Norton Basin/Little Bay Restoration Project: Historical and Environmental Background Report

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LIST OF ACRONYMS

BWM – Bureau of Waste Management
CAC – Consolidated Aggregate Corporation
CAD – Confined Aquatic Disposal
CSO – Confined Sewer Outfall
CWA – Clean Water Act
CY – Cubic Yards
DMMP – Dredged Material Management Plan
DO – Dissolved Oxygen
GNRA – Gateway National Recreation Area
JBESG – Jamaica Bay Environmental Study Group
MCY – Million Cubic Yards
NEPA – National Environmental Protection Act
NMFS – National Marine Fisheries Service
NOAA - National Oceanic and Atmospheric Administration
NPS – National Park Service
NYC – New York City
NYCDEP – New York City Department of Environmental Protection
NYCDOS – New York City Department of Sanitation
NYD – New York District
NY/NJ – New York/New Jersey
NYSDEC – New York State Department of Environmental Conservation
NYSDOS – New York State Department of State
PAH – Polycyclic Aromatic Hydrocarbons
PCB – Polychlorinated Biphenyl
SPI – Sediment Profile Image
TOC – Total Organic Carbon
USACE – U.S. Army Corps of Engineers
USAE-WES – U.S. Army Engineers, Waterways Experiment Station
USEPA – U.S. Environmental Protection Agency
VOC – Volatile Organic Compounds
WPCP – Water Pollution Control Plant
WRDA – Water Resources Development Act

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1.0 Introduction

1.1 Purpose

Norton Basin and Little Bay are two dead-end basins sharing a channel, which drains into the southeastern portion of Jamaica Bay, NY. Both are located on the Rockaway Peninsula of Queens County and have been subjected to almost four centuries of anthropogenic impacts. Both basins are hydrodynamically restricted and contain deep, artificial holes, or borrow pits, at the end of each channel. These pits were created during the development of Edgemere Landfill in 1938. The subtidal habitats of Norton Basin and Little Bay, having originally been shallow intertidal saltmarsh, are no longer reaching their full ecological potential as habitats available to the avian and aquatic species associated with the adjacent National Park Service, Gateway National Recreation Area (NPS-GNRA). These two basins are considered to be prime areas available for habitat restoration in the New York/New Jersey (NY/NJ) Harbor.

The U.S. Army Corps of Engineers, New York District (USACE-NYD) & New York State Department of Environmental Conservation (NYSDEC) have proposed to restore the Norton Basin and Little Bay borrow pits using dredged material from navigation improvements and maintenance dredging within the Port of NY/NJ for the NYD's Dredged Material Management Plan (DMMP). The proposed project would be a demonstration project investigating the beneficial use of dredged material in restoring ecological functions to a highly impacted aquatic habitat.

1.2 Objectives

The proposed demonstration project to restore Norton Basin and Little Bay will include pre-construction, construction, and post-construction monitoring to assess the potential ecological benefits associated with filling the borrow pits in each basin. The purpose of this report is to describe the historical and cultural development of the areas surrounding Norton Basin and Little Bay and to describe the known changes in environmental conditions leading up to the pre-construction monitoring of the proposed ecological restoration. This information will be used to gain a better understanding of the environmental and ecological conditions in the proposed project area and to identify any potential problems that may be encountered in implementing the proposed restoration plan due to previous anthropogenic impacts.

1.3 Authority

The authority by which a demonstration project to fill Norton Basin and Little Bay with dredged material could be implemented is provided under Section 404 (b) (1) of the Clean Water Act (CWA) of 1972, Section 1135 of the Water Resources Development Act (WRDA) of 1986, and Section 204 of WRDA 1992. Section 216 of the Rivers and Harbors Act of 1970 authorizes the USACE to review navigation projects and recommend modifications that would involve habitat creation/restoration using dredged material.

Habitat development projects in Jamaica Bay are also subject to regulation by New York State statutes, and permitting authorities. New York regulates activities in tidal waters under the State Environmental Quality Review Program, which closely follows the provisions of National Environmental Protection Act (NEPA). New York's Significant Coastal Fish and Wildlife Habitats Program states that designated coastal fish and wildlife habitats are to be protected, preserved, and where practical, restored so as to maintain their viability. Section 307 of the Federal Coastal Zone Management Act requires Federal agency actions to be consistent to the maximum extent practical with the enforceable policies of NY state's Federally approved Coastal Zone Management program. Both Federal and non-Federal activities in state waters require Water Quality Certification under Section 401 of CWA 1972. A water quality certificate is the state's certification that the proposed activity will not contravene applicable surface water quality standards.

2.0 Geology

Norton Basin and Little Bay are located on the Rockaway Peninsula of Jamaica Bay within the NY/NJ Harbor estuary (**Figure 2.0.1**). Jamaica Bay is a shallow bar-built estuary, approximately eight miles long, four miles wide and 26 square miles in area, located on the southwest corner of Long Island, NY. It represents a historic delta of the Hudson River (Grambo & Vega 1984) and drains a watershed of approximately 85,000 acres (USFWS 1997).

The Rockaway Peninsula is a low relief barrier peninsula composed of tidal sediments and upper glacial sands, which have accreted from the eastern end of Long Island (Grambo & Vega 1984). Norton Basin and Little Bay represent historic inlets on the Rockaway Peninsula, having connected the Atlantic Ocean and Jamaica Bay prior to the 1800's. Norton Basin and Little Bay, located on the bay side of the peninsula, are characterized by dark gray clayey silt to silty clay sediments typically associated with eutrophic estuaries. The underlying upper glacial sands are Upper Pleistocene deposits (NYCDOS 1991).

3.0 Historical Background

Jamaica Bay has been subjected to almost 400 years of European impacts, during the last two centuries over half of the original habitat resources in the Bay have been lost. The Bay has evolved from a shallow, unpopulated estuary to a national recreation area completely encircled by one of the most densely populated urban areas in the world. Understanding the historical impacts and cultural development of Jamaica Bay and Norton Basin may facilitate the decision making process when initiating ecological restoration in the Norton Basin/Little Bay complex.

3.1 Pre-Colonial

Before Europeans began colonizing Manhattan, and the surrounding estuary, Native Americans of the Mohegan tribes inhabited Jamaica Bay. Thirteen tribes, all part of the Algonquin nation, occupied different portions of Jamaica Bay (Dolphin 1932). The Canarsie and Rockaway tribes resided in what would become the Norton Basin area. These tribes lived off of the rich fish and shellfish resources that abounded in the Bay.

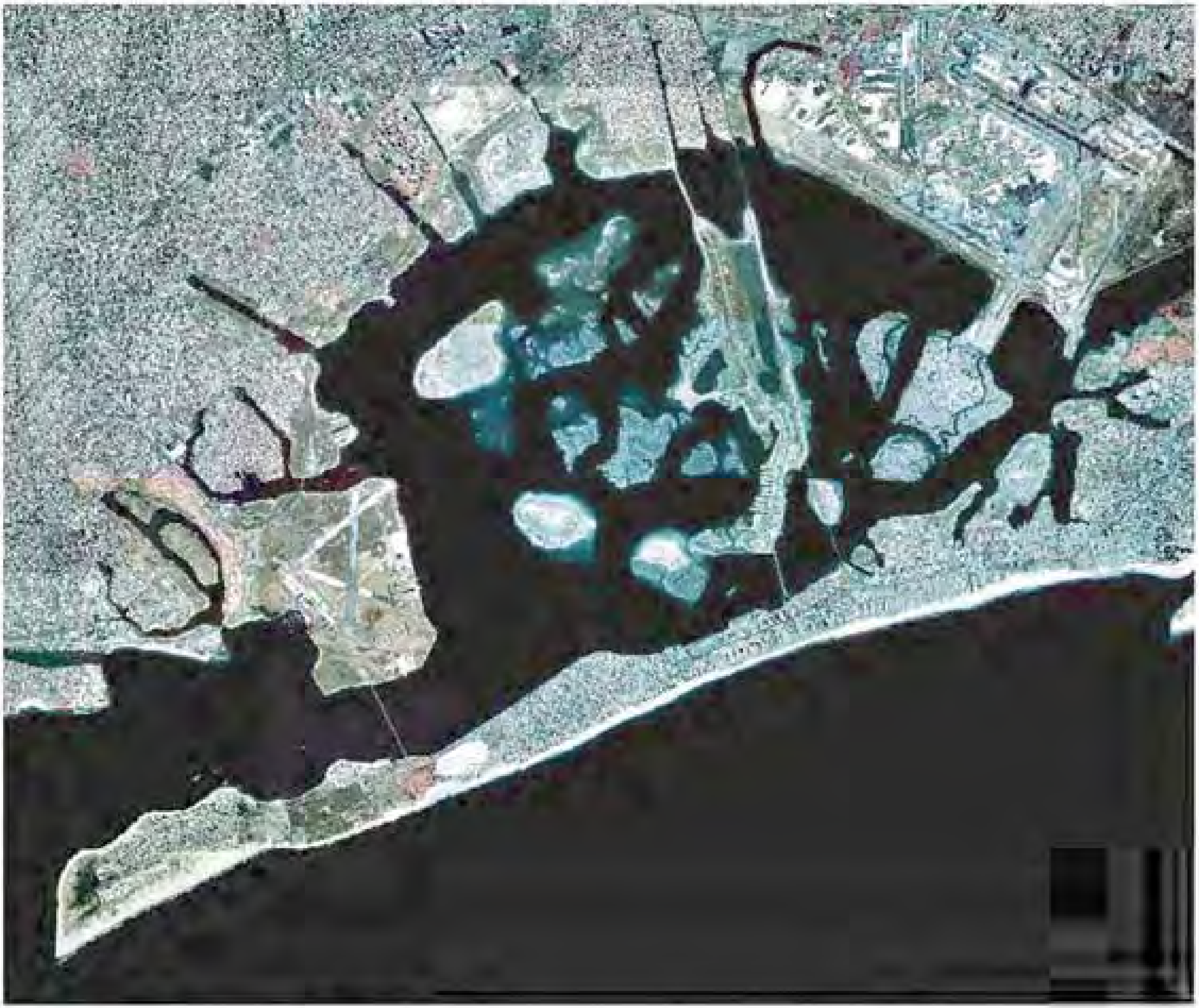


Figure 2.0.1. Aerial photograph of Jamaica Bay. Adapted from USGS aerial photograph, 1995.

Evidence of the shellfish harvesting by these tribes could been seen near Norton Basin as late as 1890's. Large mounds of discarded oyster shell were located in Inwood, Hog Island, and Bayswater (the Bayswater mounds being the largest) (Bellot 1917). These large volumes of shell hash were later used to pave several sections of the streets in towns bordering Jamaica Bay and in Manhattan. Finfish were collected using nets and fishbone hooks. Shellfish were collected using dugout canoes and wooden rakes (Black 1981).

The Canarsie tribe, along with the other tribes of the area, were displaced either through purchases of parcels of land or direct skirmishes with the Dutch and English settlers. Through displacement and significant population decline from diseases introduced by the Europeans, Native American tribes were virtually extinct from Jamaica Bay by the mid-1660's (Black 1981). Because of the level of development that has occurred in Jamaica Bay over the last 200 years, the only remnants of these tribes are the names of the towns and features currently associated with Jamaica Bay and Long Island.

It is difficult to assess the level of impact, if any, that the Native Americans had on the ecology of Jamaica Bay. It can be assumed that because of the lower concentration of people in the tribes surrounding the Bay, and the manner in which the Native Americans used the resources of the Bay, the impacts they would have had on the ecology of the system were not significant. Considering that the Iroquois tribes had resided in the Jamaica Bay area for hundreds of years before the arrival of Europeans, the rate at which the Jamaica Bay changed appears negligible compared to the changes the area has experienced since the extinction of the tribes from the area.

3.2 Colonial-Post Revolutionary War

The first recorded visit of Europeans to Jamaica Bay was in 1609. Henry Hudson attempted to enter Jamaica Bay during his exploration of the Hudson River and New York Harbor in September of 1609 (Dolphin 1932). Following Hudson's brief visit, the first residents of Jamaica Bay were the Dutch; who, from 1624 to 1664, included the western portions of Jamaica Bay in their New Netherlands providence near their fort in New Amsterdam, now Manhattan (Black 1981). The area currently known as Jamaica Bay was called "Rustdorp." The Dutch did not settle the east side of the Bay until the early 1640's. The Dutch were in the New World primarily for trade purposes and did not have any interest in expanding their land holdings outside of New Amsterdam.

The Dutch allowed English settlers to live on land owned by the Dutch as long as they claimed allegiance to Amsterdam (Dolphin 1932). The towns of Hempstead, Jamaica, and Flushing were the first areas settled on the east side of Jamaica Bay, each being English settlements under Dutch rule. The English referred to the Bay as "Jamaica" after a small resident tribe called the Jameco Indians (Black 1981). In 1690, Richard Cornell purchased a large tract of land in what is now Far Rockaway. Cornell's home was the first permanent structure in the area (Bellot 1917). The Cornells, and those who settled with him, cleared the land for farming and continued to spread out around the perimeter of the Bay. They also used Jamaica Bay as a rich source of fish and shellfish, and used the expansive salt marshes as a grazing area for livestock.

In 1664, the Dutch government in New Amsterdam fell to the British, who renamed the colony New York (Dolphin 1932). The population of European settlers continued to increase through the American Revolution. Additional settlements appeared along with an ever-evolving set of laws and regulations limiting who could harvest from the waters of Jamaica Bay. By 1720 the towns of Inwood and Bayswater also existed along the edge of what would become Norton Basin and Little Bay (Bellot 1917).

The population surrounding Jamaica Bay, and the area surrounding present day Norton Basin and Little Bay, continued to increase through the American Revolution and the end of the 18th century. Commercial harvesting of fish and shellfish from the Bay became more focused as part of the population moved away from agriculture and began manufacturing goods for sale and trade. The Native American population disappeared from the area and new towns were settled.

Through the end of the 18th century there is little evidence to suggest anthropogenic impacts to Jamaica Bay. The resident population would have been harvesting the resources of the Bay, but the concentration of people would have been too low for there to be any perceptible impact to the quantity or quality of resources in the Bay. As early as 1763 collection of fish and shellfish required permission and a written license in Jamaica Bay (Bellot 1917).

3.3 1800's

By the beginning of the 19th century, the areas surrounding Norton Basin and Little Bay were developed agricultural lands on the periphery of small towns and villages throughout the area. By 1811, the region was already popular with visitors from New York City and ferries and stagecoaches regularly made the journey from Manhattan to Far Rockaway (Dolphin 1932). Beginning in the 1830's, however, the complexion of eastern Jamaica Bay began to change dramatically. In 1830, John Norton purchased a large tract of land from the Cornell heirs (Bellot 1917). Norton's plan was to develop the land as a resort area for nearby New York City residents. In 1833, Norton built a large hotel, known as the Marine Pavilion, on the edge of what is now Norton basin. The hotel, and its adjoining infrastructure, was built on marshes filled with material dredged to make channels to access the hotel from the water of Jamaica Bay and the ocean. This filling of marsh was the beginning of 100 years of dredging and marsh filling which would lead to the upland formations we are familiar with today. The hotel, and many others like it along the Rockaway peninsula and Long Island, was enormously successful. New York City residents came to vacation and visit the resort area and its beaches from the 1830's through the mid-1940's. Because of its resort status, the Norton Basin area did not undergo the industrial development seen in the western portions of Jamaica Bay and may have been spared some of the early anthropogenic impacts experienced by areas such as Mill Basin, Barren Island, and Flatbush (Black 1981).

Some of the last areas developed on the periphery of Jamaica Bay were the towns of Arverne, Edgemere, Seaside, and Rockaway Beach. Until the 1880's, these portions of the peninsula were still used as pasture for livestock. The Edgemere area did not have commercial development plans until 1892 (Bellot 1917).

Numerous transportation advancements took place throughout the 19th century in an effort to decrease travel time from Manhattan to the Far Rockaway area. From the early 1860's to the 1930's, ferries transported passengers from Manhattan and western Jamaica Bay to the Rockaway Peninsula (Black 1981). Before a rail-line was available across Jamaica Bay, visitors could travel from Manhattan to Canarsie via the Brooklyn and Rockaway Railroad, chartered in 1863 (Black 1981). From Canarsie, a ferry was taken to the beaches and resorts of Rockaway. In 1869, Far Rockaway received its first rail-line connecting it to the rest of Long Island and New York City (Bellot 1917). The advancement decreased travel time to the resort area and substantially increased visitation and development of the Far Rockaway area. In 1872, the steam railroad was extended from Far Rockaway through Edgemere and Arverne (Bellot 1917). In 1880, the New York, Woodhaven and Rockaway Railroad Company completed the first railroad trestle across the five miles of Jamaica Bay, landing in Seaside, west of what is now Barbadoes Basin (Bellot 1917). This line, as well as the Rockaway line, was eventually acquired by the Long Island Railroad.

