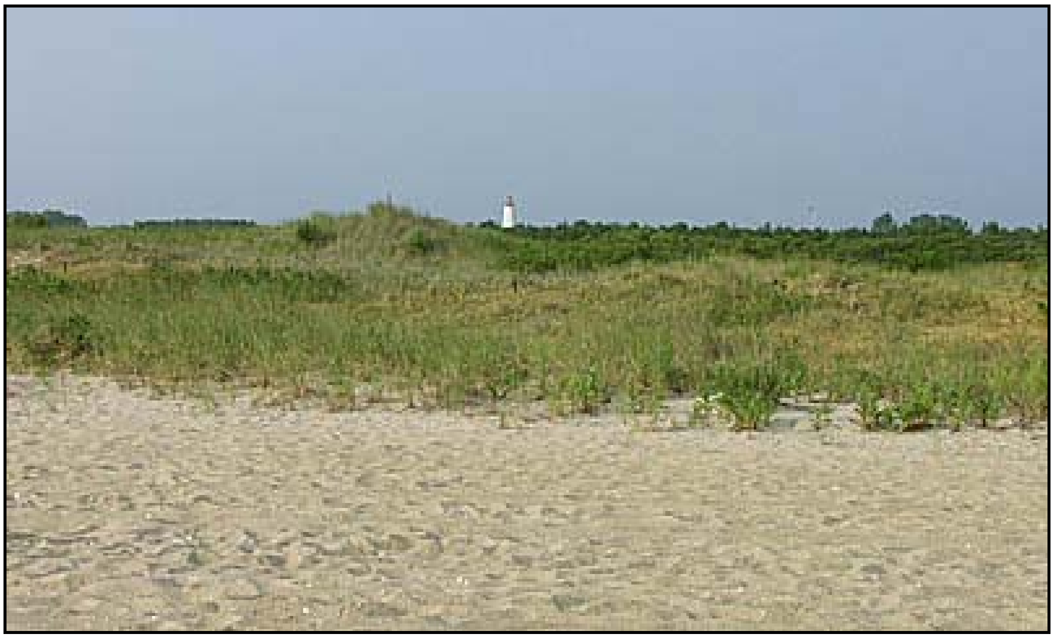
HUDSON-RARITAN ESTUARY
ENVIRONMENTAL RESTORATION FEASIBILITY STUDY

LOWER BAY

STUDY AREA REPORT



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I. INTRODUCTION

Background

1. The New York District of the Corps of Engineers (the District) is conducting a feasibility study for ecosystem restoration in the Hudson-Raritan Estuary (the Estuary) – the Hudson-Raritan Estuary Ecosystem Restoration Study, herein referred to as "HRE". The study area is delineated as the Port District, an area surrounding greater metropolitan New York City within an approximate 25-mile radius of the Statue of Liberty (Figure 1). However, for purposes of ecological continuity the actual study area may include additional portions of this system beyond the man-made Port District boundary.

2. The overall goal of the HRE is to restore ecological function and diversity that have been lost or degraded as a result of human activities. The HRE will rely on both existing and newly obtained natural resource data to identify areas to be restored or conditions that must be addressed to assure successful ecosystem restoration. The two primary components of the study are the preparation of a Comprehensive Restoration Implementation Plan (CRIP) and the implementation of restorations/enhancements at various locations in the Estuary.

3. The purpose of the CRIP is to serve as a master plan that lays out a comprehensive and coordinated strategy that, when implemented, will guide the ecological restoration of the Estuary. The CRIP will establish a framework within which the actions needed for successful restorations can be holistically evaluated and planned. The plan will address actions to enhance, expand, recreate, and diversify natural habitats, and actions to eliminate constraints to ecological functions, such as sediment contamination. The CRIP will describe the strategy for restoration efforts that will include immediate, mid-term, and long-range options. It will also provide a central focus for public input, data collection, restoration efforts, and management actions and policies, regardless of who might have authority, desire and/or funds to undertake any action.

