A Feasibility Cost Sharing Agreement was executed in June 2012 between the USACE and NJDEP.

6. The purpose of the reevaluation study is to determine if the Passaic Tidal project remains economically justifiable, technically feasible, and environmentally acceptable. A 1987 General Design Memorandum (GDM) and 1995 GDM presented preliminary designs for the project. In the 20 years since the 1995 GDM was drafted, study area conditions have changed, and engineering standards and criteria have been updated based on lessons learned from major storm events. Changes in study area conditions, post-hurricane resiliency work, updated economic forecasting, and new engineering and H&H analyses will inform the team's analysis.

7. The reevaluation study was underway when Hurricane Sandy severely impacted the study area in October 2012. The storm's tidal surge inundated the southern portion of the Main Stem project area. The Tidal Protection Area was included in the Second Interim Report to Congress in response to P.L. 113-2, listing it as eligible to be managed as its own separate project. The reevaluation study is funded for completion via P.L. 113-2. This general reevaluation study will present updated projects costs, benefits, and NEPA documentation to determine if the project is still economically justifiable, technically feasible, and environmentally acceptable.

Project History

8. A study of water resource problems in the Passaic River watershed was first authorized by the Flood Control Act of 1936. Reports recommending plans of action issued in 1939, 1948, 1962, 1969, 1972, and 1973. In October 1976, Congress authorized the Passaic River Basin Study in WRDA 1976. After a series of investigations, a General Design Memorandum (GDM) was finalized in 1987. It recommended a plan that included a tunnel diversion; channel modification of the Passaic River; and tidal levees/floodwalls in Newark, Kearney and Harrison, New Jersey.

9. Construction for the Passaic Main Stem Project was authorized by WRDA 1990. A 1995 GDM recommended modifications to the authorized project due to a change in study area conditions. Soon after, the State of New Jersey withdrew support for the project due to objections over the tunnel feature.

10. Interest in the project was given by the newly-formed New Jersey Station Passaic River Basin Flood Advisory Commission in February 2010. The commission recommended reevaluation of the study for the entire Passaic River Basin, including the tidally influenced part of the study area, in March 2011 to the USACE. In June 2012, a Feasibility Study Cost-sharing Agreement (FCSA) was executed between the USACE and NJDEP for a reinvestigation of the project. The reevaluation was underway when Hurricane Sandy severely inundated the region in October 2012. The "Tidal Protection Area" of the Passaic Main Stem Project – the current study area – was included in the Second Interim Report to Congress in response to P.L. 113-2, listing it as eligible to be managed as its own separate project. The FCSA specifically for the "Tidal Protection Area" was executed with NJDEP in October 2014.

Description of the Study Area

Location and Description

11. The study area includes the tidally-influenced and surge-prone areas in the lower Passaic and Hackensack Rivers, and Newark Bay, New Jersey that were included in the authorized Passaic Main Stem project. It includes portions of the city of Newark (Essex County), and the adjacent towns of Harrison and Kearny (Hudson County). The study area covers 5.0 square miles (3,200 acres) in the city of Newark, 0.65 square miles (400 acres) in the Town of Harrison, and 2.73 square miles (1,880 acres) in the Town of Kearny. The Passaic and Hackensack Rivers intersect the study area.

12. The study area is a mixed use area of industrial, commercial, and residential development. The waterfront is mostly developed for industrial uses including shipping (oil and gas, containers/consumer goods) and wastewater treatment. Related rail, barge, truck, and storage infrastructure line the waterfront. There are some public parks and a sports arena on the waterfront as well.

13. Most industrial development is found in two sections of the study area; 1) Kearny Point, a peninsula located between the Passaic and Hackensack Rivers, and 2) on the south/west bank of the Passaic River in Newark. In addition to these areas, the north bank of the Passaic River

in Harrison (south of the PATH railroad) is former industrial land now transitioning to mixed residential and commercial development.

14. Most residential communities in the study area are west of US-1/9 in Newark, and the northwestern portion of Harrison. Most of the rest of the study area is developed for non-retail commercial uses and industrial uses, including shipping, rail transport, oil and gas storage, and container storage.

15. Historical flood records and existing topography indicate that many structures within the study area are susceptible to significant flooding. Approximately 7,400 buildings were initially identified as being susceptible to storm damage with over half of these located in the 1% annual chance event (ACE) floodplain.

Accessibility

16. The study area is a heavily urbanized zone with access to neighboring areas via numerous major highways, including I-95 (the main interstate highway of the eastern United States) which also forms the New Jersey Turnpike in this region. The northern boundary of the study area is formed by I-280, I-78 passes close to the southern boundary, and the study area is also bisected by US-1/9. Other major roads of local importance that give access to the study area include NJ-21, which lies on the western boundary of the study area. Passenger rail services are provided to the study area by the PATH system, with a station in the Harrison section of the study area connecting to Newark Penn Station to the west and New York City to the east via Journal Square and Exchange Place. Newark Penn Station lies at the northwestern boundary of the study area and provides passenger services to further afield via New Jersey Transit and Amtrak. Several freight and other non-passenger railroad lines pass through or adjacent to the study area including links to the main PATH maintenance facility which is located in the Harrison section of the study area, and some major freight yards in the southern section of Newark. The riverfront section (particularly on the west bank through Newark) is the location of several facilities for handling waterborne freight but there are currently no passenger services operating on the river in the study area.

Socio-Economics

17. The study area falls within Essex and Hudson County, specifically the City of Newark, Town of Harrison, and Town of Kearny. In general, the study area contains predominantly industrial facilities with a mix of residential development. Profiles of the three study area communities

are presented below, followed by Tables 1 through 3 summarizing the population, income, and employment statistics for the three municipalities.

18. The City of Newark, located approximately eight miles west of Manhattan, is the largest city in the state of New Jersey. The city is situated on the western side of the Passaic and Hackensack River. It acts as one of the major hubs for air, shipping and rail transportation; including Port Newark, Newark Liberty International Airport, and several universities. Historically, the City of Newark has had a strong industrial and commercial economic base. Newark is a dense urban area surrounded by residential communities. It is home to four universities: New Jersey Medical School, New Jersey Institute of Technology, Rutgers University – Newark, and Essex County College.

19. Newark is the second most racially diverse city in New Jersey, with 52.4% African American population, followed by a 11.6% white, and a 33.8% Hispanic population. Looking further, the population in the City of Newark remains largely occupied by young adults and middle aged citizens with an average age of 32 years – the city, 25.6% of the population were under the age of 18, 11.9% from 18 to 24, 31.9% from 25 to 44, 22.1% from 45 to 64, and 8.6% who were 65 years of age or older (US Census).

20. The Town of Harrison is located in Hudson County on the Passaic River. The Passaic River opens directly into Newark Bay. Although Harrison is within Hudson County and is influenced by other Hudson County municipalities, Harrison is also influenced by the adjacent City of Newark due to its close proximity. In the past the Town of Harrison was heavily involved in industry and manufacturing, which began to move out in the late 1960s. Due to the Waterfront Redevelopment Plan of 2012, there has been an influx in residential and mixed-use development along the Passaic River and a decline in the manufacturing industrial sector. The Town of Harrison includes the Red Bull Arena, which is located near the Passaic River and was opened in 2010.

21. In the Town of Harrison, 20.8 percent of the population is under the age of 18, 10.9 percent from 18 to 24 years of age, 35% from 25 to 44 years of age, 24% from 45 to 64 years of age, and 9.3% who were 65 years of age or older (US Census). The Town of Harrison is racially comprised of 35.4% white, 2.2% African American, 16.3% Asian, and 44.2% other race (US Census).

22. The Town of Kearny, located in Hudson County adjacent to the Town of Harrison, is situated between the Passaic and Hackensack River. It is located roughly six miles west of Manhattan.

Much of the section of Kearny within the study area hosts commercial and industrial areas. From the late 1800s Kearny was an industrial area and was known as a factory town until the late 20th century. It was also the location of a ship yard for the construction of cargo ships and home of the 'Kearny Standard' for the manufacturing of tools and equipment. The Town of Kearny includes an extensive residential area in the north of the Town limits, which is located outside the boundary of this study.