Despite the thousands of residents and millions of visitors to the Far Rockaway area, the towns surrounding Norton Basin did not have a functioning public water supply until 1885, or a public sewer system until 1897 (Bellot 1917). Prior to the construction of a sewer system in the town of Far Rockaway, sewage was flushed, untreated, directly into the Bay where it came in direct contact with the fish, shellfish, and bathers. There is little documented evidence prior to the 1870's concerning restrictions on shellfish or swimming in the New York Harbor Area (Carriker et al. 1982). It can be assumed that if the effects of dumping sewage sludge, dredged material, street sweepings, cellar dirt, and ballast were being noticed Harbor-wide, the effects of unrestricted dumping were discernible in Jamaica Bay as well. There are several reports prior to this time period of the odors and waste that drove vacationers from the beaches and shoreline. The numerous sources of sewage input would have impacted the local salt marshes and their inhabitants. It is difficult to assess, however, if all these impacts would have necessarily been detrimental to the ecology of the Bay and the immediate areas of Norton Basin and Little Bay, due to the ability of intertidal marsh plants to tolerate large influxes of nutrients and metals (Mitsch and Gosselink 1993). This topic will be discussed more in Section V of this report.

In 1898, Jamaica Bay and its surrounding communities were incorporated into the City of New York, becoming the Borough of Queens (Bellot 1917). For many residents of the Rockaway Peninsula this signaled the beginning of the end. Within the next decade the resort areas of the Rockaways would see a peak and decline in the number of tourists visiting their beaches. Throughout the 1800's, the marshes and subtidal areas of Norton Basin and Little Bay were largely ignored. They were considered undeveloped areas that needed to be passed through on the way to the resort beaches. Filling of the marshes began to accelerate through the 1800's to create upland habitats for the expanding towns and resorts. Fishing and shellfishing continued, but the discharge of raw sewage into the waterways, along with the transportation developments around the Bay, was beginning to impact the resources of the Bay.

3.4 1900's

Starting in the early 1900's, the development of the Rockaway Peninsula increased dramatically. The incorporation of the area into New York City (NYC) transformed the string of summer tourist towns into a developed urban area. Improvements to water and fuel supplies, transportation, schools, churches, libraries, banks, and shopping centers were only a few of the many changes experienced the first decade of the 1900's (Dolphin 1932).

The number of visitors to the Far Rockaway area peaked in 1902 and steadily declined throughout the 20th Century. This decrease in vacationers was attributed to the growing population of Queens, which began to fill the borders of Jamaica Bay. Resorts and vacationing spots turned into residential housing. After having experienced a slump in development during World War I, the average rent in Far Rockaway doubled in the 1920's as population growth outpaced available housing (Dolphin 1932).

In 1906, the Jamaica Bay Improvement Commission was formed to investigate the proposal to develop Jamaica Bay into an industrial port. Throughout its existence the commission made many recommendations toward economic development of Jamaica Bay. Many of the alternatives suggested by the Commission were never implemented, such as filling the center of the Bay with dredged material to make two island ports with shipping channels around the outside of the Bay; or filling in Rockaway Inlet to create a more direct inlet east of what is now Riis Park (Grambo & Vega 1984). Recommendations to create deeper shipping channels were implemented and have greatly affected the appearance, hydrology, and ecology of the entire Bay.

While the developments examined by the Improvement Commission affected the entire Bay, the direct impacts to Norton Basin, Little Bay, and the southeast corner of Jamaica Bay were moderate in comparison to industrial areas such as Floyd Bennett Field, Bergen Basin, and Mill Creek. In 1920, further plans to develop Jamaica Bay as a commercial port were suspended (JBESG 1971). The Jamaica Bay Improvement Commission, as well as other organizations, would continue to view the Bay as a potential port to be exploited well into the mid-20th Century.

The 1920's began to see the threshold of the impacts that Jamaica Bay could sustain without collapse. In 1921, shellfishing was banned following several decades of typhoid and gastroenteritis outbreaks caused by raw sewage outflows into the Bay (Black 1981). Shellfish contamination and typhoid outbreaks were common throughout NY/NJ Harbor at this time. In 1931, the City of New York, initiated a plan to treat sewage flowing into the waters around the city. Prior to this program millions of gallons of raw sewage were flowing into Jamaica Bay daily (JBESG 1971).

Transportation to and from the Far Rockaway area continued to develop throughout the 1920's and 30's. In 1923, Cross-Bay Boulevard was constructed parallel to the Long Island Railroad trestle, shortening the traveling distance between Rockaway and New York City by ten miles (Dolphin 1932). As tourism began its decline, commuter traffic rose. Cross-Bay Boulevard and the Long Island Railroad are still the main throughways for traffic to and from the Rockaway Peninsula.

Prior to 1938, the direct anthropogenic impacts to Norton Basin and Little Bay were from the increase in residential population. The southeast corner of Jamaica Bay remained underdeveloped other than construction of housing to accommodate rising numbers of tourists and residents. The greatest anthropogenic impact specific to the area was probably the discharge of raw sewage into the Bay. Ecological conditions in Norton Basin and Little Bay had probably not changed dramatically since the middle of the 1800's. In 1938, Edgemere Landfill opened and began to receive municipal waste from the Borough of Queens. The landfill represents the most significant impact to the current conditions of Norton Basin and Little Bay, visually as well as ecologically. A more detailed discussion of the impacts of Edgemere Landfill is provided in Section VII.

In September of 1938, a hurricane hit the Harbor and Jamaica Bay. The oyster communities of Jamaica Bay were reportedly destroyed (Grambo & Vega 1984) and did not return to the Bay until the mid-1940's. The hurricane caused widespread flooding and would have caused raw sewage to flow into the Harbor for several days. Ecological impacts to Jamaica Bay were likely to have been substantial if the oyster populations of the Bay were temporarily destroyed. By the time the oysters were able to recover, however, the ecology of the Bay had been altered further, preventing return to historic population levels.

While 1938 was a year of significant environmental impacts in Jamaica Bay, a significant conservation effort was made to prevent complete destruction of the marsh systems in the Bay. At this time, jurisdiction of Jamaica Bay was transferred to the City Department of Parks to prevent the development of landfills in the center of the Bay (West-Valle et al. 1991). In response to this designation, Jamaica Bay was mapped to evaluate the status of the resources of the Bay. In 1948, jurisdiction was formally transferred to the NYC Department of Parks and Recreation (JBESG 1971) and the Jamaica Bay Wildlife Refuge was established (West-Valle et al. 1991). An important note in this conservation effort was that only the center islands of Jamaica Bay were designated as City Parks. The perimeter of the Bay was left out of park designation allowing for the continued development of landfills and filling of marsh habitats.

In 1941, plans were developed to construct an airport on the Idlewild Golf Course. This airfield would eventually become John F. Kennedy International Airport (Grambo & Vega 1984). The construction of the airport resulted in yet another significant impact to the ecology of the system. In 1962, runway 4-L was extended into the Bay, restricting the circulation of tidal waters around the perimeter of the Bay.

As in the 1800's, Jamaica Bay's water quality problems continued to grow. Bathing was prohibited in Jamaica Bay from 1954-56 due to contamination from sewer and storm drain overflows on the south side of the Bay (Grambo & Vega 1984). This overflow would have likely impacted Norton Basin and Little Bay. In 1963, a Jamaica Bay sewage treatment plant was forced to shut down for repairs, allowing raw sewage to build up in the Bay (Grambo & Vega 1984).

By 1971, the Jamaica Bay Environmental Study Group (JBESG) described the Bay communities as continuing to grow compared to other New York City Boroughs, but as also being plagued with problems such as inadequate mass transit, overcrowded schools, inadequate storm drainage, and poor maintenance of public facilities (JBESG 1971). The report describes deteriorating housing and urban renewal projects in South Jamaica and Arverne. The Rockaway communities were being impacted (and continue to be impacted) by noise pollution from JFK Airport. In 1971, approximately 700,000 people lived in areas of Jamaica Bay that are significantly impacted by noise from airplanes landing and taking off (JBESG 1971). As of 1980, approximately 43,300 people lived in the immediate area surrounding Norton Basin and Little Bay (NYCDOS 1991).

In 1972, NPS-GNRA was designated by Congress, transferring jurisdiction of the center of Jamaica Bay from NYC to the Federal government. The Jamaica Bay unit is approximately 65 km^2 (16,000 acres); 75% of this area is water, marsh, and meadowland and 25% is upland habitats (West-Valle et al. 1991).

The 20th century saw the most dramatic changes and degradation of Jamaica Bay. The level of impacts, however, was curtailed by the preservation of the center of the Bay. Had this foresight not been successful, the anthropogenic modification of the Bay would have continued throughout the century, leaving Jamaica Bay far more degraded than its current state.

4.0 Topographic and Hydrologic Development

In order to appreciate the level of change that has occurred to the topography and hydrology of Jamaica Bay, it is helpful to look at historic maps of the system. Numerous maps of Jamaica Bay exist, dating as far back as the 1740's (Cohen and Augustyn 1997). Prior to accurate mapping and before anthropogenic influences, Jamaica Bay was approximately 25,000 acres of intertidal marshes and open water (Grambo & Vega 1984). Average depth was approximately three feet and the Bay was dominated by large expanses of intertidal marsh. Jamaica Bay remained this way well into the 1800's. Norton Basin and Little Bay would have been virtually indistinguishable from the rest of the marshes surrounding the Bay.

Figure 4.0.1 depicts a survey of Jamaica Bay completed by the U.S. Coast and Geodetic Survey of 1878. The Bay is dominated by intertidal marsh, reported as the dark areas of the map. By 1878, the first rail line transected the Bay and the town of Far Rockaway was a thriving tourist center. Focusing on Norton Basin and Little Bay (**Figure 4.0.2**), the basin now called Norton Basin was named "Aunt Sallie's Drain" and was 1-3 ft deep. Little Bay was 1-5.5 ft deep and connected to Aunt Sallie's Drain and directly to Grass Hassock Channel, which was 8-13 ft deep. Bass Channel was dredged for access from Far Rockaway to the rest of Jamaica Bay, was a 5-8 ft deep channel connecting to the Bay of Far Rockaway, where tourists entered the town by ferry from the city. The Rockaway

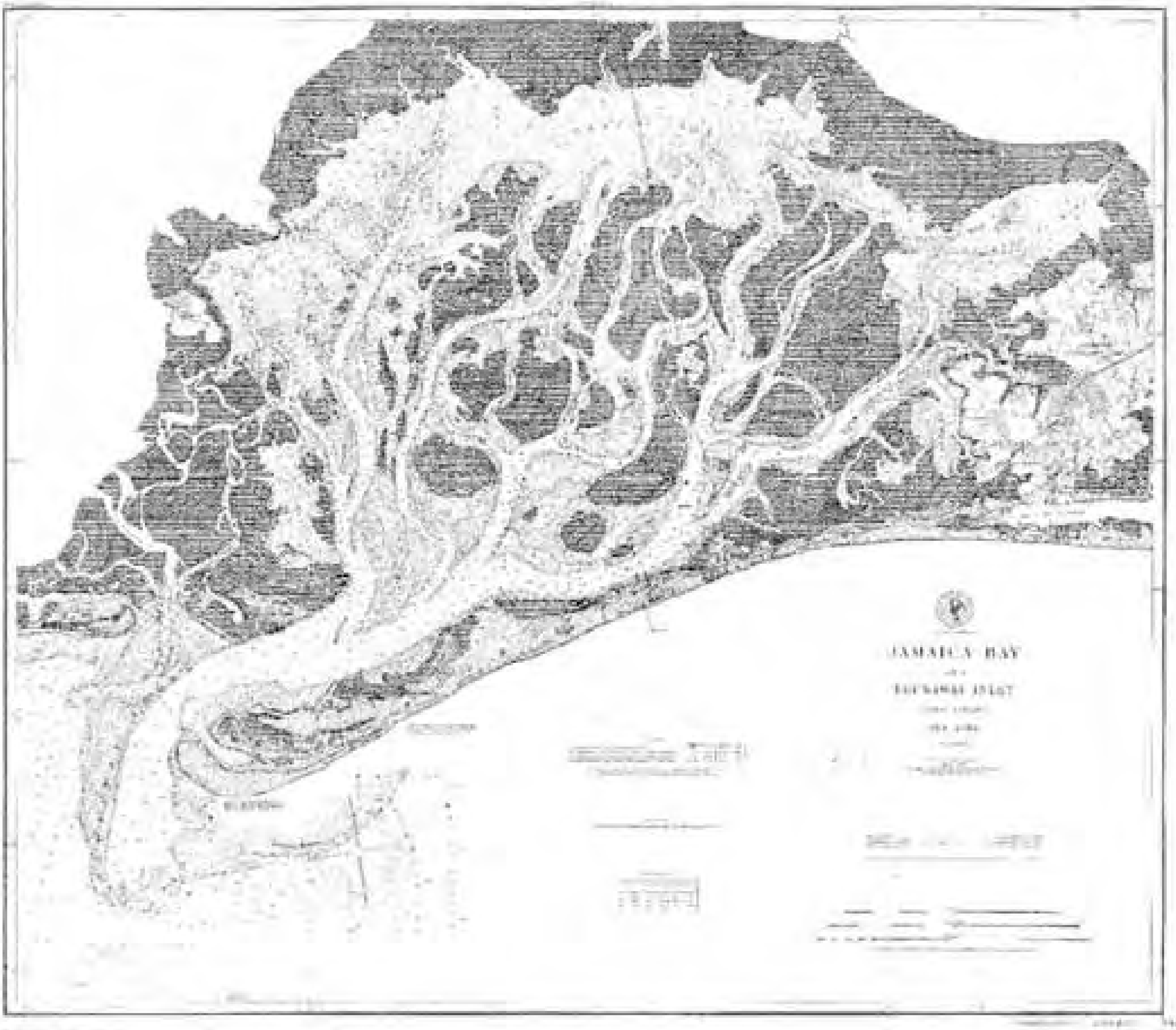


Figure 4.0.1. Topographic map of Jamaica Bay. 1899. U.S. Coast and Geodetic Survey, 1877-1878.

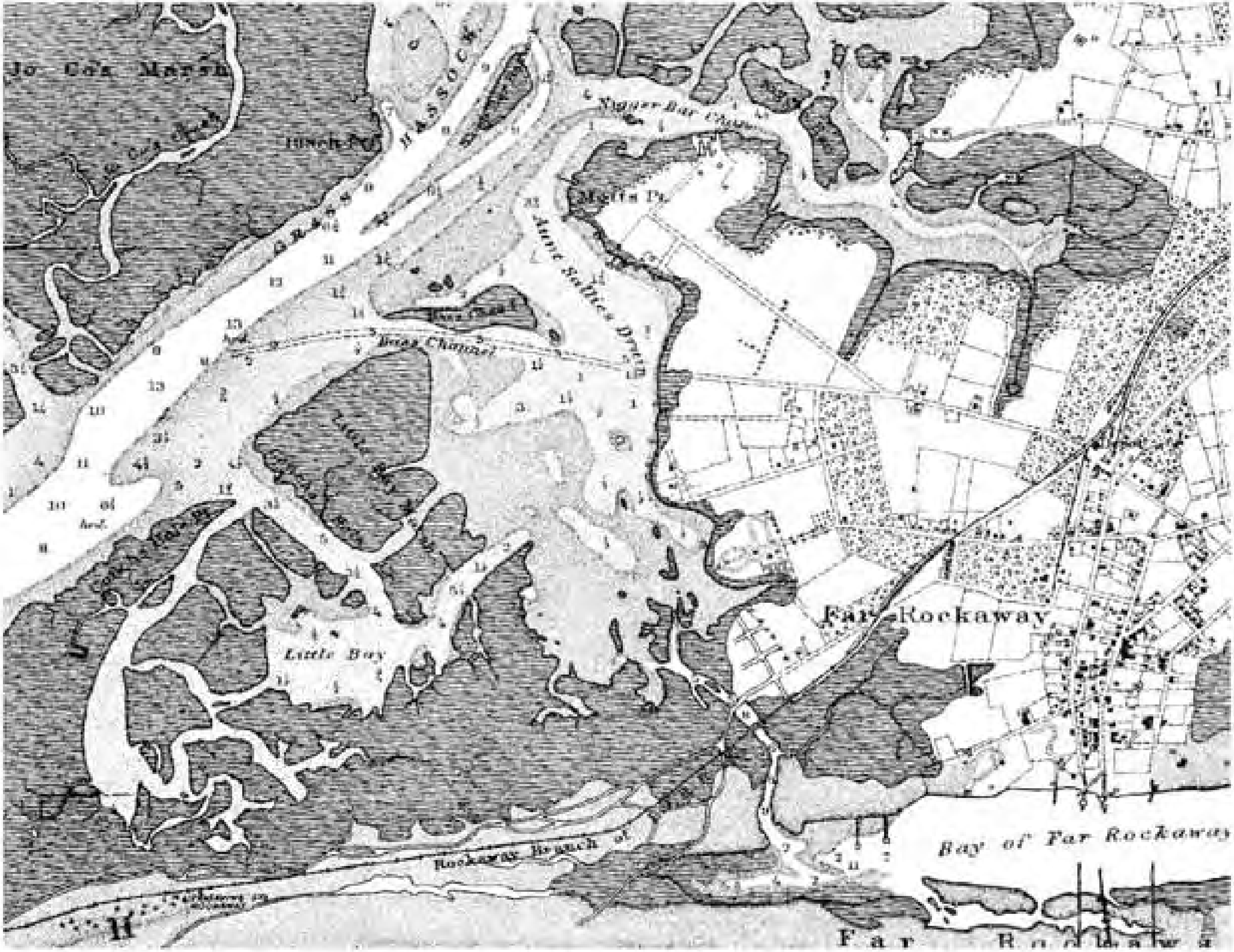


Figure 4.0.2. Topographic map of Norton Basin and Little Bay, 1899. U.S. Geodetic Coast and Geodetic Survey, 1877-1878.

