Jamaica Bay Borrow Pit Project Findings

Panelist Affiliations

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- New York State Department of Environmental Conservation
- National Marine Fisheries Service
- National Park Service
- United States Environmental Protection Agency
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- New York City Department of Environmental Protection

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Table of Contents

List of Figures & Tables

Purpose

Between 2000 and 2003, the New York District U. S. Army Corps of Engineers (USACE-NYD) and the New York State Department of Environmental Conservation (NYSDEC) conducted a series of ecological investigations of subaqueous borrow pits in Norton Basin and Little Bay. These investigations yielded data on the physical, chemical and biological features of the pits. A multi-agency evaluation panel was convened to review the data in order to assess the overall ecological function of the pits as aquatic habitat. The project background, summary of the data review, and the findings of the panel are presented below. The project-specific data reports are cited in the Appendix.

Introduction

Sandmining for commercial construction aggregate and for landfilling projects has left depressions, called borrow pits, on the bottom in several locations in the Lower Bay section of New York Harbor and in Jamaica Bay. These borrow pits differ in their configuration, but all are steep sided and considerably deeper than the ambient bay bottom. These characteristics can result in stratification, reduced current velocities, and poor water exchange within the pits. Poor circulation often leads to impaired sediment quality and water quality from the accumulation of fine grain sediments and depressed dissolved oxygen concentrations. These habitat impairments lead to diminished ecological function, typified by stressed benthic communities and reduced finfish utilization. If these conditions are present, recontouring (raising the bottom) in these areas to more natural conditions may have beneficial environmental effects.

Placement of NY Harbor sediments at the regional ocean disposal site, now known as the Historic Area Remediation Site (HARS), has been reduced in recent years, due to concerns regarding appropriate management of dredged material in the ocean environment. To explore potential alternative options to ocean disposal, the USACE-NYD, in coordination with other federal, state and local agencies, including the NYSDEC, developed the Dredged Material Management Plan (DMMP) (USACE 1999). The DMMP identifies a number of options for management of dredged material, but has put a priority on options that employ beneficial re-use (Yozzo, et al 2001). One such identified option is restoration of subaqueous borrow pits in the Harbor. If placement of dredged material in borrow pits can lead to improved ambient conditions, it would be consistent with the beneficial use category of the DMMP.

There is a stepwise process outlined in the DMMP for evaluating whether a given pit would be suitable for placement of NY Harbor dredged material. The beneficial use precept of the DMMP requires that an alternative under this category must create, enhance, and/or restore habitats through the use of dredged material. The first step, therefore, is to evaluate the existing habitat condition to determine if there are opportunities for improvement.

Two pits in Jamaica Bay, located in Norton Basin and Little Bay, were identified in the DMMP as candidate sites, partly because of their isolated location, and because preliminary information indicated they were degraded environmentally. Since the DMMP requires that a demonstration of degraded conditions has to be clearly made, it was determined that extensive environmental monitoring and information gathering would be necessary, beyond the existing preliminary information that was available. A pilot borrow pit evaluation project was developed to obtain the multi-disciplinary environmental information needed to evaluate individual pits.

To develop the project, a Technical Committee was formed including representatives from academic institutions, the National Marine Fisheries Service (NMFS), US Environmental Protection Agency (USEPA), US National Park Service (NPS), US Fish and Wildlife Service (USFWS), New York City Department of Environmental Protection (NYCDEP), NYSDEC and USACE-NYD. This committee identified the relevant physical, chemical and biological parameters to be measured, and developed the scientific methods for field investigations to be conducted. A Technical Evaluation Panel made up of representatives of the committee agencies was later assembled to review all of the data and information collected.

Study Area and Environmental Studies

Norton Basin and Little Bay are tributary embayments of Jamaica Bay **(Fig. 1)**. Field investigations were conducted in the Norton Basin and Little Bay pits and in reference areas. Grass Hassock Channel served as a deep reference and the Raunt as a shallow reference in the Bay. Shallower locations within the basins were also sampled during some investigations.