23. In the Town of Kearny 20.7% of the population is under the age of 18, 11.0% from 18 to 24, 31.2% from 25 to 44, 26.4% from 45 to 64, and 10.7% who were 65 years of age or older. The Town of Kearny is racially made up of 48.7% White, 39.9% Hispanic or Latino, 4.4% Asian, 5.4% African American (US Census).

Table 1
Population of Study Area Jurisdictions

Municipality	**1980**	**1990**	**2000**	**2010**	**2014**
City of Newark	329,248	275,221	273,546	277,140	280,579
Town of Harrison	12,242	13,425	14,424	13,620	15,376
Town of Kearny	35,735	34,874	40,513	40,684	41,837

Table 2
Median Household Income of Project Area Jurisdictions

Jurisdiction	**2000**	**2010**	**2014**
New Jersey	$55,146	$69,811	$72,062
City of Newark	$29,913	$35,659	$34,012
Town of Harrison	$41,350	$51,193	$53,772
Town of Kearny	$47,757	$58,698	$63,093

US Census Bureau

Table 3
Employment by Sector of Study Area Jurisdictions

Civilian employed population 16 years and over	**Kearny**		**Harrison**		**Newark**	
	Total	**%**	**Total**	**%**	**Total**	**%**
Sector						

Agriculture/Forestry/Fisheries/Mining	15	0.1	0	0	167	0.1
Construction	1,710	8.7	827	12.1	11,014	9.8
Manufacturing	1,923	9.8	741	10.9	9,327	8.3
Wholesale Trade	1,025	5.2	360	5.3	3,120	2.8
Retail Trade	1,538	7.9	797	11.7	10,525	9.4
Transportation/Utilities	2,327	11.9	655	9.6	10,652	9.5
Information	438	2.2	163	2.4	2,036	1.8
Finance/Insurance/Real Estate	1,330	6.8	411	6	6,618	5.9
Professional/Management	2,098	10.7	851	12.5	10,385	9.7
Educational/Healthcare	3,855	19.7	1,068	15.6	25,771	23.0
Arts/Entertainment/Hospitality	1,337	6.8	345	5.1	8,874	7.9
Public Administration	605	3.1	137	2.0	5,788	5.2
Other	1,342	6.9	473	6.9	7,107	6.4
Total	*19,543*	*100*	*6,828*	*100*	*111,834*	*100*

US Census Bureau 2010

Land Use

24. Current Land use in the study area is a combination of urban, industrial, and limited suburban developments. The following sections describe the land use in each component municipality of the study area in more detail.

25. The City of Newark has a total area of 26.107 square miles, including 24.187 square miles of land and 1.920 square miles of water (US Census, 2010), resulting a in population density of 11,600 per square mile. According to the US Census, Newark has the third smallest land area among the 100 most populous cities in the United States. The densest areas of Newark are located inland in proximity to the public transportation.

26. The city of Newark is divided into five wards: East ward, South ward, Central ward, West ward, and North ward. The East ward is zoned primarily as heavy industrial and port use. The South ward encompasses Newark Liberty Airport and airport support development. The Central ward is a mix of light industrial use, institutional, neighborhood commercial and low-rise multifamily residential development. The West and North ward consist of mostly residential use with a mix of single-family residential, one-to-three family and townhouse residential, and parks with open space (Newark 2030, PDF).

27. The future development potential of the City of Newark includes the implementation of approved projects not yet built and future proposed development plans. There are several proposals focusing on underutilized existing sites as potential redevelopment areas.

28. The Town of Harrison has a total area of 1.319 square miles, including 1.203 square miles of land and .116 square miles of water (US Census, 2010), resulting a in population density of 12,781 per square mile.. Historically, the Town of Harrison has been occupied by industrial activities. Recently the Town of Harrison developed a Waterfront Redevelopment Plan to capitalize on the Harrison PATH Station, in order to provide a variety of mixed-use, transit-oriented, and pedestrian scale development (Town of Harrison Waterfront Redevelopment Plan, PDF).

29. The Town of Harrison is primarily made up of industrial and commercial land use. The entire southern portion, south of I-280, is railroad/utility, industrial, and undeveloped land use. North of I-280 features a mix of commercial mixed use buildings, industrial use, single family

residential and multifamily residential units, with limited park/recreation use (Harrison Master Plan, PDF).

30. The future development potential of the Town of Harrison is based on the development of approved projects not yet built and future development plans. Underutilized existing, primarily nonresidential sites are identified in the Waterfront Redevelopment Plan as potential redevelopment areas.

31. The Town of Kearny has a total area of 10.193 square miles, including 8.775 square miles of land and 1.418 square miles of water, resulting a in population density of 4,757 per square mile. The Town of Kearny is divided into three sections: the Kearny Uplands, the Kearny Meadows, and Kearny Point. All sections vary in topography slightly. The Kearny Uplands is made up of residential communities, while Kearny Point is considered an industrial district. The meadows consist of wetlands and tributaries, which include both residential and industrial communities (Kearny Redevelopment, PDF). The Project Area lies within Kearny Point, a heavily used industrial area.

32. The future development potential of the Town of Kearny is based on the development of approved projects not yet built and future development plans. The town planning board does not propose any radically different land use concepts that would dramatically change the character of the community. The Town of Kearny plans to focus on the 'Transit-Oriented Development Vision Plan,' using underutilized sites for potential redevelopment areas.

Description of the Problem

Historical Flooding

33. Historically, the study area has been affected by tidal storm surges during severe extra-tropical storms, nor'easters, and hurricanes, exacerbated by rainfall-induced fluvial flooding from the Passaic and Hackensack Rivers.

34. Coastal storms characterized as nor'easters are most frequent between October and April. These storms track over the coastal plain or up to several hundred miles offshore, bringing strong winds and heavy rains. Most winters feature at least one significant coastal storm and some years see upwards of five to ten. Tropical storms and hurricanes are also a special concern along the coast. In some years, they contribute a significant amount to the precipitation totals

of the region. Damage during times of high tide can be severe when tropical storms or nor'easters affect the region.

35. Flooding in the study area can occur during any season of the year since northern New Jersey lies within the major storm tracks of North America. The worst storms have occurred in late summer or early fall when tropical disturbances (hurricanes) are most prevalent. Recent tropical storm events that have significantly affected the study area include Tropical Storm Floyd, Hurricane Irene, and Hurricane Sandy.

36. Hurricane Floyd originally made landfall in Cape Fear, North Carolina as a Category 2 hurricane on September 16, 1999. The storm crossed over North Carolina and southeastern Virginia before briefly entering the western Atlantic Ocean. The storm reached New Jersey on September 17, 1999 as a tropical storm. Record breaking flooding from rainfall exceeding 14 inches was recorded throughout the State of New Jersey, with some locations in the vicinity of the study area experiencing rainfall amounts up to 10 inches. A Federal Emergency Declaration was issued on September 17, 1999. The damage from Floyd was estimated between $4.5 billion and $6 billion, including $250 million in New Jersey (1999 dollars).

37. Hurricane Irene came ashore in Southern New Jersey on August 28, 2011. In anticipation of the storm Governor Chris Christie declared a state of emergency on August 25th, with President Obama reaffirming the declaration on August 27th. Mandatory evacuations were ordered throughout the State of New Jersey. Wind speeds were recorded at 75 mph and rainfall totals reached over 10 inches in many parts of the state. Extensive flooding caused damage to homes, businesses, and public infrastructure. The flooding was exacerbated by high water levels in reservoirs and wetlands as a result of previous heavy rains. Over 1 million customers lost power during the storm. Overall damage estimates for the State of New Jersey came to over $1 billion, with over 200,000 homes and buildings damaged.