Branch of the Long Island Railroad passed through Far Rockaway and out onto the peninsula. By 1878, the Norton Basin and Little Bay would have already been experiencing the impacts of development, both from the railroads and sewage runoff.

Jamaica Bay was surveyed again by the U.S. Coast and Geodetic Survey in 1897 **(Figure 4.0.3**). On this map considerably more open water and upland areas are depicted in the Bay. The filling of the Bay had accelerated and substantial areas of marsh habitat had been lost. Upon closer inspection of Norton Basin and Little Bay (**Figure 4.0.4**), the loss of intertidal marsh to open water and filled upland is dramatic. The Bay of Far Rockaway had been completely filled in and the Town of Arverne was developing. The Wave Crest Inlet, which had connected Norton Basin to the ocean, existed up to 1911 when it was filled to make way for the Town of Edgemere (Bellot 1917).

Figure 4.0.5 compares the 1897 map to the current topography of the Bay. While the central portion has been impacted significantly less, the periphery of the Bay has been filled and bulkheaded and only 13,000 acres of the original Bay remain. In 1907, 16,000 acres of marsh were present in Jamaica Bay (JBESG 1971); approximately 4,000 acres of intertidal marsh remain today. It has been estimated that by 1970, 71 million cubic yards (MCY) of sediment had been removed from Jamaica Bay (West-Valle et al. 1991), increasing the residence time of water entering the Bay from 11 days in the early 1900's to approximately 35 days (JBESG 1971). According to these calculations, approximately 70% of the current volume of water in the Bay can be attributed to dredging. In 1953, the East and West Ponds were dredged during a subway repair project, leaving one of the relatively few anthropogenic scars in the central portion of the Bay (JBESG 1971).

The National Oceanic and Atmospheric Administration (NOAA) Navigation Chart of 1995 (**Figure 4.0.6**) illustrates the Bay as it currently exists, including JFK International Airport, Edgemere Landfill, Cross-Bay Boulevard, as well as significantly diminished intertidal marsh and deep navigation channels. These impacts, however, are minimal relative to the changes that would have occurred had conservation efforts not been implemented. If the complete scope of the Jamaica Bay Improvement Plan had been achieved in the 1930's, all intertidal marshes would have been eliminated, the perimeter of the Bay would have been completely bulkheaded, and multiple piers and railroad lines would have been constructed (Black 1981). In the late 1960's, plans were proposed to extend JFK airport halfway across the Bay, eliminating the remainder of the intertidal marshes in the center of the Bay (JBESG 1971). If these plans had been implemented, the changes to Jamaica Bay would have been significantly greater than what exists today.

Figure 4.0.7 focuses on Norton Basin and Little Bay as they are portrayed in the 1995 NOAA Navigation Chart. The map shows Edgemere Landfill and the residential development around the basins. The borrow pits in each basin have depths of 64 and 51 feet. The entrance channel to the basins is 10 feet deep and very narrow. This map represents the starting point for the proposed restoration of Norton Basin and Little Bay.

Figure 4.0.3. Topographic survey of Jamaica Bay, 1900. U.S. Coast and Geodetic Survey, 1888-1880, 1897.

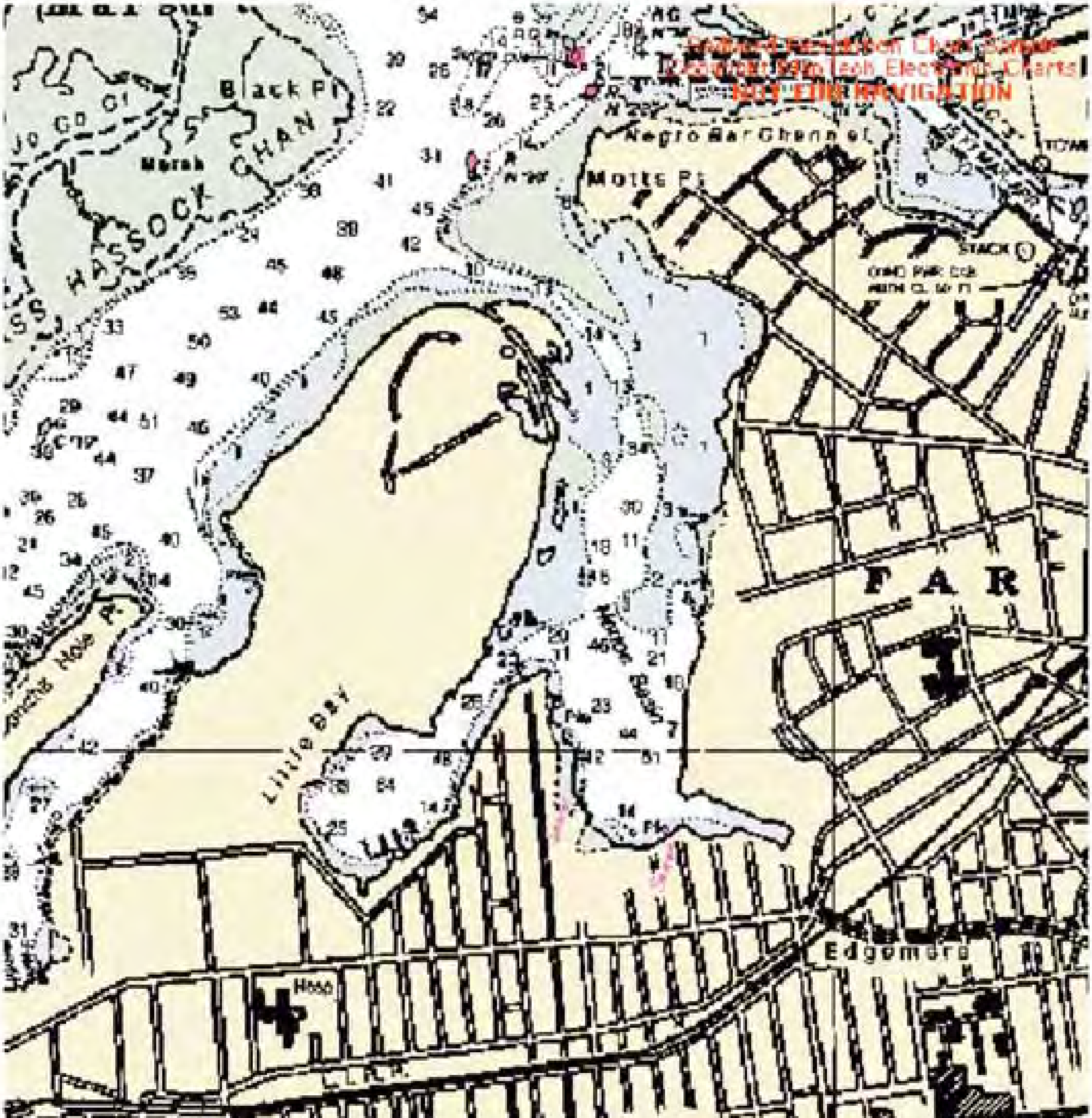


Figure 4.0.7. Navigation chart of Norton Basin and Little Bay, 1995. Adapted from NOAA navigation chart of Jamaica Bay, 1995.

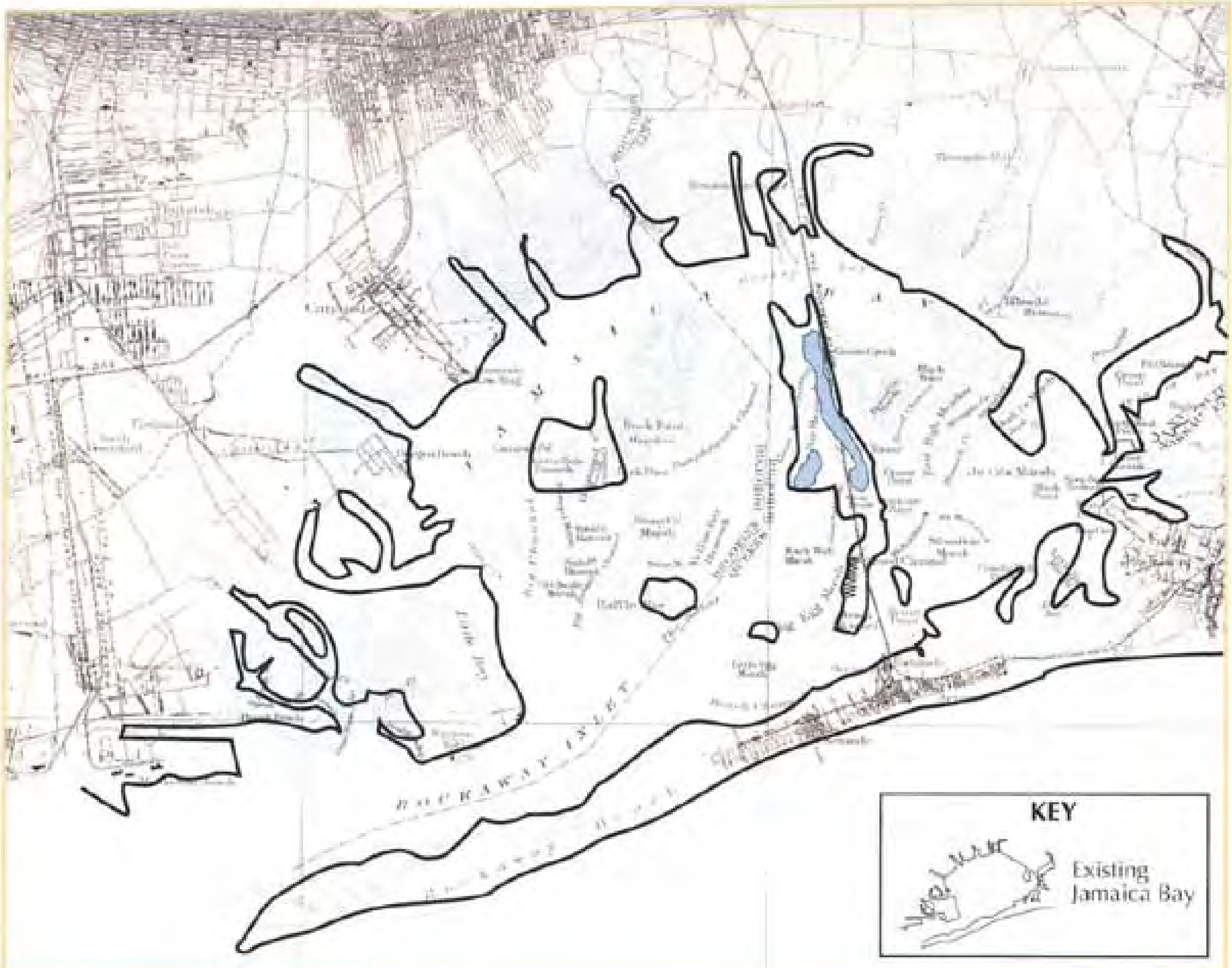


Figure 4.0.5. U.S. Coast and Geodetic Survey of Jamaica Bay (1900) overlayed with current (2000) upland boundaries of Bay. Blue areas are former intertidal marsh. Adapted from O'Brien and Gere, 2000.

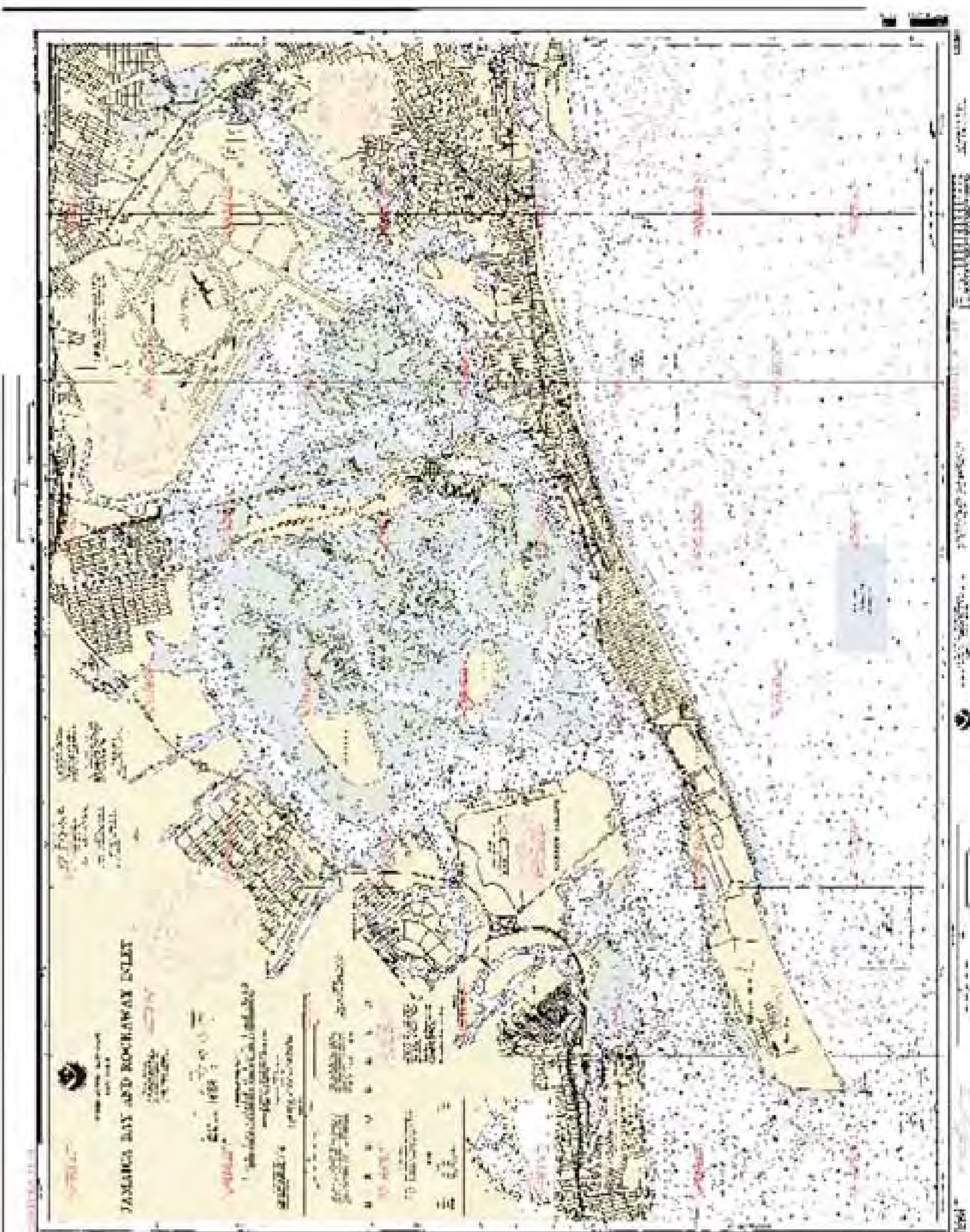


Figure 4.0.6. NOAA Navigation Chart of Jamaica Bay, 1995.