Study Area Delineation of the Estuary

4. To get a more manageable and understandable picture of the Estuary, its history of degradation, local needs and desires, potential restoration opportunities, and current restoration efforts will be documented in eight Study Area Reports (SARs). The study area boundaries are typically delineated by major watersheds and/or major physical features, such as highways or waterways. By and large, each study area can be characterized by its ecological functions, history of degradation, and resulting needs and opportunities. For example, Jamaica Bay, a historically expansive wetlands complex, has been subject to extensive fill and loss of wetlands; the Hudson River system, to hardened shorelines and contaminated sediment; and the Lower Bay contains coastal and offshore environments, experiencing loss of dunes and benthic habitat. Separating the project area into smaller study areas will enable the study team and potential stakeholders to address study area-specific restoration needs as well as individual restoration opportunities within each study area, and to collect and characterize data in a more usable and understandable way, all under the ultimate umbrella of the CRIP, which links the study areas into one major plan.

5. The eight study areas to be included in the CRIP are as follows (see Figure 1):

1) Jamaica Bay,
2) Lower Bay,
3) Lower Raritan River,
4) Arthur Kill/Kill van Kull,
5) Newark Bay/Hackensack River/Passaic River,
6) Lower Hudson River,
7) Harlem River/East River/Western Long Island Sound,
8) Upper Bay.

Purpose of the Study Area Reports

6. The identification of potential restoration opportunities in each study area will be a two-fold process. First, the District will identify potential restoration sites based upon a preliminary needs and opportunities survey of various interested groups/agencies conducted by the Regional Planning

Association (RPA) and presented in their Needs and Opportunities Report. This information will be supplemented by additional analyses of restoration needs and opportunities on a more local level. Study area needs will be determined based upon the causes of ecosystem degradation and the condition of existing natural resources in each study area. This effort is already underway (but far from completed) and potential restoration sites in the Lower Bay have been identified.

7. Second, the District will hold stakeholder meetings in each study area. The purpose of these meetings will be to incorporate additional comments from environmental organizations, community groups, and other individuals and stakeholders in each study area. This process will ensure the needs and opinions of as wide and diverse a group as possible is incorporated into the CRIP.

Format of the Report

8. This SAR addresses the Lower Bay study area (Figure 2). The **Study Area Description** section describes the setting, history of degradation, existing land/water usage, and existing natural resources in the study area. Restoration needs and existing restoration efforts are summarized in the **Ecosystem Restoration** section.

II. STUDY AREA DESCRIPTION

Setting

9. The Lower Bay forms the southeastern extent of the HRE study area and includes Lower New York Bay, Sandy Hook Bay, Raritan Bay and surrounding uplands of Middlesex and Monmouth Counties, New Jersey and Richmond County, New York (Figure 2).

Study Area History

10. Major changes to the natural landscape within the study area began with European settlement. Although the early European settlers relied heavily on the study area through the late 1700s, the study area's natural character was not greatly impacted. However, over the next two centuries the Lower Bay watershed would become a center for commerce and manufacturing with dramatic effects.

11. The New York Metropolitan Region surrounds the HRE and is one of the most densely populated areas in the United States. The waterfront has been the center of shipping and industry for over 150 years. Residential, commercial, and recreational development has impaired human uses and ecosystem function within the HRE.

History of Degradation

12. The majority of upland and wetland shoreline habitats in the Lower Bay study area have been degraded by industrial, commercial, and residential uses. As a result of industrial activities, toxic contaminants such as heavy metals, hydrocarbons, PCBs, and PAHs are present in the sediments. Numerous studies of the problems have been undertaken by various organizations and agencies, including the Environmental Protection Agency, the National Oceanic and Atmospheric Administration (NOAA), the USACE, and the States of New York and New Jersey, which have focused on the relationship between sediment contaminant levels and benthic habitat quality.

13. Sediment contamination is pronounced in Raritan Bay as a result of outflow from the Arthur Kill and Raritan River. Toxicity levels in the study area are highest in Western Raritan Bay. Because contamination in the study area is so high, shellfisheries in this area have been closed and fish

consumption advisories have been issued. Previous studies have identified areas within the Lower Bay study area as containing slightly elevated levels of arsenic, copper, and mercury, and moderate to high levels of nickel, silver, zinc, and chromium. Aldrin and hexachlorobenzene "hotspots" are also present in the Lower Bay. More detailed discussions and results of past and current studies of sediment contamination are described in the more detail in the *Summary of Sediment Characterization Studies* (USACE – under development).