There are a number of pit features within Norton Basin and Little Bay. The pits in Norton Basin are approximately 40-50 feet deep **(Figs. 2a & b)**, with the pits in the southern portion **(Fig. 2b)** the primary focus of study. The pits in Little Bay are approximately 55-60 feet deep **(Fig. 2c)**. These are all relatively steep-sided pits and are sheltered by the surrounding land features from wind-generated currents that affect Jamaica Bay. The entrance channel to Norton Basin is shallow, affecting tidal exchange with the basins. The basins do not receive any major land-based industrial inputs but there are municipal stormwater outfalls in Norton Basin, and Edgemere Landfill is a known source of leachate contamination.

The study developed by the Technical Committee included investigations of the following characteristics:

- Benthic community
- Water quality
- Hydrodynamics
- Sediment quality
- Finfish / Macroinvertebrates

As background, a site history report was prepared (BVA 2001a).

In most cases, several methods were employed to gather data in each of the above fields of study. Field investigations began in May 2000 and were completed in May 2003. The prime contractor for the majority of the field work was Barry Vittor and Associates, Inc. (BVA), with a portion of the studies conducted by the USACE-NYD and NYSDEC. The following sections include a summary of the key results and the Panel findings for each field of study. The full data reports are listed in the Appendix.

Benthic Environment

Multi-beam hydroacoustic equipment was used to obtain fine scale bathymetry of the areas (CR Environmental 2001). Seabed classification was attempted using side-scan sonar, video, and other remote techniques to obtain broad descriptions of the bay bottom (CR Environmental 2001). This approach attempted to identify bottom conditions (i.e., substrate type and epifaunal presence) through the interpretation of the acoustic data. While the system performed well in the reference areas, there were mis-interpretations in the pits, (i.e., areas in the basins were incorrectly interpreted as hard bottom where video coverage showed there was soft mud) and it was considered that more development of the technique was necessary. The other techniques employed, Sediment Profile Imagery (SPI) and traditional grab samples, proved more effective (BVA 2001b, 2002a, 2002b, 2003a, 2003b, 2004a, 2004b, Great Eastern Ecology 2003) for describing the physical and biological characteristics of the bottom habitat.

Substrate Type

The SPI results for Little Bay pit indicated an impaired benthic environment at all deep (<40') and all but one intermediate (~30') stations. The bottom in these locations was characterized by soft (high water content) black organic silts with very little, if any, evidence of biological activity. The images showed over-penetration of the camera prism, indicating sediments so soft that the operator could not control penetration to capture the targeted sediment-water interface. At the Little Bay entrance channel (~25' deep), the sediment water interface was observed. The sediments were primarily a fine silt, but evidence of oxygen in the surficial layer was present. Tube mats of an amphipod (Ampelisca vadorum) were observed on the surface.

SPI images from Norton Basin show a trend of improving bottom conditions from pit floor to intermediate depths, to shallow areas. The pit floor, below approximately 30 feet, showed consistent over-penetration of the prism, black organic silts, and little evidence of benthic life. The substrate at intermediate depths ranged from silt to fine sand, but was sufficiently firm to consistently allow capture images of the sediment surface. Evidence of oxygen in the sediment and biological activity was the norm. The bottom of the Norton Basin entrance channel consisted of sandy substrate and shell hash. Snails and other benthic organisms were commonly observed.

The Grass Hassock and Raunt reference areas showed consistently firm sediments ranging from silt (Grass Hassock) to silt-fine sand (the Raunt). Ampelisca mats were common features at both sites.

Benthic Community

The majority of samples retrieved from the deep portions of Little Bay yielded no benthic organisms. The maximum number of individuals per sample collected was three. Samples from the intermediate stations were only marginally better with the total numbers of individuals ranging from 0-573, representing only 4 taxa. The maximum density of benthic organisms in Little Bay was slightly less than 4,500 individuals per square meter (ind. m-2) at a single intermediate station. By contrast, the abundance of benthic organisms is much greater in the Raunt (>25,000 ind. m-2) and Grass Hassock (>45,000 ind. m-2), with 30 or more taxa represented at each reference area.