Figure 4.0.4. Topographic survey of Norton Basin and Little Bay, 1900. U.S. Coast and Geodetic Survey 1888-1889, 1897.

Figure 4.0.8 is a USGS aerial photograph of Norton Basin and Edgemere Landfill taken in 1995. The image shows the high level of development that has occurred around the basin over the last 150 years. Shallow sandbars are evident in the entrance channel and along the western edge of the basin. These sandbars will need to be removed if the proposed restoration proceeds in order to allow access by barges. Edgemere Landfill has been capped in this photograph, but remains the dominant feature of the immediate landscape. A small private marina has existed in the southernmost portion of Little Bay for several decades. Recent bathymetric investigations in Norton Basin and Little Bay have identified numerous boat hulls in the bottom of Little Bay (CR Environmental 2001). These boats are all less than 40 feet in size and do not immediately suggest any historic significance.

5.0 Changes in Water Quality

5.1 Jamaica Bay

A discussion of the water quality of Norton Basin and Little Bay has to be limited to what is known of the water quality of Jamaica Bay. Very little data has been collected in the basins themselves, especially with regard to long term monitoring. It could be inferred from the restricted hydrodynamics of the basins that water quality parameters, such as dissolved oxygen (DO), nutrient concentration, chlorophyll-*a*, and total coliforms would indicate a system of impaired ecological function. Comprehensive sampling of the two basins would be required, however, in order to make definitive statements about the current water quality.

The average yearly temperature of Jamaica Bay ranges from 1˚C to 26˚C, salinity ranges from 20.5 to 26 parts per thousand (ppt), and pH from 6.8 to 9 (USFWS 1997). The system is characteristic of a temperate, eutrophic estuary. For more than 50, years virtually all freshwater input to Jamaica Bay has been from urban runoff or through four sewage treatment facilities. Sewage treatment facilities contribute 29 million gallons of treated sewage annually (Tanacredi 1990). Freshwater inputs total approximately one half of one percent of the Bay's volume per day (O'Brien and Gere 1990). Two thirds of freshwater input are discharged from secondary sewage treatment plants; 10 percent of that volume being from confined sewer outfalls (CSOs) (O'Brien and Gere 1990). With each semidiurnal cycle, tidal currents exchange approximately one third of the volume of Jamaica Bay. As previously stated, the residence time of freshwater entering the Bay is approximately 30 days, an effect of the deepening of the Bay through dredging and filling (JBESG 1971).

Inferences can be made to the conditions in Norton Basin and Little Bay from data collected in other locations around Jamaica Bay. Historical and current water quality observations have been made in Jamaica Bay by the NPS-GNRA, U.S. Fish and Wildlife Service (USFWS), U.S Environmental Protection Agency (USEPA), New York City Department of Environmental Protection (NYCDEP), NYSDEC, as well as multiple academic investigations.

The NPS has conducted seasonal water quality monitoring in Jamaica Bay since the inception of the GNRA in 1972. Over the last 30 years, the NPS has observed significant recovery of the water quality in the Bay through monitoring of DO, temperature, pH,

Figure 4.0.8. Aerial photograph of Norton Basin and Little Bay. Image adapted from USGS aerial photograph, 1995.

salinity, conductivity, secchi depth, total and fecal coliforms, total and free chlorine, and chlorophyll-*a*. In 1998, chlorophyll-*a* levels ranged from 0.0 mg/m^3 at various stations throughout the Bay to 326.5 mg/m^3 on June 15th in Grassy Bay. Of the samples tested for free chlorine in 1998, none were above the lowest detectable limit of 0.02 mg/L. Also in 1998, conductivity ranged from 14.4 mS/cm to 34.0 mS/cm; nitrates ranged from 0.00 mg/L to 0.27 mg/L; orthophosphates ranged from less than 0.01 mg/L to 1.29 mg/L; pH ranged from 7.00 to 9.21; water temperature ranged from 14.3 ^{o}C to 27.0 ^{o}C; salinity ranged from 6.4 ppt to 21.4 ppt; and secchi depth ranged from 5.1 m to 0.2 m (GNRA 1981).

DO is typically regarded as the key water quality indicator of whether or not an aquatic system will support a healthy biological community. **Table 5.1.1** lists the DO measurements taken by the NPS in Jamaica Bay for 1998. Thirty-eight of the 268 measurements (14 %) taken from 9 stations around the Bay were below the NY State standard of 5.0 mg/L. Bergen Basin, which could be considered similar to Norton Basin due to its restricted hydrodynamics, had a mean dissolved oxygen level of 4.32 ± 0.35 mg/L.

NPS has collected water quality data with other studies in Jamaica Bay, such as the 1991 Jamaica Bay Fisheries Survey. **Table 5.1.2** summarizes the ranges of water quality data collected for selected stations from that study. The data selected represents those stations that experience ecological conditions similar to Norton Basin, such as restricted hydrodynamics and organic sediments.

The perimeter of the Bay, especially the canals and basins, typically exhibits the most impacted water quality measurements. Areas of tidal restriction and poor hydrodynamics lead to lower DO levels, potentially impacting biological resources. In 1971, the Jamaica Bay Environmental Study Group observed that Grassy Bay, Bergen Basin, and the perimeter of the Bay experienced seasonally low dissolved oxygen and high fecal coliform levels (JBESG 1971). They estimated that the tidal prism in Grassy Bay is approximately 10% of the total water column, with a retention time on the order of 100 days. Norton Basin and Little Bay may experience retention times similar to Grassy Bay and Bergen Basin, potentially lowering DO levels and increasing total and fecal coliform levels. All of these conditions would contribute to stressed biological communities.

5.2 Jamaica Bay Eutrophication Study

The chronic water quality problems of the perimeter of Jamaica Bay have not gone unnoticed. The Jamaica Bay Eutrophication Study was undertaken after the Jamaica Bay CSO Abatement Facility Planning Project suggested CSO abatement would significantly alleviate bacteriological problems in the tributaries of the Bay, as well as improve dissolved oxygen levels in open waters (O'Brien and Gere 2000). The study went on to suggest that abatement of water pollution control plants (WPCP's) may further restore the water quality of the open areas of the Bay and that the issue should be studied further. The objectives of the Jamaica Bay Eutrophication Study included identification and quantification of nutrient inputs, measurement of current water quality parameters to verify problems and provide comparisons for water quality models, obtain data to set model

Table 5.1.1. Dissolved oxygen measurements collected at NPS-GNRA Jamaica Bay Unit stations for May - August 1998. Shaded cells indicate measurements below the NY state standard of 5.0 mg/L. Adapted from GNRA, 1998.

Sample Location	Site	Depth	5/28/98	6/1/98	6/8/98	6/15/98	6/23/98	6/30/98	7/6/98	7/13/98	7/21/98	7/27/98	8/3/98	8/10/98	8/17/98	8/24/98	8/31/98	Mean	SE
Rockaway Inlet	JB-3	Top	9.56	8.96	---	6.09	6.76	7.29	7.31	6.67	6.70	7.33	5.84	7.08	6.32	7.48	7.05	7.17	0.27
		Bottom	4.46	7.99	---	7.72	7.62	8.04	5.75	7.47	6.56	7.25	5.21	6.24	4.85	7.25	5.50	6.57	0.33
Nova Scotia Bar	JB-5a	Top	7.80	7.89	9.52	5.56	7.23	8.70	5.54	6.17	6.14	7.05	7.80	6.45	7.77	7.24	10.94	7.45	0.38
		Bottom	8.75	7.12	9.49	6.27	6.61	7.87	5.95	7.12	5.74	6.99	5.84	6.39	6.35	7.20	7.41	7.01	0.27
Canarsie Pier	JB-6	Top	7.70	7.86	6.91	4.24	6.42	6.55	13.38	6.03	5.73	9.41	13.35	7.80	10.98	5.76	8.73	8.06	0.70
		Bottom	8.26	6.45	7.86	5.43	5.94	7.50	11.18	6.27	6.64	7.01	5.33	7.30	6.43	5.43	5.46	6.83	0.39
Pennsylvania Ave Landfill	JB-6a	Top	6.81	6.86	7.61	4.41	4.71	6.51	13.65	7.77	7.67	12.21	15.83	11.13	11.74	8.12	4.47	8.63	0.90
		Bottom	9.81	5.89	9.72	5.29	5.51	7.30	10.61	6.88	4.18	7.72	5.00	6.90	10.58	5.44	2.94	6.92	0.61
Bergen Basin	JB-16	Top	5.44	6.03	4.01	2.42	20.50	4.21	5.65	11.02	2.55	10.87	3.95	5.27	4.78	5.17	4.25	6.41	1.19
		Bottom	5.41	4.99	5.51	4.53	3.83	5.15	5.37	5.26	2.71	6.35	2.99	5.19	1.65	3.06	2.78	4.32	0.35
Bergen Basin Outflow	JB9a	Top	7.42	6.56	5.34	4.37	5.06	5.93	8.99	7.17	2.41	9.80	4.62	11.34	12.65	7.41	8.69	7.18	0.71
		Bottom	9.78	5.45	6.36	4.66	5.42	4.90	9.89	6.35	3.50	7.50	2.61	6.55	3.98	4.15	3.88	5.67	0.55
Grassy Bay	JB-9	Top	6.65	6.86	8.64	12.31	3.64	6.89	10.43	13.51	16.78	13.02	11.66	14.78	12.07	8.53	14.90	10.71	0.96
		Bottom	7.61	7.04	10.03	11.43	5.36	6.37	9.93	12.96	13.04	9.55	6.09	6.24	8.16	7.01	5.85	8.44	0.66
Jo-Co Marsh	JB-12	Top	9.65	7.65	6.71	5.01	5.37	7.76	12.05	11.05	9.11	15.17	---	11.27	10.81	10.73	12.62	9.64	0.75
		Bottom	7.58	6.98	7.23	4.91	5.05	6.74	10.74	9.30	4.82	7.61	5.02	5.30	8.95	3.35	5.88	6.63	0.52
Beach Channel	JB-15	Top	7.77	7.21	8.57	4.55	5.05	4.94	8.69	5.40	11.21	7.83	5.27	7.33	6.59	6.38	12.41	7.28	0.59
		Bottom	7.93	7.95	9.44	6.12	4.56	5.77	8.57	6.32	9.33	6.36	5.34	6.22	6.20	5.16	7.64	6.86	0.39

Table 5.1.2. Range of water quality values observed during NPS-GNRA Jamaica Bay Fisheries Survey: 1985-1986, 1988-1989. Ranges for temperature, dissolved oxygen, salinity, chlorophyll a, total coliform, and fecal coliform are summarized by sampling gear for all stations sampled under the survey (bold) and for specific stations that may be similar to, or near, Norton Basin and Little Bay. Adapted from GNRA, 1991.

Sampling Mechanism	**Temperature (°C)**		**Dissolved Oxygen (mg/L)**		**Salinity (ppt)**	
Specific Stations (NPS St. #)	min value (date)	max value (date)	min value (date)	max value (date)	min value (date)	max value (date)
Otter Trawls	**0.3**	**25.1**	**1.1**	**18.6**	**17**	**38**
Grassy Bay West (#9)	1.1 (12/85)	25.1 (7/88)	1.1 (9/86)	11.8 (12/85)	19 (6/89)	36 (10/86)
JFK Runway (#10)	1.1 (")	25.2 (")	1.5 (8/86)	11.7 (")	17 (")	35 (")
Grassy Bay South (#11)	1.0 (")	25.3 (")	1.6 (7/89)	18 (1/89)	22 (9/88)	35 (10/86)
Jo-Co Marsh (#12)	0.7 (")	25.5 (")	2.0 (")	13.3 (7/88)	18 (6/89)	35 (")
Grass Hassock Chann. (#13)	0.3 (")	26.0 (")	2.4 (9/86)	12.6 (")	19 (")	35 (")
Gill Nets	**0.2**	**25.5**	**2.6**	**12.8**	**24**	**38**
Plumb Beach (#6)	0.5 (12/85)	25.5 (8/86)	2.6 (8/86)	9.9 (5/86)	24 (4/86)	34 (10/86)
Seine	**1.2**	**25**	**3.2**	**13.4**	**19**	**36**
Conch Hole Point (#2)	3.3 (12/85)	25.2 (7/89)	4.1 (7/89)	11.5 (12/85)	20 (6/89)	34 (10/86)

Sampling Mechanism	**Chlorophyll-*a* (mg/m³)**		**Total Coliform**		**Fecal Coliform**	
Specific Stations (NPS St. #)	min value (date)	max value (date)	min value (date)	max value (date)	min value (date)	max value (date)
Otter Trawls	**0.07**	**9.95**	**0**	**TNC***	**0**	**TNC***
Grassy Bay West (#9)	9.32 (7/89)	6.90 (6/88)	288 (6/88)	TNC* (7/88)	33 (6/88)	TNC* (7/88)
JFK Runway (#10)	0.28 (6/89)	9.95 (7/88)	100 (9/88)	TNC* (")	50 (9/88)	TNC* (")
Grassy Bay South (#11)	0.08 (6/88)	7.11 (")	13 (")	1077 (")	0 (")	790 (8/88)
Jo-Co Marsh (#12)	0.36 (9/89)	4.26 (")	38 (")	1454 (")	0 (7/89)	211 (")
Grass Hassock Chann. (#13)	0.13 (9/88)	3.45 (")	167 (8/88)	4118 (7/89)	0 (6/88)	319 (7/89)

*TNC = too numerous to count

inputs and rate components, develop hydrodynamic and eutrophication models specific to Jamaica Bay, and use the model to identify effective future management alternatives.

It is important to note that Norton Basin and Little Bay were not included in the sampling and modeling of the Bay. Additional sampling efforts and modeling runs would need to be made to calibrate the current model to the confined area of Norton Basin. Inferences can be made, though, about the conditions that may exist in Norton Basin based on conditions observed in Jo-Co Marsh, Grassy Bay, Head of Bay, Bergen Basin, and Shellbank Basin.

The report concluded that the four NYC WPCP's in the Jamaica Bay drainage area were contributing the majority of the carbon, nitrogen, and phosphorus (81.2%, 94.9%, and 94.9% of input sources, respectively), inputs to the Bay (O'Brien and Gere 2000). Landfills, however, contributed only 1.7% of carbon and 1.3% of nitrogen into the Jamaica Bay system.

Important results from the model calibration include percent of time for DO standard compliance for the majority of the Bay. **Table 5.2.1** lists DO measurements taken to calibrate the water quality model for areas throughout the Bay. The 1995-96 data demonstrated that dead-end canals, such as Shellbank Basin and Mill Basin, would have hydrodynamic features similar to Norton Basin and Little Bay and would experience seasonal hypoxia (O'Brien and Gere 2000). Overall, the model indicated that the northeast sections of the Bay, which experience restricted tidal flow, are chronically below NYSDEC DO standards (**Figure 5.2.1**).