14. Wetland loss and modification has been substantial as a result of residential, commercial, and industrial development along the waterfront. Fill and altered hydrologic regimes in tidal and freshwater wetlands have allowed common reed to become the one of the predominant land cover type in many wetlands. Common reed is prevalent in many areas.

15. Riparian and shoreline habitats have also been degraded. Construction of bulkheads and flood control structures has eliminated much of the natural shoreline habitat. Breakwaters and riprap have been installed in many locations to prevent beach loss; however, the natural beach dynamics have been disrupted from this action.

16. Hydrologic modifications and construction of man-made structures such as bridges, dams, and tide gates have restricted tidal flow in numerous locations. This restricted flow has led to the degradation of wetland habitats, allowed for invasion by common reed, and led to the decline of historically productive oyster beds. These structures also act as impediments to anadromous fish.

17. Low dissolved oxygen (DO) concentrations are a continuous problem, particularly in Raritan Bay. Eutrophication in the bay is likely the result of excess nutrients that enter the water column from sewage treatment plants, CSOs, and non-point sources. Fish kills occasionally occur in the Lower Bay, presumably as a result of low DO levels. Excess nutrients also are the likely cause of the elimination of submerged aquatic vegetation beds in the study area.

Existing Land/Water Usage

18. The landscape surrounding the Lower Bay is predominantly developed. Along the waterfront land and water uses include marinas, marine parks, parkland, vacant disturbed land (wetlands and uplands), tidal wetlands, and residential land. Surface water is used for commercial shipping,

swimming, and non-contact recreation, such as fishing, boating, water/jet skiing, and windsurfing. The study area has a large and active recreational and commercial fishery. The NYC Department of Parks operates numerous public bathing beaches along the southern shore of Staten Island (Great Kills, Huguenot, Midland, New Dorp, Oakwood, South, Tottenville, and Wolf's Pond Park Beaches) and on Coney Island (Brighton, Coney Island, Manhattan, and Oriental Beaches). In addition, there are approximately 24 miles of beaches along the southern shore of the Raritan Bay in Monmouth County, NJ, and several private beaches located along these same shorelines. Water quality is monitored at these beaches and when total coliform concentrations exceed their criterion an advisory on bathing is issued until further testing shows compliance.

19. Public parks and open space present in the study area include, but are not limited to, the Sandy Hook unit of Gateway National Recreation Area, Hartshorn Woods, Huber Woods, and Fisherman's Cove Conservation Area.

20. Four sewage treatment plants (STPs) discharge treated wastewater that is assimilated by the receiving waters: the Bayshore Regional Sewage Authority (Monmouth County, NJ); the Middletown Township Sewerage Authority (Monmouth County, NJ); the Middlesex County Utilities Authority (Middlesex County, NJ); and the Oakwood Beach STP owned and operated by New York City Department of Environmental Protection (NYCDEP) (Richmond County, NY). There are no power plants withdrawing cooling water from the Lower Bay.

Natural Resources Conditions

21. Raritan Bay and Sandy Hook Bay have relatively shallow subtidal areas, compared to Lower New York Bay, which is deeper and is considered more of a marine habitat. The study area contains significant habitat for shellfish and marine, estuarine, and anadramous fish. Open water habitats in the study area are important for wintering and migratory waterfowl. Wetlands and uplands in the study area provide important nursery habitat for fish, foraging habitat for waterbirds and shorebirds, nesting habitat for diamond-backed terrapins, and migratory and wintering stopovers for songbirds, raptors, and shorebirds. In addition, several rare ecological communities and plant species are present in the study area.

22. Major tributaries to the Lower Bay include the Raritan, Navesink, and Shrewsbury Rivers in New Jersey. Several small tributaries originate in Staten Island, New York and flow into the Lower Bay. The Hudson, Passaic, and Hackensack Rivers are considered to have indirect flow in this study area.

23. A large proportion of wetland and upland areas in the study area have been developed. The remaining undeveloped land is characterized by tidal salt marshes, beaches, dunes, intertidal mudflats, shallow subtidal mudflats, upland forest, forested wetlands, and grass/scrub-shrub uplands.

24. Salt marshes in the study area are dominated by cordgrass (*Spartina alterniflora, S. patens*), with black grass (*Juncus gerardii*), marsh elder (*Iva frutescens*), and groundsel bush present in the high-tide zone. Common reed (*Phragmites communis*) is an invasive plant found in many of the wetlands in the study area. In addition, salt marsh and dredge material islands also exist.