The deep and intermediate areas of Norton Basin outperformed similar strata in Little Bay, but fell well short of the values from the Raunt and Grass Hassock. The mean number of taxa collected in these two areas of Norton Basin was similar at around 17, but the mean density of benthic organisms per sampling event was less than 15,000 ind. m-2 for the intermediate area, and less than 6,500 ind. m-2 in the deep areas. The shallow reference areas at the Norton Basin entrance channel had the highest mean number of taxa (46), with mean densities ranging from 20,000 to greater than 50,000 ind. m-2.

The Panel finds that degraded benthic conditions exist in the deep and intermediate sections of Little Bay and in deep portions (>30') of the Norton Basin pits. The substrate in these locations is of poor quality and the abundance and diversity of the benthic community are well below that observed in reference areas.

Water Quality

The primary parameter of interest was dissolved oxygen (DO), as it was identified at an early stage by the Technical Committee as a key indicator of ecological condition. From 2000 to 2002, measurements were taken weekly between July and November (June data was recorded in 2002) (NYSDEC 2003). Periodic DO readings were also recorded commensurate with sample collections for nutrient and chemical analysis (BVA 2001b).

Dissolved Oxygen

The data set in Appendix 10 indicates more depressed DO conditions in the pits. The highest number of occurrences of hypoxia (defined here as < 3 mg/l DO) at the outer reference stations was 4 (at Grass Hassock). Both of the southern Norton Basin pits had over 20 occurrences, while Little Bay failed this standard 100% of the time (44 occurrences) and was almost always anoxic (defined here as <1 mg/l DO) at depth.

The Little Bay pit demonstrated almost no water exchange at depth, which was indicated not only by the DO studies, but also by the finding of a persistent cold water layer below 25-30 feet. The temperature boundary layer, or thermocline, persisted throughout the study, indicating that there is essentially no exchange with surface or other surrounding waters. Anoxic or hypoxic conditions in Little Bay occurred in the lower half of the water column in the pit areas and persisted throughout the duration of the study.

The DO values in the Norton Basin pits were not as low or as persistent as those in Little Bay, but hypoxic conditions were common through the Summer and into early Fall. Low DO readings were recorded throughout the lower half of the water column, but were most prevalent at depths below approximately 30 feet. The waters in the Norton Basin pits were only weakly stratified, thus vertical mixing of the water column could occur more readily. During the Summer, poor DO conditions would become established at depth until the system was turned over by some event, most likely a passing storm. By the onset of November, the system appeared well mixed and acceptable DO values were established at all depths.

The Panel finds that the water quality conditions in the Norton Basin pits are impaired in terms of DO because of persistent seasonal hypoxia at depths below 25-30 feet. Water quality conditions in the Little Bay pits are impaired in terms of DO because of persistent anoxic and hypoxic conditions below 25 feet.

Nutrients

The most notable results of the nutrient and chemical analyses were that the Little Bay pits were differentiated from all other areas in terms of:

a. very high sulfide.
b. high ammonium and phosphate.
c. high dissolved silica, low biogenic silica.
d. low nitrate+nitrite.
e. low active chlorophyll/total chlorophyll ratios and high phaeophytin/total chlorophyl ratios.

These are all indicators of anaerobic conditions at depth in Little Bay. The sulfide levels would be poisonous to any finfish and invertebrates that could tolerate the low oxygen levels.

Hydrology

The main finding from the hydrology studies, which included both Acoustic Doppler Current Profiler work and S4 current meter deployments (Continental Shelf Assoc. 2001, 2002, 2004), is that there is very little water movement measured at depth in Norton Basin and Little Bay. The current meter deployments were unable to associate any measured water movement with water level changes or tidal stages. Measured current velocities were generally less than 3 cm/sec.

The strong thermocline observed in Little Bay is further evidence of a lack of vertical mixing, isolating waters below approximately 25 feet. Since the observed currents were similar in both Norton Basin and Little Bay, it may be that the greater isolation in Little Bay, or the greater proportion of pit features to shallow areas in Little Bay result in the markedly different stratification.