5.3 Norton Basin/Little Bay

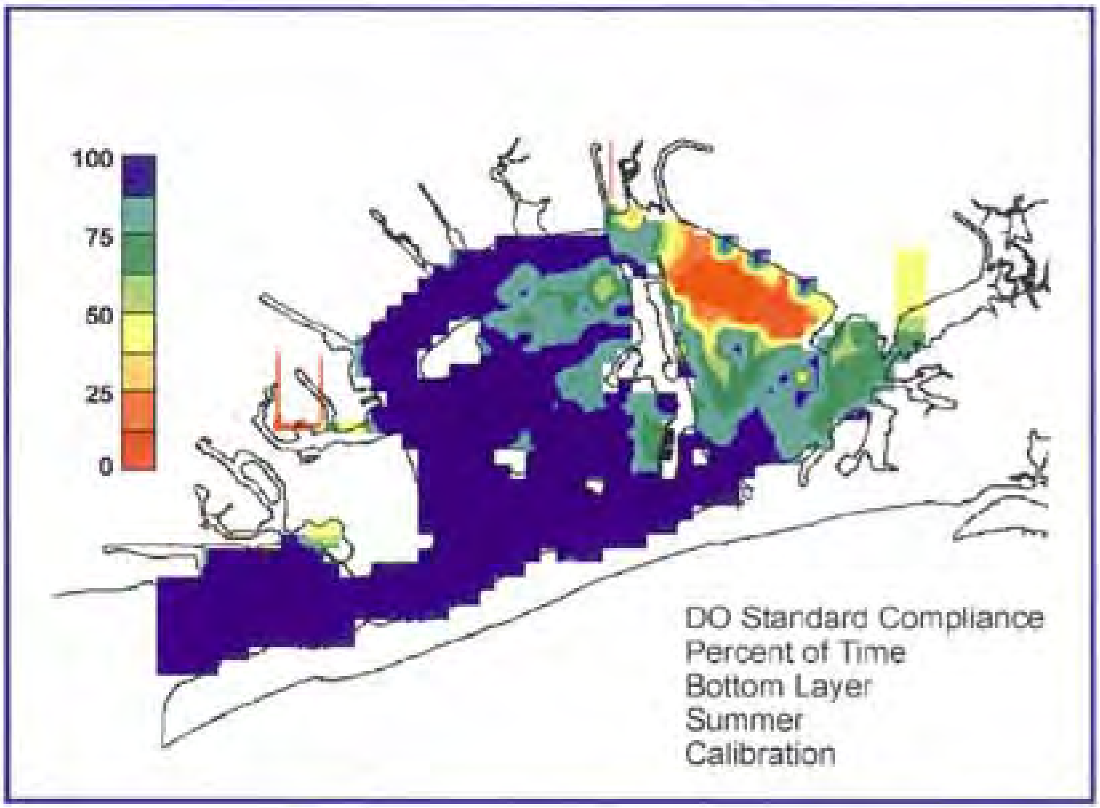
The tidal waters of Norton Basin and Little Bay have been designated Class "I" in accordance with NYSDEC, Title 6, Chapter X, Parts 700-705 (NYCDOS 1991). This designation means the water in this area is not considered to be potable and is not required to maintain maximum contaminant levels for drinking water standards. Class "I" designation requires a minimum DO level of 4.0 mg/L and notes that best usage of such waters can include secondary contact recreation, fishing, and fish propagation and survival. Virtually no long term water quality data exists for Norton Basin and Little Bay. The New York City Department of Sanitation (NYCDOS) collected short term monitoring data when assessing the potential impacts of closing the Edgemere Landfill in 1991.

Flow analysis of the landfill identified leachate flows into Jamaica Bay directly from the base of the landfill and indirectly from tidal deposits. (NYCDOS 1991). Three leachate seeps were identified at the eastern base of the landfill. The study estimated that average net flow of groundwater from the landfill to the Bay is 146,000 gallons per day (53 million gallons per year). It was also estimated that average net flow of groundwater from the neck of the landfill to Little Bay and Sommerville Basin is 130,000 gallons per day (47.5 million gallons per year).

The NYCDOS study indicated that the bottom of Little Bay in May of 1990 was hypoxic with a DO level below 1.0 mg/L (NYCDOS 1991). Tidal velocities ranged from less than 0.2 feet per second to more than 1.0 foot per second. The H2M Group calculated the daily

Table 5.2.1. Seasonal average DO concentrations from 1995-96 water quality monitoring station, Jamaica Bay Eutrophication Study. Shaded cells indicate measurements below the NY state standard of 5.0 mg/L. Adapted from O'Brien and Gere, 2000.

			Dissolved Oxygen (mg/L)				
Station No.	**Station Name**	**Strata**	**Summer 95**	**Autumn 95**	**Winter 96**	**Spring 96**	**Summer 96**
J01	Rockaway Inlet	Surface	7.10	10.91	12.93	11.79	6.71
		Bottom	6.60	10.36	12.05	9.46	6.31
J02	Island Channel	Surface	7.40	11.06	14.29	12.04	7.41
		Bottom	6.29	10.99	13.64	10.51	6.24
J03	Head of Bay	Surface	5.56	10.96	14.30	7.80	6.32
		Bottom	4.30	8.93	14.08	6.70	4.59
J04	Paerdegat Basin Ent.	Surface	7.22	8.90	13.70	10.36	6.98
		Bottom	5.76	8.14	13.23	9.58	5.67
J05	Fresh Creek Entrance	Surface	6.58	9.93	14.05	8.19	7.20
		Bottom	5.07	10.04	14.02	7.67	6.59
J06	Spring Creek Entrance	Surface	5.89	9.89	13.94	8.05	5.95
		Bottom	4.94	9.53	13.12	7.60	5.66
J07	Bergen Basin Entr.	Surface	7.03	9.30	13.58	8.53	7.69
		Bottom	3.95	8.53	13.21	7.31	5.50
J08	Grassy Bay	Surface	7.96	10.28	13.63	8.90	8.33
		Bottom	3.28	8.06	12.65	6.49	4.15
J09	Jo-Co Marsh Basin	Surface	5.78	10.97	15.14	8.09	6.68
		Bottom	4.68	9.74	14.05	6.27	4.61
J10	Grass Hassock Chan.	Surface	5.96	9.21	13.48	8.45	6.49
		Bottom	5.51	8.65	13.56	8.03	6.00
J11	Beach Channel	Surface	6.38	11.42	13.73	9.98	6.73
		Bottom	6.58	11.27	13.28	11.32	6.20
J12	The Raunt	Surface	7.87	9.88	13.69	10.36	7.59
		Bottom	7.29	9.55	13.64	10.05	7.56
J13	Big Fishkill Channel	Surface	7.55	12.77	14.65	10.94	8.07
		Bottom	6.66	12.26	14.25	10.74	8.02
J14	Pumpkin Patch Chann.	Surface	7.77	9.87	15.10	10.59	7.72
		Bottom	7.49	9.30	14.63	10.53	7.38
J15	East Broad Channel	Surface	7.21	11.84	15.98	7.97	5.99
		Bottom	3.76	10.01	14.43	6.88	5.24
J16	Mill Basin - Mid	Surface	8.54	10.92	14.98	12.52	7.86
		Bottom	4.67	9.89	13.20	8.68	4.85
J17	East Mill Basin	Surface	8.76	7.75	15.12	12.42	8.28
		Bottom	0.84	6.39	10.76	2.84	0.38
J18	Mill Basin - Head	Surface	8.21	6.79	14.84	10.49	7.82
		Bottom	1.44	5.66	13.52	5.54	2.73
J19	Shellbank Basin - Mid	Surface	6.83	8.60	15.34	8.30	4.97
		Bottom	1.42	8.43	13.04	3.20	1.76
J20	Shellbank Basin - Head	Surface	7.54	6.05	11.85	9.03	5.50
		Bottom	0.11	4.02	7.91	0.57	0.13



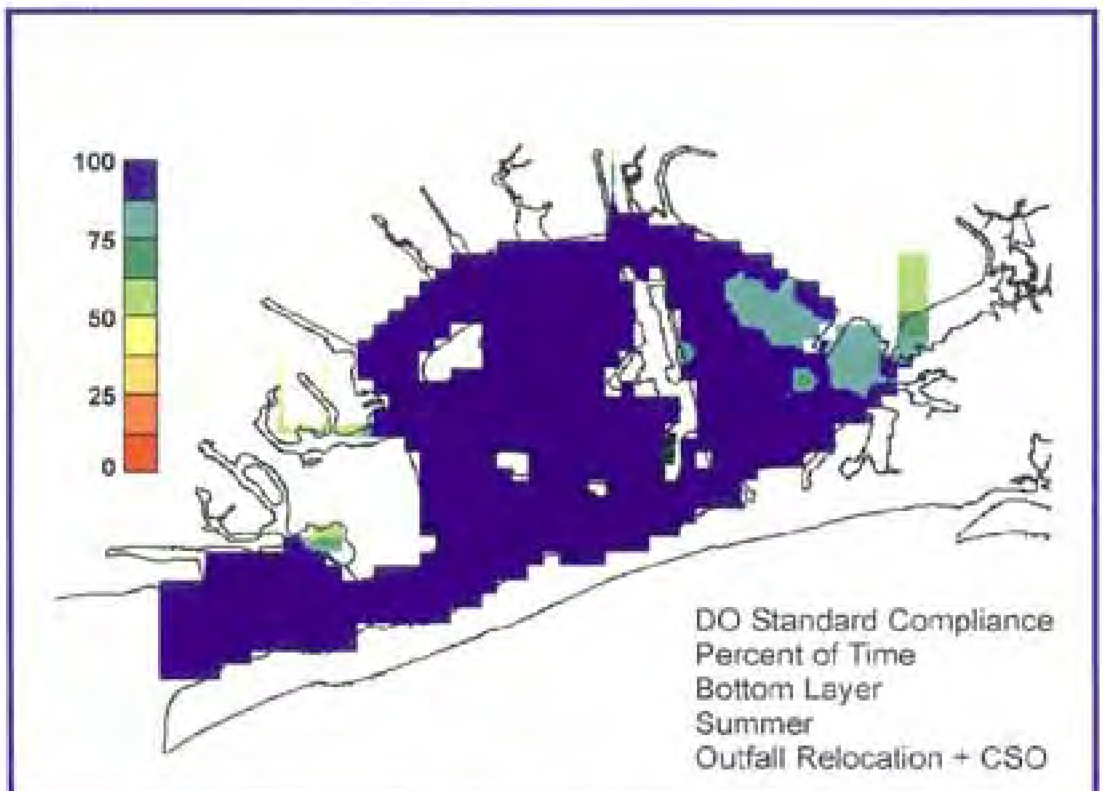


Figure 5.2.1. Change in DO standard compliance for Jamaica Bay based on model results from the Jamaica Bay Eutrophication Study. Upper image depicts percent compliance based on summer 1995 calibration. Lower image depicts estimated change in percent compliance assuming relocation of WPCP and CSO outfalls. Adapted from O'Brien and Gere, 2000.

tidal prism, non-tidal volume, and contaminated groundwater leachate for Norton Basin, Little Bay, and adjacent Grass Hassock Channel for the NYCDOS study (**Table 5.3.1**) (H2M Group 1990). Their calculations indicated that only the top 10 ft of water was being exchanged out of Little Bay with each tidal cycle. These calculations confirm that the enclosed basins, particularly Little Bay, have sub-standard water quality characteristics. Since the NYCDOS data was not collected over a long time period, however, frequent monitoring of Norton Basin and Little Bay would allow for a more detailed description of the parameters of the two basins.

Table 5.3.1. Daily tidal prism volume, non-tidal prism volume, and contaminated groundwater leachate discharge for Norton Basin, Little Bay and Grass Hassock Channel. Adapted from H2M Group, 1990.

	Volume of Tidal Prism (CY)	Non-Tidal Volume (CY)	Contaminated Groundwater Leachate Discharge (CY)	Dilution Ratio
Grass Hassock Channel	1,729,592	11,718,518	233	7423:1
Norton Basin and Little Bay	1,718,948	3,556,444	196	8770:1

6.0 Changes in Biological Resources

6.1 Jamaica Bay

As with its physical characteristics, sharp contrasts in biological resources exist within the relatively confined areas of Jamaica Bay. Jamaica Bay has been designated a Significant Coastal Fish and Wildlife Habitat by the New York State Department of State (NYSDOS) and the Bay, up to the high tide line, has been designated as a Critical Environmental Area by the NYSDEC (USFWS 1997). The Jamaica Bay Unit of the NPS-GNRA is the confluence of two principle flyways for migratory waterfowl. In 1971, approximately 300 species of birds were recorded in Jamaica Bay (JBESG 1971), making it a biological oasis in a highly urbanized area. This dense assemblage of birds is a direct result of the destruction of smaller estuaries along the coast. As smaller, more widely distributed estuarine habitats have disappeared, migratory birds have become concentrated in Jamaica Bay.

Throughout the year Jamaica Bay may support as many as 120 species of birds and 48 species of fish on a year-round or seasonal basis (USFWS 1997). **Table 6.1.1** lists some of the more common species found in Jamaica Bay. **Table 6.1.2** lists the Federally and state listed species occurring in Jamaica Bay.

Even in its preserved state, the biological resources of the Bay are a fraction of their historic levels. The decline of Jamaica Bay's resources began in the mid-1800's as human population densities increased around the perimeter of the Bay and harvesting pressure increased. In the 1860's, commercial harvesting techniques became available for the collection of shellfish, dramatically increasing the number of organisms removed from the Bay (Black 1981). The shellfish industry peaked in the early 1900's and crashed in the 1920's due to pollution. Beginning in the 1870's, a significant decrease in the quantity and

Table 6.1.1. Species commonly found in Jamaica Bay and potentially occurring in Norton Basin and Little Bay. Adapted from USFWS, 1997.

	Common Name	Species Name
Intertidal Plants	Salt Meadow Grass	*Spartina patens*
	Salt Marsh Cordgrass	*Spartina alterniflora*
	Sea Lettuce	*Ulva latuca*
Upland Plants	Autumn Olive*	*Elaeagnus umbellata*
	Bayberry	*Myrica pensylvanica*
	Beach Plum	*Prunus maritima*
	Beachgrass	*Ammophila breviligulata*
	Black Cherry	*Prunus serotina*
	Common Reed	*Phragmites australis*
	Cottonwood	*Populus deltoides*
	Grey Birch	*Betula populifolia*
	Hackberry	*Celtis occidentalis*
	Japanese Barberry*	*Berberis thunbergii*
	Japanese Black Pine*	*Pinus thunbergii*
	Japanese Knotweed*	*Polygonum cuspidatum*
	Little Bluestem	*Schizachyrium scoparium*
	Poison Ivy	*Toxidendron radicans*
	Seaside Goldenrod	*Solidago sempivirens*
	Sumac	*Rhus* spp.
	Switchgrass	*Panicum virgatum*
	Tree-of-Heaven	*Ailanthus altisima*
	Willow	*Salix* spp.
Bivalves, Mollusks, and Crustaceans	Atlantic Ribbed Mussel	*Geukensia demissa*
	Atlantic Surf Clam	*Spisula solidissima*
	Blue Crab	*Callinectes sapidus*
	Blue Mussel	*Mytilus edulis*
	Horseshoe Crab	*Limulus polyphemus*
	Mud Snail	*Ilyanassa obsoleta*
	Northern Quahog	*Mercenaria mercenaria*
	Soft-Shelled Clam	*Mya arenaria*
	Four-Eyed Amphipod	*Ampelisca abdita*

	Common Name	Species Name
Finfish	Alewife	*Alosa pseudoharengus*
	American Eel	*Anguilla rostrata*
	American Shad	*Alosa sapidissima*
	Atlantic Menhaden	*Brevoortia tyrannus*
	Atlantic Silverside	*Menidia menidia*
	Atlantic sturgeon	*Acipenser oxyrhynchus*
	Bay Anchovy	*Anchoa mitchilli*
	Black Sea Bass	*Centropristis striata*
	Blueback Herring	*Alosa aestivalis*
	Bluefish	*Pomatomus saltatrix*
	Mummichog	*Fundulus heteroclitus*
	Scup	*Stenostomus chrysops*
	Searobin	*Prionotus* spp.
	Striped Bass	*Morone saxatilis*
	Striped Killifish	*Fundulus majalis*
	Summer Flounder	*Paralichthys dentatus*
	Tautog	*Tautoga onitis*
	Weakfish	*Cynoscion regalis*
	Windopane	*Scophthalmus aquosus*
	Winter Flounder	*Pleuronectes americanus*
Waterfowl	American Black Duck	*Anas rubripes*
	American Wigeon	*Anas americana*
	Brant	*Branta bernicula*
	Bufflehead	*Bucephala albeola*
	Canada Goose	*Branta canadensis*
	Canvasback	*Aythya valisneria*
	Greater Scaup	*Aythya marila*
	Mallard	*Anas platyrhynchos*
	Red-Breasted Merganser	*Mergus serrator*
	Ruddy Duck	*Oxyura jamaicensis*
	Snow Goose	*Chen caerulescens*

*Introduced species

Table 6.1.1 (con't). Species commonly found in Jamaica Bay and potentially occuring in Norton Basin and Little Bay. Adapted from USFWS, 1997.