25. Upland forests in the study area are comprised of species such as black cherry (*Prunus serotina*), oaks (*Quercus* spp.), hickory (*Carya* sp.), and tree-of-heaven (*Ailanthus altisima*). The understory of theses forests usually includes the following species: mountain laurel (*Kalmia latifolia*), and arrowwood (*Viburnum* spp.). Forested wetlands are dominated by sweet gum (*Liquidambar styraciflua*), red maple (*Acer rubrum*), and black gum (*Nyssa sylvatica*). Many of the forested habitats in the region have been fragmented by human development.

26. Sandy Hook is a sand spit comprised of several unique habitats in the study area. This sand spit extends north from the New Jersey mainland into New York Harbor and divides the open ocean to the east from the Sandy Hook, Raritan, and Lower New York Bays to the west. On the ocean side, the southern shoreline is reinforced by a seawall and groin field. Despite these reinforcements, erosion is a continual problem. Deposition of sands and sediments is occurring at the northern end of the spit where extensive foredune and backdune areas are present. Foredunes are vegetated with beach grass (*Ammophila breviligulata*). Backdune areas are dominated by winged sumac (*Rhus copallina*), bayberry (*Myrica pennsylvanic*), and beach plum (*Prunus martima*). Dune habitat is limited elsewhere in the study area due to intense development along the shoreline.

27. Remnant patches of rare maritime forest, a once common community, exist on Sandy Hook. Maritime forests are dominated by American holly (*Ilex opaca*), black cherry, serviceberry (*Amelanchier Canadensis*), greenbriar (*Smilax rotundifolia*), and poison ivy (*Toxicodendron radicans*).

28. This study area is ecologically significant because of its geographic location and the presence of a variety of habitat types. The Sandy Hook Peninsula separates the Atlantic Ocean from the southern portion of the Estuary. Sandy Hook and Sandy Hook Bay are located at the junction between the east-west oriented coastline of New England and the north-south oriented coastline of the mid-Atlantic study area. This configuration concentrates fish and wildlife species migrating to and from New England and the mid-Atlantic coast. Development in the surrounding upland areas further concentrates migratory species into the remaining undeveloped open space (both upland and wetland) and open water areas in the Lower Bay.

29. Over 90 species of fish have been reported in the Lower Bay. Resident species include mummichog (*Fundulus heteroclitus*), white perch (*Morone americana*), and hogchoker (*Trinectes macalatus*). Fish species of recreational importance found in the study area include, but are not limited to, bluefish (*Pomatomus saltatrix*), striped bass (*Morone saxatilis*) weakfish (*Cynoscion regalis*), and winter flounder (*Pleuronectes americanus*). The Lower Bay study area, particularly around Raritan and Sandy Hook Bays, support important commercial fisheries for Amercian shad (*Alosa sapidissima*), American eel (*Anguilla rostrata*), and American lobster (*Homarus americanus*). Blue crab (*Callinectes sapidus*) and horseshoe crab (*Limulus polyphemus*) are also harvested. Commercial quantities of shellfish are present; however, portions of the study area are closed to shellfish harvesting because of pollution. Although the fish community in the Lower Bay study area is diverse, habitat quality for some species (particularly those that swim upstream to spawn) has been reduced as a result of human alteration of the landscape. For example, dams on the Swimming River and the Shadow Lake branch of the Navesink River prevent anadromous fish from reaching upstream areas to spawn. Species that have been confirmed at the base of these dams alewife (*Alosa pseudoharengus*) and blucback herring (*Alosa aestivalis*).

30. The study area also provides for marine mammals and sea turtles. Harbor seals (*Phoca vitulina vitulina*), ringed seals (*Phoca hispida*), and harp seals *(Phoca groenlandica*) are commonly seen off of Sandy Hook Peninsula. Loggerhead sea turtles (*Caretta caretta caretta*) and Atlantic ridley sea turtles *(Lepidochelys kempii*) are often seen feeding in the offshore waters of Sandy Hook Bay.