Sediment Quality

Sediments from the pits and reference areas were analyzed to determine chemical contaminant concentrations (BVA 2002b). Bioassay studies were also performed to evaluate the toxicity and bioaccumulation potential of sediments from these areas (BVA 2002c, 2003c).

Sediment Chemistry

The chemistry results were compared to existing criteria for evaluating marine sediments. The following table lists the number of exceedances of NYSDEC draft Sediment Screening Parameters (NYSDEC 1993) and NOAA Effects Range (ER) values (Long & Morgan 1990) for each pit area and reference. The NYSDEC draft Sediment Screening Parameters classify sediments according to various sediment guidelines including the NOAA ER values, and result in Classes A-C, with A being the least contaminated. NOAA ER values are the result of a compilation of a large number of laboratory and field observations of benthic organism effects or conditions paired with measured sediment contaminant concentrations. They classify sediments as either effects range low (ER-L) or effects range median (ER-M).

The data indicate a generally increasing level of contamination from the Raunt to Grass Hassock, Norton Basin and Little Bay. Although there appears to be only a minor difference by this scheme between the Grass Hassock reference and Norton Basin pit, the pit sediments showed substantially higher PCB and DDT contamination. By the finding of several Class C and six ER-M exceedances in Little Bay pit, it is clear that there is a large difference between this area and any reference area.

The Panel finds that there is a moderate level of risk posed by sediment contamination in Little Bay pit, and that the Norton Basin pits represent a slightly elevated risk from chemical contaminants compared to the reference areas.

Bioassay and Bioaccumulation Results

The solid phase bioassay tests were performed with the shrimp *Mysidopsis bahia*, and the amphipods *Eohaustorius estuarius* and *Ampelisca abdita*. The water column bioassays were performed with the fish *Menidia beryllina*, the shrimp *Mysidopsis bahia*, and mussel *Mytilus californicus* larvae. Sediment samples were collected from Norton Basin and Little Bay pits and Grass Hassock Channel, as reference.

1. All samples passed the *Mysidopsis bahia* solid phase test.
2. Grass Hassock and Norton Basin passed the *Eohaustorius estuarius* solid phase test.
3. Little Bay failed the *Eohaustorius estuarius* solid phase test.
4. All samples passed the *Ampelisca abdita* solid phase test.
5. All samples passed the *Mysidopsis bahia* and *Mytilus californicus* elutriate test, although Little Bay had only 19% larval recovery in the 100% solution compared to >30% recovery in the Norton Basin and the control samples.

In the bioaccumulation tests, Norton Basin samples had the highest copper and mercury uptakes, though these were below recognized harmful effects levels. Norton Basin samples also had higher zinc accumulations than Grass Hassock, and comparable accumulations to Little Bay.

Although the above tests do not indicate consistent adverse effects (or in the case of bioaccumulation tests, potential adverse effects) to test organisms from the borrow pit sediments, both pits demonstrated this potential to some degree in at least one of the tests. Little Bay pit sediments were toxic to the amphipod *Eohaustorius estuarius*, and Norton Basin pits accumulated higher concentrations of several metals compared to reference sites.

The Panel finds that the Little Bay pits sediments represent a slightly increased risk of adverse effects compared to the reference site. The risk of adverse effects from Norton Basin pits sediments is comparably low with that of the reference site.

Fisheries

While preliminary efforts used hydroacoustic methods as an indicator of fisheries use, trawling and gill netting were conducted to characterize finfish abundance and diversity (BVA 2001b, 2002d, 2002e, Great Eastern Ecology 2003). Trawling was not possible in Little Bay due to the extensive debris field along the pit floor. In Norton Basin, the pit features were too narrow to reliably conduct tows within distinct strata. As a result, these tows may have integrated fish from both deep and intermediate depths. There were fewer problems related to the gill net effort, though some net drift was experienced in Little Bay.