	Common Name	Species Name
Shorebirds	American Oystercatcher	*Haematopus palliatus*
	Black Skimmer	*Rhynchops niger*
	Black-Bellied Plover	*Pluvialis squatarola*
	Dunlin	*Calidris alpina*
	Great Black-Backed Tern	*Larus marinus*
	Greater Yellowlegs	*Tringa melanoleuca*
	Herring Gull	*Larus argentatus*
	Laughing Gull	*Larus atricilla*
	Least Sandpiper	*Calidris minutilla*
	Least Tern	*Sterna albifrons*
	Ruddy Turnstone	*Arenaria interpres*
	Sanderling	*Calidris alba*
	Semipalmated Plover	*Charadrius semipalmatus*
	Semipalmated Sandpiper	*Calidris pusilla*
	Willet	*Catoptrophorus semipalmatus*
Raptors	American Kestrel	*Falco sparverius*
	Sharp-Shinned Hawk	*Accipiter striatus*
Wading Birds	Black-Crowned Night Heron	*Nycticorax nycticorax*
	Cattle Egret	*Bubulcus ibis*
	Glossy Ibis	*Plegadis falcinellus*
	Great Egret	*Casmerodius albus*
	Snowy Egret	*Egretta thula*
	Tricolored Heron	*Egretta tricolor*

	Common Name	Species Name
Reptiles & Amphibians	Eastern Box Turtle*	*Terrapene c. carolina*
	Eastern Hognose Snake*	*Heterodon platirhinos*
	Eastern Milk Snake*	*Lampropeltis triangulum*
	Eastern Painted Turtle*	*Chrysemys p. picta*
	Fowler's Toad*	*Bufo woohousii fowleri*
	Gray Treefrog*	*Hyla versicolor*
	Green Frog*	*Rana clamitans*
	Northern Black Racer*	*Coluber c. constrictor*
	Northern Brown Snake*	*Storeria d. dekayi*
	Redback Salamander*	*Plethodon cinereus*
	Smooth Green Snake*	*Opheodrys vernalis*
	Snapping Turtle*	*Chelydra serpentina*
	Spotted Salamander*	*Ambystoma maculatum*
	Spring Peeper*	*Pseudacris crucifer*
Mammals	Black-Tailed Jackrabbit*	*Lepus californicus*
	Eastern Chipmunk*	*Tamais striatus*
	Eastern Cottontail	*Sylvilagus floridanus*
	Gray Squirrel	*Sciurus carolinensis*
	Hoary Bat	*Lasiurus cinereus*
	House Mouse	*Mus musculus*
	Little Brown Bat	*Myotis lucifugus*
	Meadow Vole	*Mircotus pennsylvanicus*
	Muskrat	*Ondatra zibethicus*
	Opossum	*Didelphis virginiana*
	Red Bat	*Lasiurus borealis*
	Silver-Haired Bat	*Lasionycteris noctivagans*
	White-Footed Mouse	*Peromyscus leucopus*

*Introduced species

Table 6.1.2. Federal and state threatened and endangered species occurring in Jamaica Bay. Adapted from USFWS, 1997.

Common Name	Species Name	Federally Endangered	Federally Threatened	State Endangered	State Threatened	State Special Concern	State Rare Plants
Kemp's Ridley Sea Turtle	*Lepidochelys kempii*	X					
Roseate Tern	*Sterna dougallii*	X					
Loggerhead Sea Turtle	*Caretta caretta*		X				
Piping Plover	*Charadrius melodus*		X				
Seabeach Amaranth	*Amaranthus pumilis*		X				
Peregrine Falcon	*Falco peregrinus*			X			
Least Tern	*Sterna antillarum*			X			
Willow Oak	*Quercus phellos*			X			
Northern Harrier	*Circus cyaneus*				X		
Osprey	*Pandion haliaetus*				X		
Common Tern	*Sterna hirundo*				X		
Spotted Salamander	*Ambystoma maculatum*					X	
Least Bittern	*Ixobrychus exilis*					X	
Cooper's Hawk	*Accipiter cooperii*					X	
Upland Sandpiper	*Bartramia longicauda*					X	
Short-eared Owl	*Asio flammeus*					X	
Common Barn Owl	*Tyto alba*					X	
Grasshopper Sparrow	*Ammondramus savannarum*					X	
Houghton's Umbrella-sedge	*Cyperus houghtonii*						X
Blunt Spikerush	*Elecharis obtusa*						X
Field-dodder	*Cuscuta pentagona*						X
Smartweed-dodder	*Cuscuta polygonum*						X
Schweinitz's Flatsedge	*Cyperus schweinitzii*						X

quality of oysters in New York Harbor, including Jamaica Bay, was noticed (Carriker et al. 1982). The decline was attributed to the unrestricted waste disposal practices throughout NY/NJ Harbor.

In 1900, the Oysterman's Association of Canarsie operated 266 boats on 500 to 600 oyster plots in Jamaica Bay and harvested 10,000 bushels of clams (JBESG 1971). By 1917, the majority of fishermen in Jamaica Bay were recreational and not commercial (Bellot 1917); and starting in 1921 Jamaica Bay was closed to commercial shellfishing due to health risks associated with typhoid outbreaks (JBESG 1971).

Jamaica Bay functions as a nursery for marine and estuarine species of the northeast Atlantic Coast. A gill net and otter trawl survey of the Bay from 1988–1989 collected 75 species, many of commercial and recreational significance (**Table 6.1.3**, GNRA 1991). The majority of the organisms collected during this survey were juveniles, emphasizing the use of the Bay as a nursery. Winter flounder was the dominant species collected during the survey.

Juvenile winter flounder diets in Jamaica Bay are composed almost entirely of amphipods. Franz and Tanacredi (1992) found that the amphipod, *Ampelisca abdita*, constituted 88% of the benthic organisms consumed by juvenile winter flounder at 10 stations in Jamaica Bay. They identified two cohorts of amphipods each year and the samples collected from Jo-Co Marsh Pit, which may be similar to Norton Basin and Little Bay in hydrology and sediment composition, were lower in density than other locations in the Bay, suggesting an impacted habitat not meeting its ecological potential. They also suggested that the *Ampelisca abdita* population alone was enough to support the winter flounder nursery in Jamaica Bay.

Franz and Harris (1983) also analyzed benthic invertebrate communities throughout Jamaica Bay. They collected 82 taxa from 27 stations in the Bay, and report Shannon Diversity Index values from 1.58 (Station 9 - Grassy Bay, the most impacted station) to 5.55 (Station 11) (Franz and Harris 1983). Densities ranged from 52 organisms/m^2 (Station 9 – Grassy Bay) to 44,128 organisms/m^2 (Station 7 – Motts Point). **Table 6.1.4** lists 5 of the stations in eastern Jamaica Bay which would be similar to Norton Basin and Little Bay communities. Dominant species throughout the Bay were the amphipods *Ampelisca abdita*, *Unciola dissimilis*, and *Corophium* sp. Benthic communities were dictated by sediment type. Species richness was positively correlated to percent total organic carbon (TOC), with *Ampelisca abdita* dominating muddy sand sediments and polychaete communities dominating mud and silt sediments (Franz and Harris 1983).

Both benthic invertebrate and finfish data collected around the perimeter of Jamaica Bay, where anthropogenic impacts are the greatest, suggests that areas of high silt content, where tidal flow is restricted, are depleted in biological resources compared to other areas of the Bay. In 1971, Grassy Bay, Bergen Basin, and the open channels around the perimeter of Bay had low abundance and diversity of organisms (60 species of finfish and shellfish). The standing crop of finfish in these areas was less than one pound/acre compared to 73 pounds/acre in San Francisco Bay and 200 pounds/acre in Laguna Madre,

Table 6.1.3. Finfish species collected in Jamaica Bay by National Park Service using gill nets and otter trawls, 1985-1986 and 1988-1989. Adapted from GNRA, 1991.

Common Name	Scientific Name	Common Name	Scientific Name
Sand tiger shark	*Odontaspis taurus*	Black sea bass	*Centropristis striata*
Smooth dogfish	*Mustelis canis*	Bigeye	*Priacanthus arenatus*
Spiny dogfish	*Squalus acanthias*	Short bigeye	*Pristigenys alta*
Little skate	*Raja erinacea*	Bluefish	*Pomatomus saltatrix*
Clearnose skate	*Raja elanteria*	Cobia	*Rachycentron canadum*
Cownose ray	*Rhinoptera bonasus*	African pompano	*Alectis cilaris*
Atlantic sturgeon	*Acipenser oxyrhynchus*	Yellow jack	*Caranx bartholomaei*
American eel	*Anguilla rostrata*	Crevalle jack	*Caranx hippos*
Conger eel	*Conger oceanicus*	Bigeyed scad	*Selar crumenophthalmus*
Bluback herring	*Alosa aestvalis*	Lookdown	*Selene vomer*
Alewife	*Alosa pseudoharengus*	Scup	*Stenotumus chrysops*
American shad	*Alosa sapidissima*	Northern kingfish	*Menticirrhus saxatilis*
Atlantic menhaden	*Brevoortia tyrannus*	Spot	*Leistomus xanthurus*
Atlantic herring	*Clupea harengus*	Weakfish	*Cynoscion regalis*
Bay anchovy	*Anchoa mitchilli*	Spotfin butterflyfish	*Chaetodon ocellatus*
Inshore lizardfish	*Synodus foetens*	Tautog	*Tautoga onitis*
Oyster toadfish	*Opsanus tau*	Cunner	*Tautogolabrus adspersus*
Atlantic cod	*Gadus morhua*	Striped mullet	*Mugil cephalus*
Atlantic tomcod	*Microgadus tomcod*	White mullet	*Mugil curema*
Silver hake	*Merluccius bilinearis*	Northern sennett	*Sphyraena borealis*
Red hake	*Urophycis chuss*	Northern stargazer	*Astroscopus guttatus*
Spotted hake	*Urophycis regia*	Ocean pout	*Macrozoarces americanus*
White hake	*Urophycis tenuis*	American sand lance	*Ammodytes hexapterus*
Halfbeak	*Hyporhamphus unifasciatus*	Naked goby	*Gobiosoma bosci*
Atlantic needlefish	*Strongylura marina*	Seaboard goby	*Gobiosoma ginsburgi*
Mummichog	*Fundulus heteroclitus*	Butterfish	*Peprilus triacanthus*
Banded killifish	*Fundulus diaphanus*	Northern searobin	*Prionotus carolinus*
Striped killifish	*Fundulus majalis*	Striped searobin	*Prionotus evolans*
Spotfin killifish	*Fundulus luciae*	Grubby sculpin	*Myoxocephalus aeneus*
Inland silverside	*Menidia beryllina*	Longhorn sculpin	*Myoxocephalus octodecimspinosus*
Atlantic silverside	*Menidia menidia*	Summer flounder	*Paralichthys dentatus*
Bluespotted coronetfish	*Fistularia tabacaria*	Fourspot flounder	*Paralichthys oblongus*
Fourspine stickleback	*Apeltus quadracus*	Gulf stream flounder	*Citharichthys arctifrons*
Threespine stickleback	*Gasterosteus aculeatus*	Smallmouth flounder	*Etropus microstomus*
Lined seahorse	*Hippocampus erectus*	Windowpane	*Scophthalmus aquosus*
Northern pipefish	*Syngnathus fuscus*	Winter flounder	*Pleuronectes americanus*
White perch	*Morone americana*	Hogchoker	*Trinectes maculatus*
Striped bass	*Morone saxatilis*		

Table 6.1.4. Density of benthic invertebrates, number of species, diversity, amphipod density, and percent dominance of amphipods collected from various stations in the western portion of Jamaica Bay (n=2). Adapted from Franz and Harris, 1983.

Station Name	Station #	No. Species	Shannon Diversity H'	Total Density (m^2)	Amphipoda Density (m^2)	Percent Dominance of Amphipoda (%)	Total Biomass (g/m^2)
Beach Chan./Winhole Chan.	5	30	3.21	2,676	1,492	55.8	58.30
Grass Hassock Chan.	6	38	1.75	30,476	15,152	49.7	436.87
Motts Point	7	46	1.59	4,412	22,816	51.7	119.18
Grassy Bay	9	13	1.42	52	--	--	1.40
Ruler's Bar	26	28	1.52	17,896	5,808	32.4	135.22

Texas (JBESG 1971). For Jamaica Bay, the values observed in the survey ranged from zero fish/acre in Grassy Bay to 6.5 pounds/acre in North Channel.

Of recent political and ecological significance is the issue of wetland loss in Jamaica Bay. Interagency efforts are currently being made to determine the causes of intertidal wetland loss throughout Jamaica Bay and strategies to conserve and restore the remaining wetlands. Preliminary estimates of current rates of wetland loss in Jamaica Bay are 44 acres/year (Dave Fallon, NYSDEC, pers. comm.). At this rate the remaining 1000 acres of intertidal marsh will not exist by 2024. Public interest in restoring intertidal habitats in Jamaica Bay has significantly increased in the past year. This interest has prompted local, state, and Federal agencies to begin intensive investigations into the ecological issues of Jamaica Bay.

6.2 Norton Basin/Little Bay

When compared to the habitats of Jamaica Bay located with the NPS-GNRA boundaries, virtually nothing is known of the biology of Norton Basin and Little Bay. It can be assumed that before the dredging of the borrow pits to create Edgemere Landfill in 1938, the small basins had the same relative floral and faunal characteristics as the rest of the Bay. As late as 1872 the perimeters of Edgemere and Arverne were covered with groves of cedar trees (Bellot 1917).

The only documentation of biota collected in Norton Basin comes from the NYCDOS Edgemere Landfill Closure reports (NYCDOS 1991, 1992). NYCDOS (1991) identified the following taxa of plants in the upland and intertidal portions of the landfill: *Phragmites communis*, *Artemisia vulgaris*, *Spartina* sp., *Helianthus* sp., *Ambrosia* sp., *Polygonum* sp., *Artemisia vulgaris*, Gramineae, Compositae, *Populus* sp., *Ailanthus* sp., *Prunus* sp., *Rhus* sp., and *Myrica* sp. The survey did not quantify abundances or densities of species and may not be complete. NYCDOS (1991) also identified the following finfish taxa in the subtidal habitats surrounding the landfill: Atlantic silversides, *Menidia menidia*, and winter flounder, *Pleuronectes americanus*. Conspicuously missing from this list are the mummichog, (*Fundulus heteroclitus*), Atlantic menhaden (*Brevoortia tyrannus*), and bluefish (*Pomatomus saltatrix*).

7.0 Anthropogenic Impacts

The following discussions of cultural, topographical, water quality and biological changes develop the current status of the level of impact humans have had on the ecology of

Jamaica Bay. The types of impacts experienced in Jamaica Bay are no different than those experienced in any other part of the NY/NJ Harbor. Such impacts include dredging, waste-water and sewage treatment plants, landfill runoff, shipping and boating traffic, and industry.

Approximately 71 MCY of sediment have been dredged from Jamaica Bay over the last 80 years (West-Valle et al. 1991). The largest single dredging event was the creation of the borrow pit in Grassy Bay, which was authorized to dredge 37 MCY of material to create fill for JFK Airport. It is estimated that 70% of the current water volume of the Bay has been added as the result of dredging, thereby increasing the surface to volume ratio and exacerbating eutrophication (West-Valle et al. 1991). It is also important to note that the majority of the 71 MCY of sediment removed from the subtidal habitats of Jamaica Bay was used to fill intertidal marshes around the perimeter of the Bay. The impact has been two-fold, the modification of subtidal habitats and the destruction of intertidal habitats.

West-Valle et al. (1991) estimated that approximately 287 million gallons of treated effluent per day are discharged into the Bay from the six sewage treatment plants operating in Jamaica Bay, approximately 1.3% of the tidal prism. The treatment plant discharges represent the majority of freshwater input to the Bay. By 1980, more than 1.5 million people were using the six sewer districts that empty into the Bay (West-Valle et al. 1991). O'Brien and Gere (2000) calculated that the water treatment facilities are the greatest sources of carbon, nitrogen, and phosphorus to the Bay (**Figure 7.0.1**). The water treatment facilities were cited as the primary source adding to the continued eutrophication of Jamaica Bay.

In 1987 ship traffic in Jamaica Bay totaled 20,341 vessels, including recreational, industrial, and commercial vessels (West-Valle et al. 1991). The impacts associated with this traffic include fuel spillage, increased wave erosion, and loss of cargo. These impacts are relatively less than other areas of the Harbor simply because Jamaica Bay does not receive the same frequency of ships and boats passing through its channels. The Long Island Railroad bridge limits the size and frequency of large barges passing through the eastern channels of Jamaica Bay. This has helped to lessen the impacts of shipping in the western portions of the Bay. Boat traffic in Norton Basin and Little Bay would be limited to recreational traffic that would be able to navigate through the shallow entrance channel to the basin.