38. Hurricane Sandy was a very large system, having a diameter spanning approximately one-thousand miles. The large girth of the storm caused abnormally high storm surge elevations along the shoreline in addition to a naturally occurring high astronomical tide (spring tide) causing record flood levels and inundation along the North Atlantic Coast. Record storm tides (storm surge + normal astronomical tide) and storm surges were measured in the NYC metropolitan area with flooding depths up to nine feet above the local ground level measured in some areas. Governor Chris Christie declared a state of emergency on October 31, 2012. As of October 15, 2013 more than $7.9 billion in National Flood Insurance Program (NFIP)

payments had been made to policy holders to account for the damages from Hurricane Sandy, and the storm was estimated to cost the State of New Jersey over $36 billion overall.

39. While these storms may be the most notable of those having impacted the study area, many more have made landfall in the vicinity of the study area. For example, in the 30 years prior to 1962, no less than 90 hurricanes, tropical storms or extra-tropical storms significantly impacted the New York City Area (USACE, 1964), often bringing with them storm surges of over 4 feet.

WITHOUT-PROJECT FUTURE CONDITIONS

40. The without-project future conditions for the Passaic Tidal Protection Area have been identified as: (1) flooding and wave impacts from future storm events and (2) continued development and fill of areas vulnerable to flooding.

41. It is expected that future storms will continue to cause damages in this area. Although some storm risk reduction from small storm events (e.g. 2-year event) is provided by local topography, a large storm event in the future could result in extensive damages. Since no major changes to the shorefront are expected, the level of vulnerability will increase as sea level rises and storm surge impacts become more severe.

42. It is also expected that continued development, subject to local floodplain management ordinances, will occur in the floodplain. Based on recent trends, previously industrial land will be redeveloped with commercial/retail developments and multi-residence structures such as condominiums and townhouses. Fill in the floodplain may also occur as new construction is elevated above the base flood elevation. This fill may reduce storage of runoff and thereby exacerbate flood conditions.

43. While no long-term plan exists to maintain private bulkheads and seawalls, historic patterns indicate that they will be rebuilt to pre-existing levels after storm-related failure.

44. Tidal inundation is expected to increase gradually over time, in direct relation to the anticipated rise in relative sea level. Based upon long-term trends measured at the NOAA Sandy Hook Gage, a 0.0134 foot per year increase is anticipated, resulting in an increase of approximately 0.7 feet over the 50-year period of analysis for the project. In future years this will result in more frequent and higher stages of flooding.

STORM DAMAGE

General

45. In order to address the storm damage problem in the Passaic River Tidal Protection Area, several structural alternatives have been analyzed to evaluate their effectiveness in reducing the risk of inundation damage.

46. The following basic steps were used in the analysis of inundation damage:
    - Assign evaluation reaches,
    - Inventory floodplain development,
    - Estimate depreciated replacement cost,
    - Assign generalized damage functions,
    - Calculate aggregated stage vs. damage relationships.

47. Flood inundation damage calculations were performed using Version 1.4 of the Hydrologic Engineering Center's Flood Damage Analysis computer program (HEC-FDA). This program applies Monte Carlo Simulation to calculate expected damage values while explicitly accounting for uncertainty in the input data.

Project Reaches

48. For the purposes of the analysis, the study area was divided into reaches corresponding to the extents of areas potentially covered by components of the proposed structural alternatives. These reaches are as follows:
    - Harrison Section 1
    - Harrison Section 2
    - Kearny Section
    - Newark Section
    - Minish Park Section
    - Newark Flanking Section
    - Newark Gap (area not covered by proposed alternatives)

49. Independent of the main economic reaches listed above, 16 interior drainage areas were delineated as separate reaches to facilitate the analysis of residual flooding due to ponding of runoff behind the Line of Protection. These areas and their analysis are discussed in appropriate detail in the Interior Drainage Section of the Engineering Appendix.

Conditions

50. Estimates of damages and benefits are based on February 2015 price levels and a 50-year period of analysis. Damages have been annualized over the 50-year analysis period using the fiscal year 2015 discount rate of 3.125%.

Inventory Methodology

51. A structure inventory was completed in February 2015 for use in computing flood inundation damages in the study area using standard planning methods and models. In addition to theoretical flood damages, the team is collecting historic damage figures from local and state government, and businesses.

52. FEMA Preliminary Flood Insurance Rate Maps (FIRMs), released on 12/20/2013 for Hudson County and 05/30/2014 for Essex County, were used within the municipalities of Kearny, Harrison, and Newark to delineate floodplains and identify structures subject to inundation during flood events, notably the 1% Annual Chance of Exceedance ("100-year") event and the 0.2% ACE ("500-year") event. A floodplain corresponding to the 500-year event plus two feet of freeboard was also developed to define the maximum extent of the structure inventory.

53. Building footprint data for the more than 7,700 structures initially identified as covered by the study structure inventory was obtained from the City of Newark, the New Jersey Meadowlands Commission, and the New Jersey Department of Environmental Protection. The 100-year, 500-year, and 500-year +2 feet floodplain extents were compared with the locations of each structure in the structure inventory. Structures that fell within each floodplain limit were assumed to be inundated by each respective stillwater elevation. To

be classified as falling within the floodplain limits, only a portion of geometry representing the structure had to fall within the geometry of the floodplain extents.

54. To ensure that the properties were correctly located, tax parcel data was obtained from the MOD-IV tax list search database. The MOD-IV property tax system is the mandatory method of tax record keeping in the state of New Jersey. It provides for the uniform preparation, maintenance, presentation, and storage of detailed property tax information. This information includes property address, block/lot, owner, property class (use), land value, and improvement (building or structure) value.

55. Due to time and budgetary constraints, a field survey to collect data for all 7,000 or so structures in the area could not be conducted. Instead, a sample of 500 structures was selected for detailed survey in the field, and their typical characteristics were extrapolated to the remaining structures to populate the full inventory database.

56. The survey sample included structures in each of the project reaches and was focused on the largest structures in the high frequency floodplains, since these structures were expected to account for the bulk of the inundation damages in the without-project condition:

- Newark: The 300 largest structures in the 100-year floodplain plus 100 additional structures in 10 randomly-selected clusters in the 100-year floodplain.
- Kearny: The 100 largest structures in the 100-year floodplain.
- Harrison: The 50 largest structures in the 100-year floodplain plus 30 structures in the 500-year floodplain in the Harrison Section 2 area.

57. A "windshield survey" of the sample structures was conducted during January and February 2015. For each structure, the footprint area was extracted from GIS shapefiles and a ground elevation was assigned using LiDAR, while the following data was gathered in the field:

- Type/Damage Category
- Usage
- Size
- Basement
- Foundation Type
- Number of Stories
- Construction Material

- Quality of Construction
- Condition
- First Floor Elevation Above Grade
- Low Opening Relative to First Floor

58. This data was subsequently used to calculate depreciated structure replacement values for each structure, based on square foot costs and location adjustment factors published by RS Means in January 2015. Depreciated structure replacement value is the standard measure of building worth used in NED flood risk reduction analyses.

59. Attributes for the remaining non-surveyed structures in the study area were extrapolated from publicly available data and from the average characteristics and average square foot costs of the 500 surveyed structures. The extrapolation was further refined based upon adjacent parcel information and reference to the Mod-IV data.

60. Following the computation of structure values and extrapolation of average/typical parameters to the non-surveyed structures, further research using publicly available sources (such as company websites) was undertaken for the larger commercial structures to refine structure and content values and the assignment of damage functions.

61. Based on the field survey and subsequent analyses described above, the study area contains more than 6,770 eligible structures within the floodplain corresponding to the 500-year event plus two feet of freeboard, with a total depreciated structure value of $8.9 billion. The numbers and depreciated structure replacement values of structures in the inventory are presented by reach and category in Tables 4 through 19 below.