31. The Lower Bay study area is provides significant wintering and migratory habitat for waterfowl species including greater scaup (*Aythya* spp.), Canada goose (*Branta candensis*), American black duck (*Anas rupripes*), brant (*Branta bernicla*), and long-tailed duck (*Clangula hyemalis*). Breeding waterbirds include American black duck, mallard (*Anas platyrhynchos*), clapper rail (*Rallus longirostris*), marsh wren (*Cistothorus palustris*), and willet (*Cataptrophours semipalmatus*).

32. The study area is an important stopover for migratory landbirds and shorebirds. During spring and fall migration sanderling (*Calidris alba*), ruddy turnstone (*Arenaria interpres*), and semipalmated sandpiper (*Calidris pusilla*) forage in the mudflats and subtidal shallows along the south shores of Monmouth County and Staten Island.

33. The majority of upland and wetland areas have been developed or their uses impaired due to industrial, commercial, and residential uses. Industrial use has resulted in discharges of toxics. Oils spills are common and water quality is degraded due to point and non-point sources of pollution. Low concentrations of dissolved oxygen occasionally cause fishkills in the study area. Shoreline and nearshore habitats have been degraded as a result of bulkhead and sea wall construction. Extensive human use of beach areas degrades habitat quality for beach-nesting species, such as the piping plover (*Charadrius melodus*).

III. ECOSYSTEM RESTORATION

34. The New York-New Jersey Harbor Estuary Program (HEP 1996) has identified five primary factors that have caused ecosystem impairments or otherwise degraded water or habitat quality in the Estuary. These factors are:

- Habitat Loss and Degradation: Recent wetland inventories estimate at least 80% of the Estuary's wetlands have been lost or significantly altered.

- Toxic Contamination: The presence of toxins in the Estuary's waters, sediments, and biota is the result of historic and residual contamination by industrial and non-point sources. Today, wastewater discharges, combined sewer overflows (CSOs), accidental releases, vehicle exhaust emissions, household chemicals, pesticides, atmospheric deposition, landfill leachate, urban runoff, and other non-point sources are continuing sources of toxic substances (HEP 1996).

- Pathogens: The primary sources of pathogens include CSOs, sewage treatment plant malfunctions, illegal connections to storm sewers, vessel sewage discharge, urban runoff, and other non-point sources.

- Floatable Debris: Floatable debris is made up of two primary components: trash or litter and harbor drift. Trash and litter enters the Estuary via runoff, storm sewer discharges, CSOs, beach and boat litter, and poor solid waste handling operations. Harbor drift composed primarily of material from dilapidated shoreline structures such as piers, bulkheads, and pilings, is a significant of floatable debris in the Estuary.

- Nutrient and Organic Enrichment: Eutrophication due to excessive discharges of nitrogen is a significant problem in the Estuary. Organic matter comprised primarily of carbon is decomposed as DO and used in the biochemical process. Nitrogen and carbon enter the Estuary through point and non-point sources such as sewage treatment plants, runoff (primarily from over-fertilized lawns), rivers and tributaries and atmospheric deposition.

Primary Restoration Needs of the Hudson-Raritan Estuary

35. The overall goal of the HRE is to restore and enhance aquatic and nearshore terrestrial habitats that have been lost or degraded as a result of human activities. To achieve this goal, primary restoration needs of the Estuary have been established. These categories were identified in the document entitled *Restoration Opportunities in the Hudson-Raritan Estuary* (USACE 2001). These need are:

- Restore and create intertidal wetlands and mudflats,
- Restore benthic habitats and remediate "hot spots" of contaminated sediments,
- Restore and create freshwater/riparian wetlands,
- Restore fish habitat (remove impediments to fish passage; construct artificial reefs),
- Restore shellfish habitat,
- Restore and enhance shoreline/coastal fringe habitat (including upland areas),
- Create, restore, or enhance vegetated and non-vegetated shallow water habitat.

Restoration Needs of the Lower Bay Study Area

36. The natural ecosystems of the Lower Bay study area have been dramatically altered due to human activities. However, given current use and level of development, the goal of ecosystem restorations may not always be to restore a given area to previous, "historic" conditions. More realistic goals may involve restoring what is left through the establishment of native vegetation or clean-up of contaminated sediments.

37. The RPA (2003) *Needs and Opportunities for Environmental Restoration in the Hudson-Raritan Estuary* identified restoration needs for the Raritan Bay. These needs can, in general, be applied to the entire Lower Bay study area and are described in more detail below.