Jamaica Bay may be severely impacted, but has still received less industrial pollution relative to other areas of the Harbor (JBESG 1971). Skinner et al. (1996) analyzed tissue samples of 26 species of finfish, bivalves, crustaceans, and squid in six areas of the NY/NJ Harbor estuary for polychlorinated biphenyls (PCBs), DDT compounds, mercury, chlordane compounds, and polycyclic aromatic hyrdocarbons (PAHs). The tissue samples collected from Jamaica Bay contained detectable concentrations of each of these chemicals, but were in significantly lower proportions compared to other areas of the NY/NJ Harbor. This is due to the fact that Jamaica Bay has received less industrial pollution relative to areas such as the Arthur Kill, Kill Van Kull, and Newark Bay. **Table 7.0.1** compares the furan and dioxin levels in tissues of commercially and recreationally

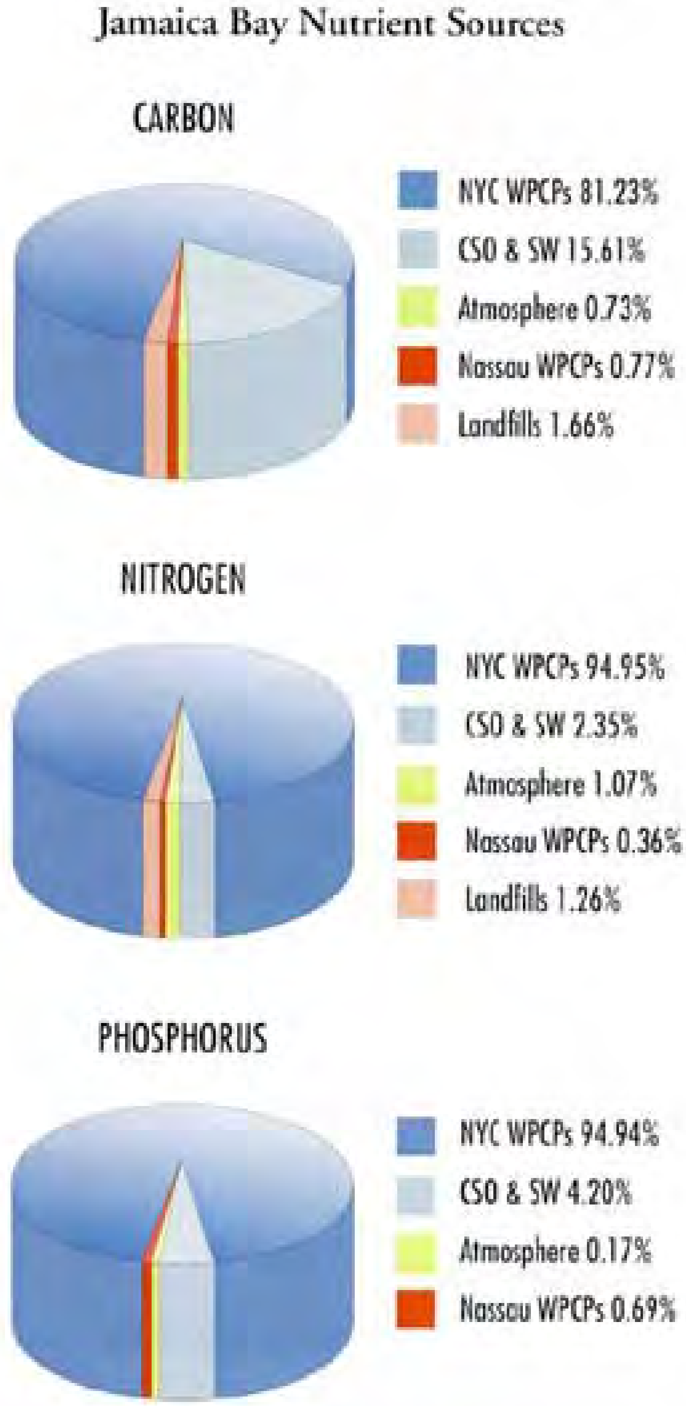


Figure 7.0.1. Sources of carbon, nitriogen, and phosphorus into Jamaica Bay. Calculated by O'Brien & Gere (2000) for the Jamaica Bay Eutrophication Study, NYCDEP.

Table 7.0.1. Total dioxin and total furans levels [measured in pico-grams/gram (pg/g)] from tissues collected from edible organisms in Jamaica Bay and Upper Bay, NY/NJ. Adapted from Skinner et al. 1997 for NYSDEC survey of tissue contaminant levels in six areas of NY/NJ Harbor Estuary. Upper Bay (Area 1) was selected as a relative comparison to Jamaica Bay (Area 4). Samples were also collected from the Hudson River, East and Harlem Rivers, Newark Bay, Lower Bay, and New York Bight Apex.

		Jamaica Bay (Area 4)				**Upper Bay (Area 1)**			
		Total Dioxins pg/g (wet weight)		**Total Furans** pg/g (wet weight)		**Total Dioxins** pg/g (wet weight)		**Total Furans** pg/g (wet weight)	
Species	**Size/Tissue**	Sample 1*	Sample 2*	Sample 1*	Sample 2*	Sample 1*	Sample 2*	Sample 1*	Sample 2*
American Eel		6.19	2.86	2.99	1.64	6.42	7.13	2.30	3.23
Bluefish	< 12 inches TL	2.37	3.00	1.82	2.54	4.20	3.85	3.23	2.39
	12 - 22 inches TL	1.41	5.87	1.57	2.28	na	na	na	na
	> 22 inches TL	5.34	2.10	5.20	2.47	62.06	36.58	63.94	37.49
Striped Bass	18 - 24 inches TL	na	na	na	na	7.13	45.62	8.40	4.54
	24 - 30 inches TL	5.14	2.93	13.94	10.80	7.40	5.58	44.72	16.85
	> 30 inches TL	5.40	na	12.54	na	3.52	6.27	3.36	7.35
Tautog		0.85	1.71	0.50	2.21	0.52	4.42	0.34	4.17
White Perch		5.93	8.86	1.16	2.26	5.62	24.58	5.52	23.28
Winter Flounder		2.00	2.37	0.71	2.03	1.44	1.85	0.87	1.57
Blue Crab	muscle	2.40	1.80	0.32	0.57	13.98	2.58	3.60	1.00
	hepatopancreas	13.55	14.30	4.94	5.77	240.40	98.60	566.60	340.00

* Legal edible size organisms were collected by angling and crab pots. Tissue samples were taken to make 25 - 30 gram aliquots for analysis. Each aliquot was given a NYSDEC identification number. For the purposes of this report, the aliquots are refered to as sample 1 or sample 2.

harvested finfish and crustaceans from Jamaica Bay to the Upper Bay. The Upper Bay had relatively higher levels of the majority of dioxins and furans but did not contain the highest level of tissue concentrations in the study. Areas such as Newark Bay and the East and Harlem Rivers exhibited the highest levels of bioaccumulation of PCBs in the study (Skinner et al. 1997).

Eastern Jamaica Bay has not received the level of industrial impacts experienced by the western portion of the Bay. Between 1859 and 1934, twenty eight companies operated on Barren Island alone (West-Valle et al. 1991). These industries included fish processing plants as well as refuse and fertilizer disposal facilities (Black 1981). To date the only major facility to have operated on the shores of Norton Basin and Little Bay is the Edgemere Landfill.

A Master's Thesis from Hunter College in 1978 investigated PCB bioaccumulation and was unable to detect significant differences between PCB's in the sediment and biological tissue samples collected from Jamaica Bay (Gelbart 1978). The project collected tissue samples from the soft-shelled clam, *Mya arenaria,* and Atlantic menhaden from two sites located near Norton Basin and Little Bay.

While the impacts of PCBs and heavy metal contamination of the sediments of Jamaica Bay has been significant, a decrease has been observed in relative levels over the last four decades. Bopp et al. (1993) examined sediment cores taken from Grassy Bay for historic PCB and heavy metal levels. The study estimated that the sedimentation rate of Grassy Bay from mid-1950's to late-1980's was 1.4 cm/yr. This material was almost exclusively fine grain silt. The sediment core samples revealed that PCB, copper, lead, zinc, chromium, and mercury levels peaked in the late 1960's and had steadily declined to approximately half of their highest levels by the late 1980's (PCB levels were 420 ppb in surface sediments from 1983) (**Table 7.0.2**).

The NPS-GNRA also conducted an analysis of intertidal sediment and tissue samples from Grassy Bay (Quinn and Cairns 1995). Their results indicated similar PCB and PAH congeners between sediment samples and tissue samples from the mud snail (*Ilyanassa obsoleta*), ribbed mussels (*Geukensia demissa*), and soft-shell clams (**Table 7.0.3**). The relationship between contaminant levels in the sediments and tissues from each station was not significant.

7.1 Edgemere Landfill

Edgemere Landfill was opened in 1938 to receive the tremendous volumes of trash being produced by the Borough of Queens. From 1938 to its closure in June 1991, the landfill received over 9 MCY of municipal waste (NYCDOS 1991). The presence of the landfill has had a profound impact on the ecological characteristics of Norton Basin and Little Bay and was identified as one of the two major contamination sources at Edgemere (the second being the neck of the peninsula leading to the landfill where illegally buried drums were discovered in 1982).

Table 7.0.2. Trace metal data from cores JB6 and JB13 taken from Grassy Bay. Adapted from Bopp et al., 1993.

Core	Depth (cm)	Cu (ppm)	Pb (ppm)	Zn (ppm)	Cr (ppm)	Hg (ppm)
JB 6	12-16	334	350	554		
	28-32	250	280	414		
	36-40	164	208	401		
	40-44	188	237	633		
	44-47	169	188	460		
JB 13	0-2	208	152	325	102	1.0
	2-4	251	196	369	124	1.1
	4-6	277	190	417	131	1.0
	6-8	226	241	873	150	1.3
	8-12	205	201	387	133	1.3
	12-16	222	231	412	148	1.0
	16-20	280	267	496	165	1.4
	20-24	385	332	622	187	1.5
	24-28	372	339	598	198	2.0
	28-32	406	372	704	243	2.4
	32-36	382	336	606	225	2.3
	36-40	289	249	464	166	1.6
	40-44	285	269	479	140	1.6
	44-48	221	242	384	136	1.3
	48-52	196	210	382	118	1.2
	52-54	151	165	285	105	1.0

Prior to the construction of the landfill, Norton Basin and Little Bay were two open areas of intertidal marsh and mudflat connected by shallow channels. The sediment used to create the base for the landfill was taken from the channels and placed on the intertidal areas of the basin. Approximately 2 MCY of dredged material were taken from adjacent areas and used to create the 118 acre landfill (CR Environmental 2001). The consequence of the landfill was a loss of wetland habitat and the creation of two borrow pits in the southern end of each basin.

The landfill itself created a new habitat in Jamaica Bay. In 1965, the claim was made that Edgemere Landfill had more herring gulls living and feeding off of its surface than all of the area north of Cape Anne, MA, which is traditionally identified as the home nesting region of herring gulls (JBESG 1971). Herring gulls in Jamaica Bay represent the greatest potential source of airstrike hazards at JFK. Edgemere Landfill represented a significant

Table 7.0.3. Surface sediment organic and tissue organic contaminants collected from intertidal stations in Jamaica Bay for the NPS-GNRA 1995 survey of organic contaminants in organisms and sediments from Grassy Bay stations adjacent to Kennedy International Airport. Tissue samples were analysed from soft-shell clam (*Mya areneria*), ribbed mussel (*Geukensia demissa*), and mud snails (*Ilyanassa obsoleta*). Adapted from Quinn & Cairns, 1995.

Surface Sediment Organic Contaminants and Organic Carbon

Station Name	NPS St. Number	Total PCBs (ng/g)	Total PAHs (ng/g)	Organic Carbon (OC) (ng/g)	PCBs/OC (ng/g)	PAHs/OC (ng/g)
JFK Outflow Pipe 1	1	29.6	337.0	2.3	12.9	146.0
JFK Outflow Pipe 2 (outside boom)	2a	117.0	3130.0	4.4	26.6	711.0
JFK Outflow Pipe 2 (inside boom)	2b	1380.0	11800.0	17.7	77.9	667.0
JFK Outflow Pipe 2 (outfall)	2c	0.9	101.0	2.3	0.4	43.9
Grassy Bay NW	3	3.1	13.1	2.4	1.3	5.5
Grassy Bay SW (control site)	4	5.5	515.0	4.6	1.2	112.0
Grassy Bay South	6	2.8	49.6	2.8	1.0	17.7
Grassy Bay SE	7	7.0	9440.0	51.0	0.1	185.0
East Broad Chan./Cross Bay Blvd.	10	1.2	75.2	2.9	0.4	25.9
Ruler's Bar	11	3.3	74.4	3.3	1.0	22.6
Black Bank Marsh	12	6.0	90.1	4.1	1.5	21.9
Rockaway Inlet	16	0.2	4.2	1.5	0.1	2.8

Tissues Organic Contaminants

Station Name	NPS St. Number	Total PCBs (ng/g)	Total PAHs (ng/g)
CLAMS			
JFK Outflow Pipe 1	1	885	3930
JFK Outflow Pipe 2	2	490	8040
Grassy Bay NW	3	285	1390
Grassy Bay SW	4 (control)	234	794
MUSSELS			
JFK Outflow Pipe 1	1	1218	3540
JFK Outflow Pipe 2	3	760	2630
Grassy Bay SW	4 (control)	251	772
MUD SNAILS			
JFK Outflow Pipe 1	1	4320	7580
JFK Outflow Pipe 2	2	2960	8120
Grassy Bay NW	3	935	1290

hazard because it is located directly in the path of runway 4L at JFK airport and was concentrating such a great number of gulls.

In 1982, approximately 3,000 illegally disposed 55 gallon drums of industrial waste were found buried on the Edgemere Landfill property (NYCDOS 1991). The discovery and subsequent clean-up of these hazardous materials led to the closure of the landfill and an investigation by the NYCDOS into the effects Edgemere Landfill was having on adjacent areas. In 1991 and 1992 Remedial and Feasibility Investigations were completed outlining the closure of the landfill. These reports offer the only direct information concerning the geological, hydrological, and ecological characteristics of Norton Basin and Little Bay. The Remedial and Feasibility Investigations concluded that of the upper glacial sand deposits underlying the landfill material at Edgemere effectively contained landfill contaminants. Contaminant levels in the upper glacial sand were below recommended cleanup levels and were a fraction of the levels recorded in the landfill material (NYCDOC 1991). The report also estimated that approximately 1,128 cubic yards (CY) of sediment/year were eroding from Edgemere Landfill into adjacent waters (NYCDOS 1992). The investigation concluded that the contaminants in these sediments were not a direct threat to the ecological health of the basins.

Even though biological and hydrological impacts were assessed in the NYCDOS reports, chemical levels in sediment and water were the primary focus of the investigations. Volatile organic compounds (VOCs) in surface water samples in Little Bay were observed to be less than 10 ppb, lower than six Jamaica Bay reference stations. **Table 7.1.1** lists the ranges of VOCs and Bureau of Waste Management (BWM) parameters collected from the subtidal sediments surrounding the landfill. The report stated that Edgemere Landfill accounted for less than one percent of contaminants found in Jamaica Bay. They commented that contaminant levels do not exceed maximum contaminant levels for drinking water, but observed that some contaminant levels below the drinking water standard do have toxic effects on aquatic organisms.

The NYCDOS also reviewed previous reports investigating the status and health standard compliance of Edgemere Landfill when completing the remedial investigation and feasibility study of the landfill closure. The following reports may have related information on the level of contamination and water quality in the areas surrounding Edgemere Landfill (NYCDOS 1991):

- “Analytical characteristics of landfill waters,” October 1979, New York City Department of Environmental Protection.
- “Study of six Department of Sanitation landfill disposal facilities and their compliance with the applicable Federal and state laws, rules and requirements,” January 1980, Parsons Brinckerhoff-Cosulich.
- “Preliminary report – hydrogeologic conditions at four (4) landfills in New York City,” March 1982, Leo M. Page.
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Table 7.1.1. Volatile Organic Compound (VOC) and Bureau of Waste Management (BWM) parameters measured in Norton Basin and Little Bay. Adapted from NYCDOS, 1991.