Table 4
Structures by Floodplain - Newark Section

Damage Category	**10-year**	**100-year**	**500-year**	**500-year +2ft**
Apartment	15	44	85	101
Commercial	45	119	142	154
Industrial	211	341	402	418
Municipal	13	24	25	26
Residential	63	149	269	346
Total	**347**	**677**	**923**	**1,045**

Table 5
Structures by Floodplain - Kearny Section

Damage Category	10-year	100-year	500-year	500-year +2ft
Apartment	0	0	0	0
Commercial	7	8	8	8
Industrial	144	241	243	243
Municipal	7	9	10	10
Residential	0	0	0	0
Total	**158**	**258**	**261**	**261**

Table 6
Structures by Floodplain - Harrison Section 1

Damage Category	10-year	100-year	500-year	500-year +2ft
Apartment	4	18	23	23
Commercial	12	31	39	39
Industrial	21	33	39	43
Municipal	1	2	2	2
Residential	41	150	175	197
Total	**79**	**234**	**278**	**304**

Table 7
Structures by Floodplain - Harrison Section 2

Damage Category	10-year	100-year	500-year	500-year +2ft
Apartment	0	0	0	0
Commercial	0	1	1	1
Industrial	10	18	18	18
Municipal	0	0	0	0
Residential	0	0	0	0
Total	**10**	**19**	**19**	**19**

Table 8
Structures by Floodplain - Minish Park Section

Damage Category	10-year	100-year	500-year	500-year +2ft
Apartment	20	200	280	332
Commercial	9	175	246	298
Industrial	4	40	58	65
Municipal	5	13	14	15
Residential	23	605	987	1,262
Total	**61**	**1,033**	**1,585**	**1,972**

Table 9
Structures by Floodplain - Newark Flanking Section

Damage Category	10-year	100-year	500-year	500-year +2ft
Apartment	7	168	258	329
Commercial	15	196	299	358
Industrial	12	212	260	298
Municipal	3	18	27	32
Residential	4	563	1,017	1,274
Total	**41**	**1,157**	**1,861**	**2,291**

Table 10
Structures by Floodplain - Newark Gap

Damage Category	10-year	100-year	500-year	500-year +2ft
Apartment	0	19	49	74
Commercial	1	26	49	68
Industrial	0	15	38	43
Municipal	0	0	0	2
Residential	0	153	438	695
Total	**1**	**213**	**574**	**882**

Table 11
Structures by Floodplain - Study Area Total

Damage Category	10-year	100-year	500-year	500-year +2ft
Apartment	46	449	695	859
Commercial	89	556	784	926
Industrial	402	900	1,058	1,128
Municipal	29	66	78	87
Residential	131	1,620	2,886	3,774
Total	**697**	**3,591**	**5,501**	**6,774**

Table 12
Value of Structures by Floodplain ($,000) - Newark Section

Damage Category	10-year	100-year	500-year	500-year +2ft
Apartment	$12,537	$86,446	$207,824	$241,317
Commercial	$79,679	$230,707	$275,339	$605,720
Industrial	$343,503	$695,951	$963,357	$988,637
Municipal	$17,239	$238,054	$239,248	$239,328
Residential	$10,503	$34,852	$75,576	$107,999
Total	**$463,461**	**$1,286,010**	**$1,761,343**	**$2,183,002**

Table 13
Value of Structures by Floodplain ($,000) - Kearny Section

Damage Category	10-year	100-year	500-year	500-year +2ft
Apartment	$0	$0	$0	$0
Commercial	$63,245	$64,177	$64,177	$64,177
Industrial	$1,069,439	$1,257,684	$1,258,858	$1,258,858
Municipal	$39,829	$216,267	$222,256	$222,256
Residential	$0	$0	$0	$0
Total	**$1,172,513**	**$1,538,128**	**$1,545,292**	**$1,545,292**

Table 14
Value of Structures by Floodplain ($,000) - Harrison Section 1

Damage Category	10-year	100-year	500-year	500-year +2ft
Apartment	$39,991	$142,761	$147,291	$147,291
Commercial	$31,721	$242,153	$285,286	$285,286
Industrial	$128,738	$247,862	$333,130	$337,662
Municipal	$1,219	$2,066	$2,066	$2,066
Residential	$12,290	$34,548	$40,733	$47,486
Total	**$213,959**	**$669,389**	**$808,504**	**$819,790**

Table 15
Value of Structures by Floodplain ($,000) - Harrison Section 2

Damage Category	10-year	100-year	500-year	500-year +2ft
Apartment	$0	$0	$0	$0
Commercial	$0	$200,000	$200,000	$200,000
Industrial	$699	$145,722	$145,722	$145,722
Municipal	$0	$0	$0	$0
Residential	$0	$0	$0	$0
Total	**$699**	**$345,722**	**$345,722**	**$345,722**

Table 16
Value of Structures by Floodplain ($,000) - Minish Park Section

Damage Category	10-year	100-year	500-year	500-year +2ft
Apartment	$22,789	$269,381	$371,869	$426,999
Commercial	$7,555	$162,252	$210,510	$241,456
Industrial	$714	$48,308	$80,447	$83,350
Municipal	$8,055	$17,235	$30,101	$42,270
Residential	$7,661	$179,301	$292,286	$370,730
Total	**$46,773**	**$676,478**	**$985,213**	**$1,164,805**

Table 17
Value of Structures by Floodplain ($,000) - Newark Flanking Section

Damage Category	10-year	100-year	500-year	500-year +2ft
Apartment	$13,022	$292,265	$487,325	$620,171
Commercial	$22,104	$327,301	$413,524	$489,244
Industrial	$5,960	$291,946	$380,166	$427,505
Municipal	$10,312	$47,757	$142,483	$201,756
Residential	$1,483	$231,619	$410,380	$506,907
Total	**$52,881**	**$1,190,888**	**$1,833,878**	**$2,245,583**

Table 18 Value of Structures by Floodplain ($,000) - Newark Gap				
Damage Category	**10-year**	**100-year**	**500-year**	**500-year +2ft**
Apartment	$0	$20,094	$68,965	$153,231
Commercial	$1,592	$59,626	$79,496	$115,194
Industrial	$0	$22,439	$51,448	$58,902
Municipal	$0	$0	$0	$6,976
Residential	$0	$48,560	$131,765	$216,906
Total	**$1,592**	**$150,719**	**$331,673**	**$551,209**

Table 19 Value of Structures by Floodplain ($,000) - Study Area Total				
Damage Category	**10-year**	**100-year**	**500-year**	**500-year +2ft**
Apartment	$88,338	$810,947	$1,283,273	$1,589,009
Commercial	$205,895	$1,286,217	$1,528,332	$2,001,076
Industrial	$1,549,053	$2,709,911	$3,213,129	$3,300,636
Municipal	$76,654	$521,379	$636,153	$714,652
Residential	$31,937	$528,880	$950,739	$1,250,029
Total	**$1,951,877**	**$5,857,334**	**$7,611,626**	**$8,855,403**

62. In addition to buildings and their contents, the analysis also evaluated inundation damages to motor vehicles associated with residential structures in accordance with the guidance found in EGM 09-04, “Generic Depth-Damage Relationships for Vehicles”, 22 June 2009. To facilitate this component of the analysis, the following simplifying assumptions were made during the estimation of the number and value of vehicles likely to be present in the study area during flood events:

1. The number of vehicles associated with each housing unit in the study area was taken from the most recent U.S. Census bureau data.

2. The average depreciated value of a vehicle in the study area was assumed to be $16,800, based on sources found during an internet search (Detroit Free Press, 18 February, 2015: http://www.freep.com/story/money/cars/2015/02/18/used-car-prices-record/23629241/)

3. In the absence of more detailed data, sedans were assumed to be the predominant vehicle type in the study area; hence the Sedan depth-damage function in Table 4 of EGM 09-04 was assigned to all vehicles in the inventory.

4. The total number of housing units in any residential structure was estimated by assuming that each structure covered by one of the EGM 01-03 and EGM 04-01 (see paragraph68) depth-damage functions contains a single unit, and that the number of units in an apartment building or other multi-family residence can be derived by dividing the building's total square footage by 1,200 (1,000 square feet for the assumed average apartment size plus an additional 200 square feet to account for hallways and other common areas).

5. The probability that vehicle owners would move their vehicles to higher ground before a flood was assumed to be 73%. In the absence of any specific information regarding local warning times in advance of flood events this figure is derived from an average of the percentages given in Table 5 of EGM 09-04.

6. The damage reference elevations for all motor vehicles in the inventory were assumed to be equal to the ground elevation of the associated structure.