Creation of Shellfish and Reef Habitat

38. The Lower Bay study area also provides many opportunities for restoration of shellfish habitat. Artificial reefs could be constructed and seeded with oysters or other species grown by local

community groups. This type of restoration effort has been successful in the study area. The Estuary historically contained nearly 35 square miles of oyster reef. The Lower Bay study area is the largest expanse of open water in the Estuary and opportunities for reef creation may exist here.

Protect/Restore Existing Wetlands and Create New Wetlands

39. Tidal wetlands in tributary creek mouths and other tidal areas should be restored to remove invasive species, improve tidal flow, and enhance habitat for fish and wildlife. Tidal flow can be restored in filled wetlands by regrading and removing fill. Invasive species can be eliminated to allow the reestablishment of native salt marsh vegetation (e.g., *Spartina* spp.). Restoration of these habitats will improve foraging habitat for wading birds, waterfowl, raptors, and fish. Erosion is a problem in many of the saltmarsh areas because of high wave energy in the study area. Wave attenuation structures should be incorporated into restoration plans for this study area to reduce erosion problems in restored marshes. Mudflats can be created by recontouring former shallow water habitats using clean dredge material. Increasing the area of intertidal mudflats within the study area will improve habitat for benthic invertebrates and provide foraging habitat for shorebirds.

40. Intertidal wetland and mudflat areas should be restored to remove invasive species. Filled wetland sites should be regraded to restore tidal flow, eliminate common reed, and reestablish native salt marsh vegetation. Other blockages that restrict tidal flow should also be removed. Restoration of these habitats will improve foraging habitat for wading birds, waterfowl, raptors, and fish. Increasing the area of intertidal mudflats will improve habitat for benthic invertebrates and provide foraging habitat for shorebirds.

41. Like many of the tidal wetlands in the study area, freshwater and riparian wetlands have been degraded due to human disturbance and the placement of fill. Freshwater wetlands can be restored by removing fill, regrading, and planting native freshwater wetland vegetation. Managing stormwater runoff and restoring hydraulic connections between upland freshwater wetlands and riparian environments can enhance habitat in riparian zones. Restoration of freshwater wetlands will improve habitat for reptiles and amphibians (herpetofauna) as well as waterbirds.

42. Opportunities may also to increase the amount of wetlands within the study area by constructing new wetlands. Locations where it may be feasible to construct new wetlands include remediated brownfield sites, closed landfills, or other vacant upland parcels.

Restore Stream/River Habitat

43. There is also a need to restore stream and river habitat in the study area. This could be achieved by removing debris and structures that restrict tidal flow and fish movement. Fish ladders could be installed in areas where structures cannot be removed. Riparian habitat along many of the streams and rivers has been greatly reduced. Floodplain restoration efforts could be included in projects that involve restoration of stream and river habitat. Removal of fill and bulkheads could soften shorelines. Planting of native floodplain vegetation along newly softened shorelines could help improve water quality, reduce flooding, and provide wildlife habitat.

44. Several dams and other impediments to fish movement are present on Lower Bay tributaries. Anadromous fish runs could be restored to these tributaries through the installation of fish ladders and removal of debris blockage. Such efforts, combined with improved water quality, could help restore historic fish runs to tributaries such as the Navesink River and the Shrewsbury River.

45. Many freshwater wetlands and riparian areas have been filled or significantly disturbed. Freshwater wetlands can be restored through the removal of fill. Riparian wetlands and habitats can be improved by softening modified shorelines or removing fill from these areas, where feasible. Managing stormwater and restoring hydraulic connections between upland freshwater wetlands and riparian environments can enhance habitat in riparian zones. Restoration of freshwater wetlands will improve habitat for reptiles and amphibians (herpetofauna) as well as waterbirds

Remediate Leachate Sources, Persistent Oil Spill "Hotspots" and Contaminated Sediments

46. Efforts should be made to identify and remediate leachate sources in the study area. Leachate recovery and treatment systems could be installed or wetlands could be constructed to treat contaminated leachate from former landfills and industrial sites where groundwater contamination contributes to water quality problems.