		Range of Levels in Tidal Sediments
VOC#		
	Acetone	**7,600 -33,000 ppb** tidal channel in Norton Basin = 12,000 ppb; borrow pit in Little Bay = 11,000 ppb
	Methylene chloride	**29 - 60,000 pbb** tidal channel in Norton Basin = 29,000 pbb; borrow pit in Little Bay = 60,000 ppb
	Butanone	**170 - 24,000 pbb** tidal channel in Norton Basin = 16,000 pbb; borrow pit in Little Bay = 24,000 pbb
	Tetrachloroethene	**11 - 830 pbb** tidal channel in Norton Basin = 620 pbb; borrow pit in Little Bay = 830 pbb
BWM#	**Chlorides**	**2,300 - 15,200 ppm**
	TDS	**4,250 - 27,200 ppm**
	NH_3	**293 - 1280 ppm**
	NO_3	**6.5 - 47.9 ppm** (highest levels were in pits and channels)

- "Trip report and findings," March 1983, New York City Department of Environmental Protection.
- "Engineering investigations at inactive hazardous waste sites in the state of New York, Phase I – preliminary investigation – Edgemere Landfill," September 1983, New York State Department of Environmental Conservation.
- "Boring report for Fountain Avenue Landfill, Pennsylvania Avenue Landfill, and Edgemere Landfill," October 1983, Malcolm Pirnie, Inc.
- "Regulatory requirements for the continued operation of the Fountain Avenue, Pennsylvania Avenue, and Edgemere Landfill," November 1983, Gibbs & Hill, Inc.
- "Cover management plan for the Fountain Avenue, Pennsylvania Avenue, and Edgemere Landfills," May 1984, SCS Engineers.
- "Hydrogeologic study - Fountain Avenue, Pennsylvania Avenue, and Edgemere Landfills - Part 1 and Part 2 – regional and site report," 1984, Gibbs & Hill, Inc.
- "Permit applications outline for the continued operation and closure of the Fountain Avenue, Pennsylvania Avenue, and Edgemere Landfills," March 1984, Gibbs & Hill, Inc.
- "Memorandum of preliminary assessment of landfill gas problems at Fountain Avenue, Pennsylvania Avenue, and Edgemere Landfill," April 1984, SCS Engineers.

- “Memorandum of additional landfill gas investigation at Fountain Avenue, Pennsylvania Avenue, and Edgemere Landfills,” April 1985, SCS Engineers.
- “Environmental factors report – Edgemere Landfill,” 1985, Gibbs & Hill, Inc.
- “Operations plan report – Edgemere Landfill,” 1985, SCS Engineers.
- “Long term ground and surface water monitoring program for Fountain Avenue Landfill, Pennsylvania Avenue Landfill, and Edgemere Landfill,” August 1985, Gibbs & Hill, Inc.
- “Hazard/risk evaluation of buried drum area of Edgemere Landfill,” 1985, Gibbs & Hill, Inc.
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- “Leachate management for the Edgemere Landfill,” November 1985, SCS Engineers, Inc.
- “Scope of work for remediation of buried drum area at Edgemere Landfill,” November 1985, Gibbs & Hill, Inc.
- “Final summary test report for the three phase air quality monitoring programs at the Fountain Avenue, Pennsylvania Avenue, and Edgemere Landfills,” 1985, York Research Corporation.

While these reports may not directly address water quality or ecological issues associated with the aquatic habitats of Norton Basin and Little Bay, they could provide insight into potential sources and levels of contaminants that could be expected in the borrow pits of the two basins.

8.0 Additional Borrow Pit Studies

Finding ecologically acceptable solutions to dredged material placement has become a top priority of virtually all major shipping ports over the last 20 years. Potential solutions range from decontamination of the sediment to be used for commercial construction to creation and enhancement of upland, intertidal, and aquatic habitats. The creation of confined aquatic disposal (CAD) cells has become a viable technology for safely disposing of contaminated dredged material in the system it was originally located. This placement alternative, however, is more expensive than the alternative of filling pre-existing borrow pits, which typically exist in an urban harbor from decades of development and dredging. Borrow pits also offer an attractive beneficial use alternative for dredged material placement, an advantage not shared by CAD cell technology.

Borrow pit research, however, has produced a wide variety of conflicting information in regards to the ecological significance borrow pits have in marine and freshwater systems. Research into the placement and development of CAD cells lends some insight into addressing the potential impacts associated with filling a borrow pit with dredged material, but does not assess whether filling the pit constitutes a beneficial use application to the system where the pit is located. It is not unusual to find multiple borrow pits in the same system, each having different levels of ecological significance to the system, some beneficial, some detrimental. Thus far, the debate over the ecological function of borrow pits is unresolved. Each borrow pit must be analyzed based on the system in which it exists and a pre-determined definition of what constitutes an ecologically significant habitat.

In regards to the Norton Basin and Little Bay borrow pits, previous research into the filling of borrow pits and CAD cells can provide guidance for the development of the pilot project in Jamaica Bay. The majority of projects initiated throughout the country have been CAD cell operations. Examples of CAD cell projects include the Duwamish Waterway in Seattle, WA; Gloucester Harbor, MA; Ross Island Lagoon in Portland, OR; Los Angeles Harbor, CA; and the Puget Sound MUDS project (USACE 1999, Palermo et al. 2000). Each of these initiatives is in different stages of development or completion and validate capping of contaminated sediments as a viable placement alternative for dredged material. These projects offer some insight into the placement criteria and monitoring necessary to fill a borrow pit, but do not address the issue of habitat enhancement. The following discussion identifies specific sources of information on borrow pits and CAD cells that may be useful for the development of the Norton Basin demonstration project.

8.1 New York /New Jersey Harbor

Due to the potential volume of dredged material that could be placed in borrow pits in the NY/NJ Harbor (approximately 85 MCY) (Yozzo et al. 1999), research into the ecology of borrow pits has received the most attention from state and Federal agencies in the New York metropolitan area. Since the late 1970's, research has been carried out in attempts to determine the habitat potential and degree of contamination of NY/NJ Harbor borrow pits. Results and opinions vary from pit to pit.

Characterization of the oxygen demand of sediments in borrow pits of Lower Bay indicated that borrow pits do affect the oxygen demand of the sediments and water column above the pit based on borrow pit location, season, and hydrodynamic characteristics (Swartz and Brinkius 1978). Borrow pits found on the West Bank of the Lower Bay generally had lower dissolved oxygen levels and higher sediment oxygen demand compared to borrow pits on the East Bank of the Lower Bay. The West Bank pits contain sediments of higher silt/clay content (SAIC 1996) and have lower tidal flow that the East Bank borrow pits. During the brief time period in which Swartz and Brinkius studied the West and East Bank borrow pits they did observe DO levels below 3.0 mg/L, but not for extended periods of time. Seasonal hypoxia is not uncommon for shallow water estuaries and only becomes a critical influence ecologically when sustained hypoxia or anoxia occurs in a given area (Diaz and Rosenberg 1995). Because pit location and hydrodynamic environment are so influential in determining a borrow pit's ecological value to its immediate system, it may be safe to assume that the Norton Basin and Little Bay pits have lower DO levels and higher oxygen demand compared to borrow pits in other areas of NY/NJ Harbor that are less eutrophic and have greater tidal velocities.

Clarke et al. (1998) characterized the Consolidated Aggregate Corporation (CAC) pit, also in the Lower Bay of NY/NJ Harbor, for water column, sediment, and biological characteristics. Their results characterized the CAC pit, which is located on the West Bank of Ambrose Channel, as "neither a 'biological desert' or a 'biological oasis'". They did not observe hypoxic events during the five seasonal sampling events. Fine grained sediments were accumulating in the bottom of the pit but not to the detriment of benthic invertebrate and finfish communities. SAIC (1996) characterized the sediments of the

CAC pit as mixed, with fine grained sediments at the center of the pit and sandier sediments in the outer edges. The analysis of the data collected for the Clarke et al. (1998) study of the CAC pit is still being completed. Final results may give a more conclusive description of the pit's role in its immediate environment, but preliminary results indicate that the pit is not significantly impairing the ecological functions of the surrounding environment.

At this time, Norton Basin and Little Bay are the first two borrow pits to be proposed for filling with dredged material. Issues of primary concern are finfish utilization of the pits and defining if the borrow pits are of any ecological significance as they exist now. Because both Norton Basin and Little Bay are located at the end of dead-end basins in the tidally restricted portions of Jamaica Bay, they offer one of the most hydrodynamically stable areas for dredged material placement in the NY/NJ Harbor and are the prime candidates.

8.2 Boston Harbor

The USACE, New England District and the Port Authority of Boston Harbor have recently completed the construction phase of nine CAD cells in the shipping channels of Boston Harbor as part of the Boston Harbor Navigation Improvement Project. The multidisciplinary project comprehensively monitored siting, pre-construction, construction, and is currently monitoring post-construction phases. In the planning phases of the project the USACE estimated that $6-10 million would be needed to cap the 1.0 MCY of dredged material identified for the nine CAD cells. While borrow pits were not used in this project, the results of the monitoring can be related to issues that may be encountered when proceeding with the Norton Basin and Little Bay demonstration project.

In 1997 four test cells were filled with 1.0 MCY of dredged material unsuitable for open ocean placement and allowed to settle for different time periods, then capped with 3 feet of clean sand to monitor the effectiveness of the cap based on depth and consolidation of fill material. Monitoring indicated that one month was not enough time to allow for proper consolidation of fill material in the cell. In this sort time period the underlying fill breached the cap, allowing contaminated material to escape. Further monitoring found that 4-6 months of consolidation was sufficient time for fill sediments to dewater before the cap was placed. Because the cells were in the middle of a shipping channel, special arrangements were made to reduce boat traffic and other disturbances to prevent resuspension of the dredged material while it was consolidating in the CAD cells before capping.

High resolution bathymetry, sidescan sonar, sub-bottom profiling, and sediment-profile imaging was used, along with GIS to monitor the placement and capping of dredged material in the Boston Harbor CAD cells. Water quality monitoring during cell dredging and fill placement indicated no significant water quality effects downstream of the dredging activity. Disposal plume was difficult to identify in some cases. Monitoring indicated that the suspended sediment plume was limited to within 300 ft of the dredge and no differences in DO were detectable between monitoring and reference stations. Because of precautions taken, the project met with water quality certification compliance.

Preliminary results of NOAA-National Marine Fisheries Service (NMFS) benthic invertebrate monitoring indicated no significant differences in abundance or diversity of invertebrates, redoximorphic sediment depth, and trace metal concentrations between caps, adjacent areas, and undisturbed sites in the harbor. In addition to benthic invertebrate monitoring, a model was developed to investigate the potential results of varying cap depth in the CAD cells. The model determined that a 20-cm thick cap would be sufficient to prevent transport of dredged material through the cap by bioturbation (Shull and Gallagher 1998). Results of the model were dependent on contamination levels of dredged material. The model recommended that a 50 cm cap be used to protect PCBs and PAHs from bioturbation. The model was simulated based on a “worst case scenario” of the cap being recolonized by deep-burrowing benthic organisms. Shull and Gallagher acknowledged that cap thickness should vary by region based on analysis of a suite of variables, including benthic community composition of a specific area.

Long-term monitoring of the integrity of the cell caps and movement of the fill material is ongoing. The results of this project are important to the Norton Basin and Little Bay project because of the innovative techniques used to monitor the placement and behavior of dredged material and cap material in a confined pit. The techniques used and recommendations produced from this report should be directly applicable to current proposals to fill borrow pits in NY/NJ Harbor using dredged material.

8.3 Hong Kong Harbor

The Government of Hong Kong has also addressed the issue of dredged material placement by using CAD cells for contaminated dredged material. From 1991 to 2006 the Hong Kong government has estimated that 558 MCY of dredged material will be produced. Of this, 47 MCY will have sufficient contamination levels to warrant special placement (EVS Environmental Consultants 1996). Starting in 1991, an extensive review of placement alternatives identified a shallow water area near Hong Kong Harbor to be developed as a CAD cell facility. The site was selected based on its stable sediments, low energy hydrodynamics, ease of access and transportation, and proximity to environmentally sensitive areas. The CAD cells were specifically excavated for disposal of the dredged material. Landfill and treatment facility alternatives were rejected due to the large volume of material being considered. Hopper dredges were used to excavate the pits. The pits were filled from surface release barges and hoppers. Risk evaluation of contaminant effects on fisheries and human health was determined to be the same or less than ambient conditions in Hong Kong Harbor.

Biological monitoring for bioaccumulation of contaminants took place from 1992-1995. Contaminant impacts from heavy metals were not observed in benthic communities. Differences in species abundance and diversity were attributed to direct impacts from dredging and placement of material (EVS Environmental Consulting 1996). These impacts were also observed to be short in duration. Benthic invertebrate monitoring using sediment profile images (SPI) and benthic grabs indicated that benthic abundances and diversity decreased in the borrow pit as filling occurred (Binnie Consultants, Ltd. 1995). Early successional species were the first to return to the pits after filling. The monitoring also investigated the recolonization rates of dredged material placed with a trailer-dredge compared to a cutter-dredge. Preliminary results suggest that the relatively more compact material from the cutter-dredge increases the rate at which invertebrates can recolonize the dredged material.

The results of this effort could be relevant to the Norton Basin and Little Bay project because the Hong Kong sediments are primarily silt, similar to the sediments found or used in Jamaica Bay.

8.4 USAE-WES CAD Cell Research

For almost two decades USAE-WES has studied, the environmental effects of capping dredged material, whether it be in CAD cells, borrow pits, confined disposal facilities, or unconfined area, in an effort to support the technical knowledge required to safely dispose of dredged material unsuitable for ocean disposal. Recent reports have reviewed the criteria necessary for successful placement of dredged material in aquatic habitats. These criteria are summarized as site selection, design objectives, geometry, fill sequencing, placement operations, dispersion and retention during placement, cap design, and monitoring (Palermo 1999). Considerations for each criteria assist in the site selection, placement method, capping, and monitoring of a borrow pit or CAD cell. This comprehensive research has been modified for specific programs (*i.e.*, the Puget Sound MUDS Program) (Palermo et al. 2000) and should be the basis for any project with the goal of confining dredged material in an aquatic habitat.

USAE-WES also published a Dredging Research Technical Note (DRP-5-09) which summarized investigations into the effectiveness of sediment caps at containing contaminated material over the long term (USAE-WES 1994). The paper sites evidence from the New England Division, the Seattle District, and the NYD USACE indicating that heavy metals, PCB's, and PAH's do not move into the caps or are released from beneath caps placed over contaminated dredged material, both in the short-term and long-term (up to 11 years).

9.0 Summary

In order to proceed with an ecological investigation of filling the borrow pits in Norton Basin and Little Bay an investigation into the historical and current conditions of the basin is necessary. Knowledge of historical condition is necessary to determine the goals and objectives of a restoration effort and in identifying issues such as contaminants and biological resources that would need to be addressed during the project. Establishing sources of information for current conditions of the study area allows for a starting point for baseline monitoring.

Norton Basin and Little Bay have experienced a tremendous amount of anthropogenic influence over the last four centuries. The topography, hydrology, and ecology of the two basins have been significantly altered. The areas surrounding Norton Basin and Little Bay have been used for residential and recreational purposes and have been spared many of the industrial impacts experienced in other areas of NY/NJ Harbor. The establishment of Edgemere Landfill has been the greatest impact to the basin. The impacts of the landfill appear to have been stabilized, however, with the closure of the landfill in 1991. According to NYCDOS and the Jamaica Bay Eutrophication Study, the impacts of the landfill to the Bay are negligible compared to other inputs. Monitoring of the landfill has provided some information on water quality and sediment contamination in the study area.

Virtually no data has been collected on the current biological resources in the two basins. A detailed baseline study must be completed to demonstrate the degree of ecological impairment within the system. In the NY/NJ area controversy over the biological utilization of borrow pits has precipitated the need to quantitatively identify the organisms and habitats associated with each borrow pit. Norton Basin and Little Bay are unique in the controversy over the ecological significance of borrow pits in that they are located in dead-end basins with significant hydrologic restrictions.

The Norton Basin/Little Bay Restoration Project is currently addressing the baseline conditions of the basin. Comprehensive water quality, hydrological, contaminant, and biological studies are being conducted to assess the ecological status of the study area and to determine if a restoration effort should proceed. If the project is to proceed, several considerations should be taken into account. They include: 1) the limited access to the study area due to a sand berm at the entrance to the basin. This berm would restrict access to the borrow pits by barges and would need to be removed. 2) The transport of dredged material would also be limited by the bridges over Broad Channel in Jamaica Bay. 3) The source of dredged material to fill the borrow pits and the need for a cap covering the dredged material would also need to be considered. 4) Preliminary investigations into the borrow pits have revealed several wrecks at the bottom of Little Bay. The historical significance of these wrecks is being considered to determine if special precautions are necessary before the project can continue.

Restoring Norton Basin and Little Bay to their historic conditions of intertidal salt marsh may not be feasible and may offer little chance of success. Rehabilitating the current subtidal habitat to one of potentially greater ecological value, via bathymetric recontouring, could benefit the immediate area as well as contribute to the overall ecological function of Jamaica Bay system.

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