7. It was assumed that no vehicles would remain outside non-residential structures during a flood event.

63. The resulting value of vehicles estimated to be at risk of inundation damage in the study area is presented in Table 20.

Table 20 Value of Vehicles by Floodplain ($,000)				
Damage Category	**10-year**	**100-year**	**500-year**	**500-year +2ft**
Newark Section	$514	$1,760	$3,551	$4,565
Kearny Section	$0	$0	$0	$0
Harrison Section 1	$981	$3,468	$3,658	$3,750
Harrison Section 2	$0	$0	$0	$0
Minish Park Section	$576	$8,512	$13,224	$16,396
Newark Flanking Section	$337	$8,859	$15,315	$19,614
Newark Gap	$0	$1,036	$3,205	$6,008
Total	**$2,409**	**$23,635**	**$38,953**	**$50,332**

Stage Frequency Data

64. Stage-frequency relationships for the study area were based on North Atlantic Coast Comprehensive Study (NACCS) data for all reaches directly fronting the Passaic River. For the Newark Flanking Section, since the principal source of flooding is anticipated to be overland flow from the south rather than directly from the Passaic River, the most recent FEMA stage-frequency data was assigned to this reach.

Table 21 Base Year Stage vs. Frequency Data							
Frequency	**Stage at Reach Index Station (Ft NAVD88)**						
	Harrison Section 1	**Harrison Section 2**	**Kearny Section**	**Newark Section**	**Minish Park Section**	**Newark Flanking Section**	**Newark Gap**
0.5	6.0	5.9	5.9	5.9	6.0	2.7	5.9
0.2	7.2	7.1	7.1	7.1	7.2	4.2	7.1
0.1	8.1	8.1	8.1	8.1	8.1	5.3	8.1
0.04	9.2	9.1	9.1	9.1	9.2	6.4	9.1
0.02	10.8	10.7	10.7	10.7	10.8	7.9	10.7
0.01	12.1	12.0	12.0	12.0	12.1	9.1	12.0
0.005	13.3	13.2	13.2	13.2	13.3	10.3	13.2
0.002	14.8	14.8	14.8	14.8	14.8	11.8	14.8

Sea Level Rise

65. Under future without-project conditions, the study area will continue to be subject to flooding due to storm surge from coastal storms. Storms are predicted to be more frequent and severe in the future due to climate change. Inundation due to storm surge is expected to increase gradually over time in direct relation to sea level change. Based on long term trends measured in the area (specifically at the Sandy Hook NOAA gage), sea level is projected to rise 0.0134 feet per year over the 50-year period of analysis. Hence the baseline analysis in HEC-FDA used a lower bound sea level rise value of 0.7 feet in the year 2070, resulting in an increase in expected annual damage over the base year.

66. In accordance with current policy (specifically Engineering Regulation ER 1100-2-8162 (incorporating Sea Level changes in Civil Works Program, 31 Dec 2013) proposed projects must be also evaluated for a range of possible sea level rise rates in addition to the historical/lower bound value described above. According to the guidance, the project must also be evaluated using “intermediate” and “high” rates derived from modified NRC Curves I and III, which for this study are projected to result in increases of 1.2 ft. and 2.8 ft. respectively over the fifty year period-of-analysis.

Inundation Damage Functions

67. The analysis also required the assignment of appropriate depth-damage relationships to all structures in the inventory. While several sets of damage functions have been developed by the US Army Corps of Engineers for use in studies such as this one, the functions selected for this study were drawn from two sources.

68. The most recent standard depth damage curves for residential structures issued by the US Army Corps of Engineers are the Generic Depth-Damage Relationships for Residential Structures without Basements (EGM 01-03, 4 December 2000) and the Generic Depth-Damage Relationships for Residential Structures with Basements (EGM 04-01, 10 October 2003). These functions have become the standard flood depth-damage functions for use in Corps studies in both coastal and riverine areas for single-family residential and similar structures since their release.

69. The Passaic River Basin (PRB) functions for residential and non-residential structures were developed specifically for use in the Passaic River Basin in the years 1980-1982, and were

derived from approximately 3,500 interviews with owners of flood-damaged properties in the floodplain. Several recent studies have been accepted using the EGM 01-03 and EGM 04-01 functions for most residential structures and the PRB functions for non-residential and larger residential structures.

70. This study used a combination of PRB and EGM 01-03 and EGM 04-01 functions as described above, but with the existing "other" damage component of the PRB functions (originally intended to cover damage to motor vehicles, landscaping and outbuildings, as well as non-physical costs associated with evacuation and re-occupation, debris removal, and temporary housing) discarded in favor of the following additional modeled damage categories:

- Motor vehicles in accordance with EGM 09-04 and based on assumptions described in paragraph 62 above
- Emergency costs and debris removal (based on tools developed as part of the recent North Atlantic Coast Comprehensive Study (NACCS))

71. The final category of benefits evaluated for this study was the cost to clear and dispose of storm damage debris subsequent to each damaging storm event. The estimation of debris costs utilized a matrix developed by the FEMA Modeling Task Force, debris removal costs from the NACCS Emergency Costs Report, and outputs from the Passaic Tidal Protection Area HEC-FDA model run for structures only. Table 22 shows an excerpt from the FEMA matrix, which categorized flood damage into four levels according to water depth: Affected, Minor, Major, and Destroyed. For each level, the matrix assigned a debris weight per 1,000 square feet of building area. Since wave damage was not incorporated into the damages for the Passaic Tidal Protection Area, the "Destroyed" category was not used.

Table 22
Tons of Debris by Flood Depth, as Estimated by FEMA MOTF Matrix

Building Damage Level	Water Depth Ft	Tons of Debris per 1,000 Sq Ft
Affected	>0 to 2	2.05
Minor	>2 to 5	4.1
Major	>5	6.8

72. Structures in one of the output files from the without-project analysis in HEC-FDA were categorized into Residential and Nonresidential. For each flood event, structures were

further categorized into one of three FEMA building damage levels according to water depth. Each structure's total footprint square footage was divided by 1000 and multiplied by a debris weight according to the criteria in Table 22. The resulting debris weight was multiplied by an average tipping fee for the Northeast and Mid-Atlantic states, provided by the NACCS Emergency Costs Report. The resulting values were aggregated into reaches and grouped by flood event to be aligned with the appropriate stages and depths for each reach, at each flood event. This enabled reach-specific direct depth-damage functions to be derived and input to HEC-FDA to represent the cost of debris removal in each reach.

Average Annual Damages

General

73. The HEC-FDA program quantifies uncertainty in discharge-frequency, stage-discharge, and stage-damage functions and incorporates it into economic and performance analyses of existing conditions and alternative plans. The process applies a procedure (Monte Carlo simulation) that computes the expected value of damage while accounting for uncertainty in the basic value. The HEC-FDA program presents results for expected annual damages and equivalent annual damages, where equivalent annual damage is the sum of the discounted value of the expected annual damage, which is then annualized over the period of performance.

Uncertainty

74. Under current Corps of Engineers guidance, risk and uncertainty must be incorporated into flood risk management studies. The following areas of uncertainty were incorporated into the HEC-FDA program:

- stage vs. frequency
- structure main floor elevation
- structure value
- content-to-structure value ratio
- mean structure damage at increments of depth above main floor
- mean content damage at increments of depth above main floor

75. The uncertainty associated with structure value was assumed to follow a normal distribution with a 10% standard deviation, to be consistent with other recently accepted flood risk reduction studies for same region. EM 1110-2-1619 suggests that in lieu of better site-specific information, content-to-structure value ratios based on large samples of Flood Insurance Administration (FIA) claims records can be used (Table 6-4 presented in EM 1110-2-1619). A normal distribution with average standard deviation of 25% was utilized for structure-to-content value ratio uncertainty for both residential and non-residential content value in accordance with the referenced table. Since the damage functions present other damage as a percent of structure value, the other-to-structure value ratio was estimated to have a standard deviation of 10% for all categories.