Trawl Results

Regardless of the sample location, trawl results showed generally low numbers of individuals and low catch per unit effort (CPUE), measured in grams of fish per minute of tow (g/min). Over the three years of study, the catch ranged from 2-28 individuals per event in Norton Basin, 1-85 in the Raunt, and 0-175 in Grass Hassock. CPUE ranged from 17-438 in Norton Basin, 0.4-856 in the Raunt, and 0-205 in Grass Hassock. Species composition was generally highest in the Raunt, with typically 10 or more species represented. Species composition was comparably low at Grass Hassock and Norton Basin. Flatfish, such as Summer and Winter Flounder, were more abundant at Grass Hassock (20 individuals) and the Raunt (18 individuals) than at Norton Basin (6 individuals).

Gill Net Results

The deeper areas in Little Bay are essentially devoid of fishes, with only a single specimen collected over the course of the study from depths below 30 feet. [The 41 individuals reported as collected from the bottom of Little Bay in October 2001, were later shown to be catches from nets that had drifted into intermediate water depths.] Intermediate depths in Little Bay also yielded few fish, averaging 17 individuals per event. Shallower areas in Little Bay showed highly variable catches, with a range of 0-271 individuals per event.

Norton Basin, the Raunt and Grass Hassock support a greater abundance and diversity of fish than Little Bay. Comparing bottom data, the stations had similar numbers of species and similar species composition. Other studies performed by the National Park Service found similar species and species diversity in Jamaica Bay (NPS-GNRA. 2002). Numerically, Striped Searobin (*Prionotus evolans*) was the most abundant finfish species, with particularly large numbers from Norton Basin (632) and Grass Hassock (328). Total catch per sampling event from these bottom stations ranged from 23-439 in Norton Basin, 18-158 in Grass Hassock, and 12-217 in the Raunt. CPUE ranged from 270-3115 in Norton Basin, 530-6400 in Grass Hassock, and 574-2801 in the Raunt. Flatfish were again more abundant at Grass Hassock (6 individuals) and the Raunt (16 individuals) than at Norton Basin (3 individuals).

The Panel finds that finfish utilization of Little Bay is extremely limited and approaches zero at depth. Finfish utilization is variable, but comparably higher among all other sites.

Overall Findings

Evaluating habitat function cannot typically be accomplished by looking at a single parameter but rather a matrix of the physical, chemical, and biological characteristics that contribute to function.

The comparative performance or value of these characteristics between pit sites and reference sites is summarized below in Table 2.

Little Bay produced the poorest results for all parameters in all the areas studied. The data show that significant portions of Little Bay are severely impaired. Little Bay appears to be hydrologically isolated from the rest of Jamaica Bay by the series of inlets and irregular bottom contours encountered from the connection to Jamaica Bay at the mouth of Norton Basin. Tidal exchange appears to occur only in surface layers, and the water column and bay bottom below 25 feet are nearly inhospitable. The stagnant bottom waters are stripped of oxygen and the substrate is a fine, fluid mass that does not support benthic organisms. Primary and secondary production from the depths of Little Bay approaches zero.

The pits of Norton Basin exhibited substantially poorer results than reference sites in three characteristics: occurrence of hypoxia, substrate type, and benthic community. While the results are better than those for Little Bay, the chronic effects of artificial deepening are still evident. The fine, fluid sediments that have accumulated on the pit floor result from the inability of the sluggish currents in the pits to transport, redistribute, and mix sediments that enter the pits. The lack of circulation also results in depressed oxygen levels at depths below 30 feet during summer months. The low abundance and diversity of benthic organisms in the Norton Basin pits is a direct result of the poor sediment quality and water quality. Though the hypoxic conditions appear to be seasonal, and rebound to acceptable levels in the Fall, the data suggest the sediments would not support a more robust benthic community even under well oxygenated conditions.

For all pit areas studied, the benthic habitat, in particular, is functioning suboptimally. The reference areas, including the intermediate and shallow areas in Norton Basin, support a more abundant and diverse assemblage of benthic organisms, which suggests the levels of production possible in the pit footprint with improved circulation and substrate. This, in turn, would provide a better forage base for the finfish that were found to occur in Norton Basin and could reasonably be expected to occur in Little Bay.