47. Contaminated bottom sediments are a significant problem in the study area, particularly in the Raritan Bay. Some areas are "sources," which contribute to contamination of other areas when the sediments are transported by littoral currents. Other areas are "sinks" for contaminated sediments. These "sinks" accumulate contaminated sediments that are moved by the currents within the waters of the study area. Several options exist for the remediation of contaminated sediments. One potential option is to cap areas of contaminated sediments using clean dredge material. Another option is to remove the contaminated sediments by dredging and replacing the sediments that were removed with clean dredged material. Contaminated sediments that are removed from waterbodies in the study area could be treated and then used in upland locations. These treated sediments could, for example, be used to cap landfills or brownfields.

Restore/Remediate Brownfield Sites

48. Many abandoned industrial and commercial facilities (brownfield sites) adversely affect adjacent habitats as well as the habitats present within individual sites. Contamination at existing brownfield sites could be remediated and the sites restored to more ecologically viable conditions. Abandoned, man-made structures could be removed and native vegetation could be re-established. In addition, depending upon their position in the landscape, brownfield sites could be used to establish buffers between existing industrial uses and natural communities and, in many cases, serves as parks and open space as well.

Restore Upland Habitats

49. Upland habitats such as shoreline and coastal fringe should be restored or enhanced. These habitat types include beach and sand dune habitat, which is important habitat for several threatened and endangered species, including least tern and piping plover. Other upland habitats in the study area are severely fragmented and degraded. Enhancement of mainland upland and coastal fringe habitat will benefit nesting waterbirds, reduce fragmentation, and provide additional upland habitat for herpetofauna, mammals, and migratory and resident landbirds.

50. The study area contains pockets of undeveloped land across a highly developed landscape. In addition, many abandoned industrial sites exist. Opportunities may exist to restore these abandoned

properties to a natural state and link sites that are currently isolated from other natural areas. Connections between isolated natural areas have the potential to provide important corridors for fish and wildlife. These corridors could also serve as parks, trails, or other public open space areas that would provide passive and active recreational opportunities, as appropriate.

Existing Restoration Efforts

51. Habitat restoration work in the Estuary has been underway for some time and various organizations, most notably, the Harbor Estuary Program (HEP) Habitat Workgroup, have identified potential sites and sought to promote restoration efforts. Several habitat restoration initiatives have been completed or are moving forward in this study area. To date, feasibility studies and restoration activities have commenced only at Leonardo and Drier Offerman Park, respectively. In addition, other restoration efforts, such as the Keyport Oyster Reef Restoration have been completed in the study area.

Leonardo Site

52. The Leonardo site is located in Raritan Bay, near the town of Leonardo, Monmouth County, New Jersey. The site consists of a tidal creek that traverses an undeveloped area and flows into Raritan Bay. The undeveloped area is a former tidal wetland that was filled with dredged material, partially from the municipal boat basin. The majority of the site is dominated by common reed. Portions of the site are not vegetated while other areas include some sand dune vegetation.

Drier Offerman Park

53. Drier Offerman Park, a man-made peninsula, extends from the southwestern corner of Brooklyn, New York into Gravesend Bay. The shoreline of Gravesend Bay, within the park, extends approximately 3,200 linear feet and is reinforced with rubble and construction debris. A 20-acre embayment separates Drier Offerman Park from the adjacent Six Diamonds Park. The New York City Parks Department (Parks Department) manages both parks and the embayment. The Parks Department completed a tidal wetland and sand dune restoration project at Six Diamonds Park and is currently planning a similar project in Drier Offerman Park. The proposed project entails restoring

1,200 linear feet of shoreline to more natural conditions. In addition, restoration of horseshoe crab breeding habitat has been identified as a high priority at this site.

Keyport Oyster Reef Restoration

54. An oyster reef was established at Keyport Harbor during the summer of 2001. The restoration was the result of efforts by the NY/NJ Baykeeper and the National Oceanic and Atmospheric Administration's Restoration Center. The reef was established by placing approximately 10,000 bushels of oyster shells in the vicinity of a historic oyster reef near Keyport Harbor in Raritan Bay. Community volunteers raised the oysters used to seed the reef. Monitoring efforts are the result of collaboration between the National Marine Fisheries Service laboratory at Sandy Hook, Brooklyn College, and the NY/NJ BayKeeper. Although the shellfish inhabiting the reef are not for human consumption, public involvement and interest in the program has been extremely high. Additional plans are now underway for a establishment of a similar reef in the Navesink River, Monmouth County, New Jersey.