76. The Monte Carlo simulation technique, which HEC-FDA uses as the basis for computing flood damages while accounting for risk and uncertainty associated with key variables, is based on random sampling from the user-selected probability distributions used to define each uncertain variable. During each execution of the model, the program performs many iterations of the damage computations while sampling from the input probability distributions until an allowable tolerance in the overall mean damage is attained. This analysis used default tolerance within the HEC-FDA program of 0.5%, which represents an error of approximately $306,000 in the without-project base year expected annual damage (see Table 23). Use of this default tolerance is standard practice and is consistent with other recently accepted flood risk reduction studies for same region. Inspection of the model outputs indicates that most simulations require 10,000 –20,000 iterations before the 0.5% tolerance is reached.

Estimated Damages

77. Expected annual damages calculated using HEC-FDA version 1.4 for the without-project/base year condition, and for the without-project/future year conditions are provided in Tables 23 and 24, respectively. Equivalent annual damages over the 50-year project life are presented in Table 25.

Table 23 - Summary of Without-Project Damages Expected Annual Damage - Base Year 2020								
Economic Reach	**Damage Categories**							**Total**
	Apartment	**Commercial**	**Industrial**	**Municipal**	**Residential**	**Vehicles**	**Debris**	
Harrison Section 1	$149,100	$1,790,000	$2,763,000	$36,100	$758,800	$97,000	$56,400	$5,650,400
Harrison Section 2	$0	$482,500	$695,000	$0	$0	$0	$13,300	$1,190,800
Kearny Section	$0	$3,598,200	$16,027,900	$3,493,700	$0	$0	$281,000	$23,400,800
Newark Section	$237,500	$5,516,600	$9,782,200	$2,343,000	$734,400	$82,400	$209,100	$18,905,200
Minish Park Section	$330,100	$1,430,300	$203,200	$218,900	$1,261,000	$105,100	$11,200	$3,559,800
Newark Flanking Section	$383,700	$3,199,100	$1,539,500	$486,800	$1,645,900	$111,000	$41,800	$7,407,800
Newark Gap	$29,600	$629,700	$91,700	$3,000	$360,900	$15,100	$3,300	$1,133,300
Totals	*$1,130,000*	*$16,646,400*	*$31,102,500*	*$6,581,500*	*$4,761,000*	*$410,600*	*$616,100*	*$61,248,100*

Price Level: February 2015

Table 24 - Summary of Without-Project Damages Expected Annual Damage - Future Year 2070								
Economic Reach	**Damage Categories**							**Total**
	Apartment	**Commercial**	**Industrial**	**Municipal**	**Residential**	**Vehicles**	**Debris**	
Harrison Section 1	$217,100	$2,667,100	$4,418,800	$56,300	$1,203,400	$150,900	$89,500	$8,803,100
Harrison Section 2	$0	$646,000	$983,600	$0	$0	$0	$18,600	$1,648,200
Kearny Section	$0	$5,703,500	$24,827,000	$5,305,500	$0	$0	$442,300	$36,278,300
Newark Section	$357,900	$8,515,500	$15,221,100	$3,457,000	$1,138,800	$126,200	$325,000	$29,141,500
Minish Park Section	$477,300	$2,037,900	$290,600	$315,500	$1,809,000	$150,300	$16,000	$5,096,600
Newark Flanking Section	$577,200	$4,728,000	$2,289,400	$724,600	$2,442,900	$164,500	$62,600	$10,989,200
Newark Gap	$44,600	$914,000	$132,500	$4,500	$521,500	$22,100	$4,900	$1,644,100
Totals	*$1,674,100*	*$25,212,000*	*$48,163,000*	*$9,863,400*	*$7,115,600*	*$614,000*	*$958,900*	*$93,601,000*

Price Level: February 2015

Table 25 - Summary of Without-Project Damages Equivalent Annual Damage								
Economic Reach	**Damage Categories**							**Total**
	Apartment	**Commercial**	**Industrial**	**Municipal**	**Residential**	**Vehicles**	**Debris**	
Harrison Section 1	$174,100	$2,111,600	$3,370,100	$43,500	$921,800	$116,800	$68,500	$6,806,400
Harrison Section 2	$0	$542,400	$800,800	$0	$0	$0	$15,200	$1,358,400
Kearny Section	$0	$4,370,100	$19,253,900	$4,158,000	$0	$0	$340,200	$28,122,200
Newark Section	$281,600	$6,616,100	$11,776,200	$2,751,400	$882,600	$98,400	$251,600	$22,657,900
Minish Park Section	$384,000	$1,653,100	$235,300	$254,300	$1,461,900	$121,700	$13,000	$4,123,300
Newark Flanking Section	$454,700	$3,759,600	$1,814,400	$574,000	$1,938,100	$130,600	$49,400	$8,720,800
Newark Gap	$35,100	$734,000	$106,700	$3,500	$419,800	$17,700	$3,900	$1,320,700
Totals	$1,329,500	$19,786,900	$37,357,400	$7,784,700	$5,624,200	$485,200	$741,800	$73,109,700

Price Level: February 2015, Interest Rate 3.125%

COASTAL RISK MANAGEMENT BENEFITS

Introduction

78. Several alternative plans to reduce the risk of storm damage were formulated and analyzed. The majority of plans were dismissed during screening analyses conducted prior to Hurricane Sandy. As described in the main text, a series of floodwalls was determined to meet the study objectives in the most cost-effective manner. Detailed descriptions of the design and features of these floodwalls are provided in the Engineering Appendix, while this Appendix evaluates the benefits of the floodwall plans with varying crest elevations.

Methodology and Assumptions

79. Benefits from the proposed plans of improvement were estimated by comparing damages with and without the proposed measures under existing and future conditions.

80. Three alternative stillwater design elevations of 14 Ft, 16 Ft, and 18 Ft (all NAVD88) were considered in the analyses, covering Harrison Section 1, Harrison Section 2, Kearny Section, Newark Section, Minish Park Section, and Newark Flanking Section. Additionally, a smaller alternative, referred to as the Flanking Plan, set back from the shoreline was also evaluated in a second iteration. This alternative, which has been identified as the Locally Preferred Plan (LPP) featured a stillwater design elevation of 14 Ft NAVD88.

81. For each floodwall alternative inundation and debris removal damages were calculated for all the frequencies presented in Table 21, converted to equivalent annual damage, and summarized in the tables below for each reach. Table 26 presents the with-project damage for each alternative, while Table 27 presents the benefits. For both tables, damages and benefits refer only to those specifically associated with the line of protection, and do not include any residual damages resulting from rainfall runoff ponding behind the line of protection.

Table 26 - Summary of With-Project Damages Equivalent Annual Damage				
Economic Reach	**Floodwall Alternative Elevations**			**LPP**
	14' NAVD	**16' NAVD**	**18' NAVD**	**12'& 14' NAVD**
Harrison Section 1	$1,480,500	$613,600	$196,800	$6,806,400
Harrison Section 2	$365,400	$149,400	$60,400	$1,358,400
Kearny Section	$3,704,600	$1,366,700	$412,500	$28,122,200
Newark Section	$3,872,100	$1,632,000	$552,600	$22,658,000
Minish Park	$1,731,700	$758,800	$263,200	$1,731,700
Newark Flanking Section	$849,800	$233,500	$30,000	$849,800
Newark Gap	$1,320,600	$1,320,600	$1,320,600	$1,320,600
Totals	*$13,324,700*	*$6,074,600*	*$2,836,100*	*$62,847,100*

Price Level: February 2015
3.125% Discount Rate, 50-year period of analysis

Table 27 - Summary of Line of Protection Benefits Equivalent Annual Benefits				
Economic Reach	**Floodwall Alternative Elevations**			**LPP**
	14' NAVD	**16' NAVD**	**18' NAVD**	**12'&14' NAVD**
Harrison Section 1	$5,325,900	$6,192,800	$6,609,600	$0
Harrison Section 2	$993,000	$1,209,000	$1,298,000	$0
Kearny Section	$24,417,600	$26,755,500	$27,709,700	$0
Newark Section	$18,785,900	$21,026,000	$22,105,400	$0
Minish Park	$2,391,600	$3,364,500	$3,860,100	$2,391,600
Newark Flanking Section	$7,871,000	$8,487,300	$8,690,800	$7,871,000
Newark Gap	$0	$0	$0	$0
Totals	*$59,785,000*	*$67,035,100*	*$70,273,600*	*$10,262,600*

Price Level: February 2015
3.125% Discount Rate, 50-year period of analysis

Screening of Plan Components

82. Comparing annual costs to equivalent annual benefits of the proposed line of protection alternatives on a section-by-section basis reveals that all of the floodwall alternatives are viable for all sections except for Harrison Section 2. This section was consequently eliminated from further consideration in the study.