The process initially developed by the Technical Committee for evaluating these pits for placement of dredged material called first for a determination of whether they were degraded, and if this was found, to then apply hydrodynamic modeling to determine whether a net environmental benefit could result from improved water exchange. The Panel finds that the pits in the southern portion of Norton Basin and in Little Bay are sufficiently environmentally degraded to warrant implementation of the next step in the evaluation process.

It is recommended that hydrodynamic modeling be conducted to evaluate the potential for net environmental benefits by increasing water exchange in the pit areas by recontouring them to various depths, and/or by increasing water flow through a restored channel constructed through the Edgemere peninsula.

Developing management goals for the restoration project will be important. For instance, one such goal could be to increase utilization by demersal species such as winter flounder. Very few demersal species were collected in Norton Basin and Little Bay pit bottoms. Comparing the National Park Service results to data from Raritan Bay, Wilk, et.al (1998) suggest much of Jamaica Bay could be good habitat for benthic feeding winter flounder, which is currently at low stock levels. Managing for this species may be a desirable goal.

Figures and Tables

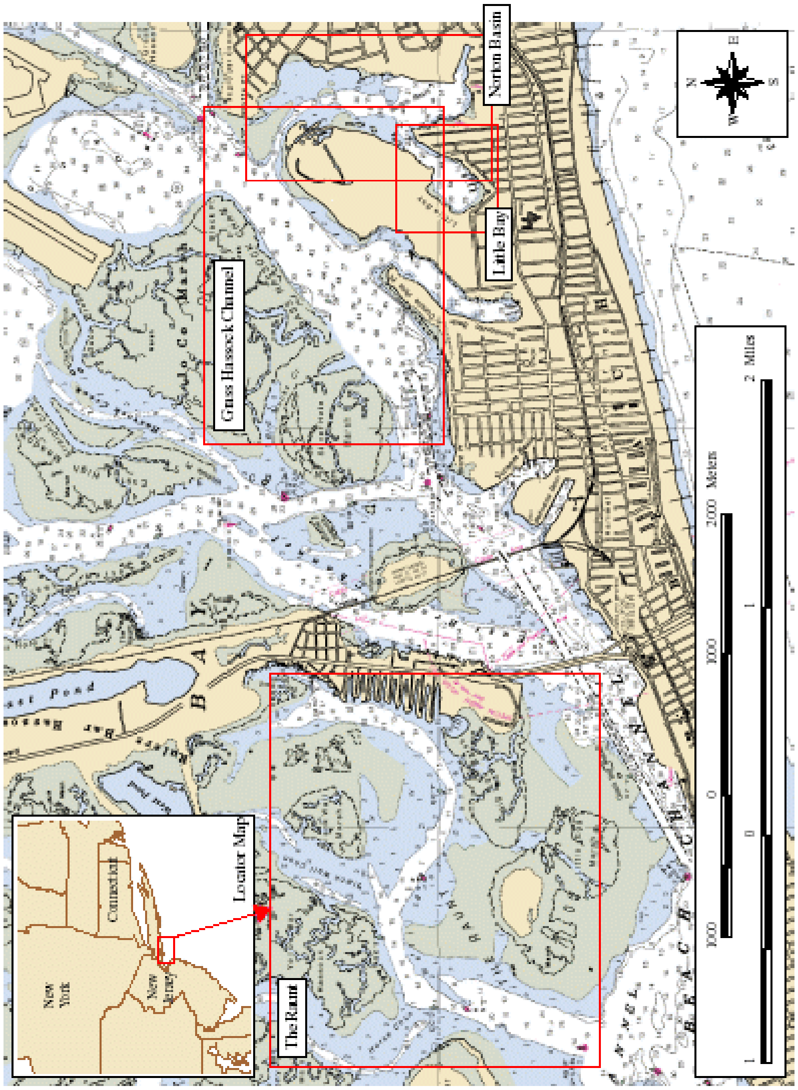

Figure 1: Study Area

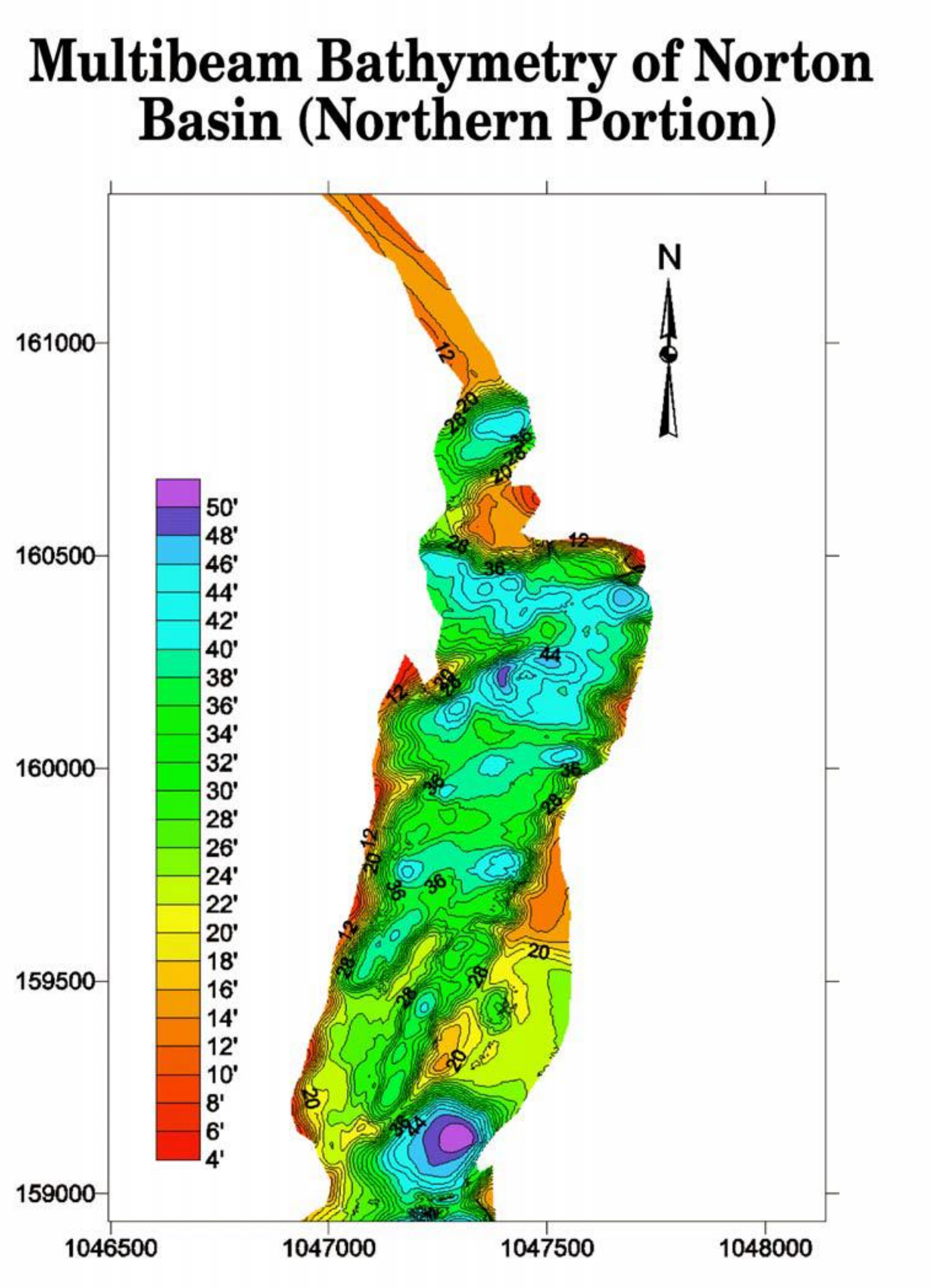

Figure 2a: Bathymetry of Norton Basin (North)