Potential Restoration Sites

55. Thirty-five potential restoration sites have been identified in the Lower Bay study area and are listed in Table 1. Each site will be evaluated to determine which of the proposed restoration activities, if any, are feasible from an engineering and economic perspective. Also of special interest are sites that offer opportunities to connect and/or expand existing high-quality areas or create habitats that are in especially short supply or have suffered disproportionate losses in the past.

Table 1 - Potential Restoration Sites in the Lower Bay

HRE Site ID	Name	Restoration Opportunities[1]
1LB	Coney Island Creek	1
2LB	Dreier-Offerman	1,4,6
3LB	Gravesend Bay	1,4,6
4LB	Fort Wadsworth Beach	6
5LB	Hoffman-Swinburne Islands	4,6
6LB	Verrazano-Narrows	4
7LB	Sea View Avenue Wetlands	*
8LB	Oakwood Beach	1
9LB	Great Kills, Gateway NRA	*

HRE Site ID	Name	Restoration Opportunities[1]
10LB	Great Kills Park	1,6
11LB	Arden Heights Woods	9,10
12LB	Crookes Point	6
13LB	Lemon Creek	1,7
14LB	Mt. Loretto	1
15LB	South Amboy	*
16LB	Old Morgan Landfill/Raritan County Park	10
17LB	Laurence Harbor	1,4,9
18LB	Cheesequake Marsh	1
19LB	Global Landfill	*
20LB	Cheesequake State Park	*
21LB	Marquis Creek	1,10
22LB	Treasure Lake	3,7,9,10
23LB	Matawan Creek/Keyport Harbor	1,4,5,6,7
24LB	Matawan Creek/Keyport Harbor Mouth	5
25LB	Raritan Bay (Oyster Bed Restoration)	5
26LB	Natco Lake/Thorns Creek	7
27LB	Raritan Bay (Submerged Rock Berm)	4,5,7
28LB	Leonardo	1,7
29LB	Sandy Hook Beaches	6
30LB	Sandy Hook (Sand By-Pass System)	6
31LB	Sandy Hook Bay (Shellfish Restoration)	5
32LB	Shrewsbury/Navesink Rivers	1,3,4,5,6,7
33LB	Shadow Lake Dam	4
34LB	Shrewsbury River Watershed	4,3,7
35LB	PSE&G Gasification Plant	*
36LB	Lower Bay Reef	*

(1) Restoration Opportunities:
1 – Restoration/Creation of Intertidal Wetlands/Mudflats
2 – Benthic Habitat Restoration (Hotspot Removal)
3 – Restoration/Creation of Freshwater/Riparian Wetlands
4 – Restoration of Fishery Habitats (Anadramous Fish Migration, Artificial Reefs)
5 – Shellfish Habitat Restoration
6 – Restoration/Enhancement of Shoreline/Coastal Fringe Habitat (Dunes, Bird Habitat)
7 – Creation/Restoration/Enhancement of Shallow Water Habitat (including Eelgrass)
8 – Shoreline Enhancement/Bank Stabilization
9 – Water Quality Improvement
10 – Riparian Habitat Restoration
11 – Environmental Interpretation
* To be determined

IV. CONCLUSIONS

56. The Lower Bay study area contains the largest span of open water in the Estuary. The study area connects the Estuary to the Atlantic Ocean and provides a migratory route for anadromous fish species and many bird species. It is also host to several important commercial fisheries.

57. Because the study area contains such a large amount of open water, opportunities may exist to restore shellfish reefs and shellfish beds. At least one shellfish restoration project has already been completed in the Lower Bay study area. This project, located a Keyport Harbor, received a large amount of community support. Oyster reefs provide important nursery habitat for fish. Therefore, fish populations may also benefit from additional reef restoration.

58. The Lower Bay study area also contains the most significant amount of beach and sand dune habitat in the Estuary. This type of habitat is important to beach nesting birds like the piping plover, a federally listed threatened species. Piping plover nesting success is highest in the Lower Bay study area compared to other study areas in the Estuary. Therefore, efforts should be made to improve and expand dune and beach habitat. Restoration efforts may have secondary benefits to recreational activities such as wildlife viewing and fishing.

V. REFERENCES

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FIGURES