Table 28 - Screening of Plan Components Equivalent Annual Damage					
Project Section	Annual	Project Alternative			
		14 ft NAVD	*16 ft NAVD*	*18 ft NAVD*	*LPP*
Harrison Section 1	Benefits	$5,326,000	$6,193,000	$6,610,000	$0
	Costs	$3,261,000	$3,585,000	$3,819,000	$0
	Net Benefits	$2,065,000	$2,608,000	$2,791,000	$0
	BCR	1.6	1.7	1.7	0.0
Harrison Section 2	Benefits	$993,000	$1,209,000	$1,298,000	$0
	Costs	$2,398,000	$2,841,000	$3,370,000	$0
	Net Benefits	-$1,405,000	-$1,632,000	-$2,072,000	$0
	BCR	0.4	0.4	0.4	0.0
Kearny Section	Benefits	$24,418,000	$26,756,000	$27,710,000	$0
	Costs	$11,838,000	$13,054,000	$13,912,000	$0
	Net Benefits	$12,580,000	$13,702,000	$13,798,000	$0
	BCR	2.1	2.0	2.0	0.0
Newark Section	Benefits	$18,786,000	$21,026,000	$22,105,000	$0
	Costs	$10,554,000	$11,042,000	$12,647,000	$0
	Net Benefits	$8,232,000	$9,984,000	$9,458,000	$0
	BCR	1.8	1.9	1.7	0.0
Minish Park	Benefits	$2,392,000	$3,365,000	$3,860,000	Included in Newark Flanking Section
	Costs	$358,000	$497,000	$834,000	
	Net Benefits	$2,034,000	$2,868,000	$3,026,000	
	BCR	6.7	6.8	4.6	
Newark Flanking Section	Benefits	$7,871,000	$8,487,000	$8,691,000	$10,263,000
	Costs	$538,000	$606,000	$702,000	$2,261,000
	Net Benefits	$7,333,000	$7,881,000	$7,989,000	$8,002,000
	BCR	14.6	14.0	12.4	4.5
Total Benefits		*$59,786,000*	*$67,036,000*	*$70,274,000*	*$10,263,000*
System Net Benefits		*$30,839,000*	*$35,411,000*	***$34,990,000***	***$8,002,000***

Price Level: February 2015 (Benefits), 2016 (Costs)
3.125% Discount Rate, 50-year period of analysis

NED Plan Optimization

83. It is apparent from Table 28 that the estimated with-project damages are reduced with a higher stillwater design - all of which are much less than the No-Action Plan. In order to identify the NED Plan, the cost of each design level was compared to the associated benefits

to determine the design with the highest Net Benefits. For this stage of the study, the net benefits were refined by the addition of the residual interior drainage damages to the analysis. The interior drainage damages were analyzed separately from the line of protection and were based on 16 individual ponding areas behind the Newark, Harrison, and Kearny line of protection sections, and discussion of the facilities implemented to reduce interior damages to these levels are provided in the Interior Drainage Section of the Engineering Appendix.

84. It should be noted that while residual interior drainage damages were not evaluated for the Minish Park and Newark Flanking Sections since the complexity of the required analysis was beyond the scope of the study at its current stage, but they are not anticipated to be of sufficient magnitude to make floodwall implementation covering these reaches unviable. Table 29 presents the refined with-project equivalent annual damages for each plan and section.

85. Following Table 29, Table 30 presents the total benefit and cost relationships for the three stillwater design levels. Quantities, costs and plan details for the three designs are provided in the Engineering Appendix. As shown in Table 30, the 18 ft. alternative provides the highest the net benefits of the three stillwater design levels and was selected as the NED Plan.

Table 29
Total With Project Equivalent Annual Damage (Reaches included in Selected Plan)

Reach	**Floodwall Alternative Elevations**			**LPP**
	14' NAVD	**16' NAVD**	**18' NAVD**	**12'&14' NAVD**
Harrison Section 1				
Line of Protection	$1,480,500	$613,600	$196,800	$0
Interior Drainage	$210,600	$210,600	$210,600	$0
Total	*$1,691,100*	*$824,200*	*$407,400*	*$0*
Kearny Section				
Line of Protection	$3,704,600	$1,366,700	$412,500	$0
Interior Drainage	$152,300	$152,300	$152,300	$0
Total	*$3,856,900*	*$1,519,000*	*$564,800*	*$0*

Table 29 Total With Project Equivalent Annual Damage (Reaches included in Selected Plan)				
Reach	**Floodwall Alternative Elevations**			**LPP**
	14' NAVD	**16' NAVD**	**18' NAVD**	**12'&14' NAVD**
Newark Section				
Line of Protection	$3,872,100	$1,632,000	$552,600	$0
Interior Drainage	$963,600	$963,600	$963,600	$0
Total	*$4,835,700*	*$2,595,600*	*$1,516,200*	*$0*
Minish Park Section				
Line of Protection	$1,731,700	$758,800	$263,200	$1,731,700
Interior Drainage*	$0	$0	$0	$0
Total	*$1,731,700*	*$758,800*	*$263,200*	*$1,731,700*
Newark Flanking Section				
Line of Protection	$849,800	$233,500	$30,000	$849,800
Interior Drainage*	$0	$0	$0	$0
Total	*$849,800*	*$233,500*	*$30,000*	*$849,800*
Total With Project Damage	***$12,965,200***	***$5,931,100***	***$2,781,600***	***$2,581,500***

Price Level: February 2015
3.125% Discount Rate, 50-year period of analysis
*Interior drainage damage not estimated for this reach

Table 30 - Economic Comparison of Plans Total Equivalent Annual Benefit and Costs					
Project Section	**Annual**	**Project Alternative**			**LPP**
		14 ft NAVD	***16 ft NAVD***	***18 ft NAVD***	**12'&14' NAVD**
Harrison Section 1	Benefits	$5,253,000	$6,143,000	$6,571,000	$0
	Costs	$3,261,000	$3,585,000	$3,819,000	$0
	Net Benefits	$1,992,000	$2,558,000	$2,752,000	$0
	BCR	1.6	1.7	1.7	0.0
Kearny Section	Benefits	$24,917,000	$27,317,000	$28,297,000	$0
	Costs	$11,838,000	$13,054,000	$13,912,000	$0
	Net Benefits	$13,079,000	$14,263,000	$14,385,000	$0
	BCR	2.1	2.1	2.0	0.0
Newark Section	Benefits	$18,300,000	$20,601,000	$21,708,000	$0
	Costs	$10,554,000	$11,042,000	$12,647,000	$0
	Net Benefits	$7,746,000	$9,559,000	$9,061,000	$0
	BCR	1.7	1.9	1.7	0.0

Table 30 - Economic Comparison of Plans Total Equivalent Annual Benefit and Costs					
Project Section	**Annual**	**Project Alternative**			**LPP**
		14 ft NAVD	***16 ft NAVD***	***18 ft NAVD***	**12’&14' NAVD**
Minish Park	Benefits	$2,456,000	$3,455,000	$3,964,000	Included in Newark Flanking Section
	Costs	$358,000	$497,000	$834,000	
	Net Benefits	$2,098,000	$2,958,000	$3,130,000	
	BCR	6.9	7.0	4.8	
Newark Flanking Section	Benefits	$8,082,000	$8,715,000	$8,924,000	$10,538,000
	Costs	$538,000	$606,000	$702,000	$2,261,000
	Net Benefits	$7,544,000	$8,109,000	$8,222,000	$8,277,000
	BCR	15.0	14.4	12.7	4.7
Total Benefits		*$59,008,000*	*$66,231,000*	*$69,464,000*	*$10,538,000*
System Net Benefits		*$32,459,000*	*$37,447,000*	*$37,550,000*	*$8,277,000*
Selected as NED Plan		☐	☐	✓	☐

Price Level: June 2016 (Benefits updated from 2015 Price Level using Consumer Price Index)3.175% Discount Rate, 50-year period of analysis

Sensitivity Testing: Sea Level Rise

86. As mentioned in an earlier section, Current USACE guidance requires that potential relative sea level change must be considered in every USACE coastal activity as far inland as the extent of estimated tidal influence. The base level of potential relative sea-level change is considered the historically recorded changes for the study site, which is estimated to be an increase of 0.0134 feet/year. All economic analyses for which results are tabulated in previous sections of this report were based on this historic rate of sea level change. However, in accordance with Engineering Regulation ER 1100-2-8162 (incorporating Sea Level changes in Civil Works Program, 31 Dec 2013), proposed projects must be also evaluated for a range of possible sea level rise rates: In addition to the historical rate (“low”) which is a 0.7 ft. increase over the period of analysis, the project was also evaluated using “intermediate” and “high” rates derived from modified NRC Curves I and III, which for this Interim Study are estimated to be 1.2 ft. and 2.8 ft. increases, respectively over the fifty year period of analysis.

87. In addition to the three stillwater design levels of 14, 16, and 18 feet NAVD, an additional analysis was conducted to evaluate the effectiveness of an ‘adaptable’ 16 Ft NAVD plan.

Under this plan (referred to as '16A') the floodwalls would be constructed initially to the 16 Ft NAVD stillwater elevation design, but would be modified to raise the wall height to the 18 Ft NAVD design at some point in the future. Plan 16A was analyzed and benefits were computed in HEC-FDA for the "Intermediate" and "High" sea level rise conditions under the assumption that the wall height would be raised when the sea level rise matched the total 50-year sea level rise under the historic/lower bound condition. This elevation is anticipated to be reached in year 30 in the Intermediate condition and in year 15 in the High condition.

88. The results of all analyses under all three sea level rise conditions are presented in Table 31. For Plan 16A, the cost estimate was revised to incorporate additional items including modifications to the foundations at initial construction to facilitate a larger wall in the future, in addition to the future extension of the wall height. This analysis indicates that the Adapted 16 Ft wall would not supplant the 18 Ft wall as the NED Plan under either of the two higher sea level rise scenarios.

Table 31
Impacts of Sea Level Rise on Damages and Benefits

Damages/ Benefits	Condition/ Alternative	Historic "Low"	Curve I "Intermediate"	Curve III "High"
Equivalent Annual Damages	WoP	$73,110,000	$84,123,000	$124,946,000
	L14	$15,644,500	$17,663,500	$24,351,500
	L16	$8,610,500	$9,743,500	$13,844,500
	L16A		$8,285,500	$10,062,500
	L18	$5,460,500	$6,141,500	$8,660,500
	LPP	$62,847,100	Pending	Pending
Total Benefits	*L14*	*$57,465,500*	*$66,459,500*	*$100,594,500*
	L16	*$64,499,500*	*$74,379,500*	*$111,101,500*
	L16A		*$75,837,500*	*$114,883,500*
	L18	*$67,649,500*	*$77,981,500*	*$116,285,500*
	LPP	*$10,263,000*	Pending	Pending
Annual Costs	L14	$26,549,000	$26,549,000	$26,549,000
	L16	$28,784,000	$28,784,000	$28,784,000
	L16A		$32,219,000	$34,344,000
	L18	$31,914,000	$31,914,000	$31,914,000
	LPP	$2,261,000	$2,261,000	$2,261,000

Table 31 Impacts of Sea Level Rise on Damages and Benefits				
Damages/ Benefits	**Condition/ Alternative**	**Historic "Low"**	**Curve I "Intermediate"**	**Curve III "High"**
Net Benefits	L14	*$30,916,500*	*$39,910,500*	*$74,045,500*
	L16	*$35,715,500*	*$45,595,500*	*$82,317,500*
	L16A		*$43,618,500*	*$80,539,500*
	L18	***$35,735,500***	***$46,067,500***	***$84,371,500***
	LPP	*$8,002,000*	Pending	Pending
BCR	L14	2.2	2.5	3.8
	L16	2.2	2.6	3.9
	L16A		2.4	3.3
	L18	2.1	2.4	3.6
	LPP	4.6	Pending	Pending

Sub Appendix A

Line of Protection - Project Performance

Line of Protection - Project Performance and Risk Analysis

1. ER 1105-2-101, “Risk Analysis for Flood Damage Reduction Studies (USACE, January 3, 2006) stipulates that the risk analysis for a flood risk reduction 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 all the evaluated line of protection alternatives under the low sea level rise condition has been computed by HEC-FDA and the results are presented in Table A1.

2. 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.

3. The target stage for each reach was used in HEC-FDA to calculate the base year median and expected annual exceedance probability for the NED Plan. The median value reflects the basic as-designed performance of the plan without the application of uncertainty to the basic discharge-frequency and stage-discharge functions, while the expected value is computed from the results of the Monte Carlo simulations which take into account uncertainty in hydrologic/hydraulic functions and project features such as diversion structures. Hence the difference between the two is an indication of the uncertainty associated with the project performance.

4. The long-term risk of exceedance is the probability that the design stage will be exceeded at least once in the specified durations of 10, 30, and 50 years, and the conditional non-exceedance probability measures the likelihood that the project will not be exceeded by a specified hydrologic event. For this analysis the base year conditional non-exceedance probability has been computed for each alternative for the 10%, 4%, 2%, 1%, 0.4% and 0.2% annual chance exceedance events (10-, 25-, 50-, 100-, 250- and 500-year floods). These indicators of project performance and residual risk for the evaluated alternatives under the low sea level rise scenario are presented in Table A2.

5. Additionally, the same performance criteria have been computed in HEC-FDA for the NED plan at the end of the 50-year period of analysis under the Intermediate and High sea level rise scenarios, and the results are presented in Table A3.

Table A1 Expected and Probabilistic Values of Structure/Contents Damage Reduced						
Alternative	Equivalent Annual Damage **(Line of Protection Only)**			Probability that Damage Reduced Exceeds the Indicated Values		
	Without Project	With Project	Damage Reduced	75%	50%	25%
14' NAVD	$70,430,600	$11,638,700	$58,791,900	$44,130,200	$58,669,700	$73,138,300
16' NAVD	$70,430,600	$4,604,600	$65,826,000	$47,229,400	$64,018,500	$82,374,700
18' NAVD	$70,430,600	$1,455,100	$68,975,500	$48,423,000	$66,220,300	$86,424,300

Base Year only

Table A2 Project Performance Analysis - Line of Protection				
Performance and Reliability Criteria		**14 ft NAVD**	**16 ft NAVD**	**18 ft NAVD**
Annual Exceedance Probability of Target Stage	Median	0.32%	0.10%	0.02%
	Expected	0.45%	0.14%	0.04%
Long Term Exceedance Probability	10 Years	4%	1%	0.4%
	30 Years	13%	4%	1%
	50 Years	20%	7%	2%
Conditional Non-Exceedance Probability	10%	100%	100%	100%
	4%	100%	100%	100%
	2%	100%	100%	100%
	1%	91%	100%	100%
	0.40%	59%	95%	100%
	0.20%	29%	80%	99%

Base Year only

Table A3 Project Performance Analysis - 18 Ft Line of Protection Intermediate and High Sea Level Rise			
Performance and Reliability Criteria		**Curve I**	**Curve III**
Annual Exceedance Probability of Target Stage	Median	0.15%	0.18%
	Expected	0.21%	0.19%
Long Term Exceedance Probability	10 Years	2%	17%
	30 Years	6%	45%
	50 Years	10%	61%
Conditional Non-Exceedance Probability	10%	100%	100%
	4%	100%	94%
	2%	100%	58%
	1%	99%	23%
	0.40%	87%	4%
	0.20%	63%	1%