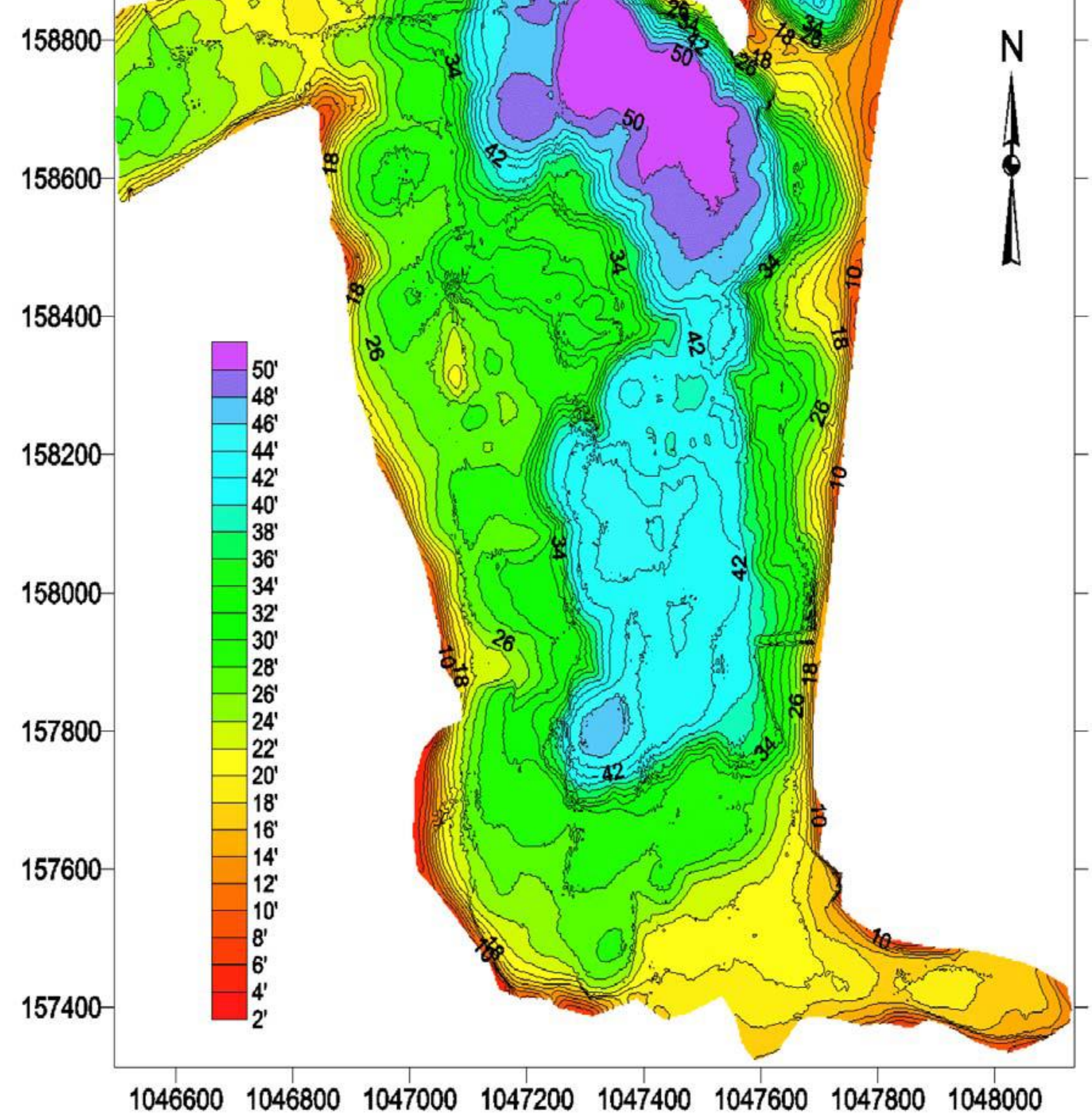

Figure 2b: Bathymetry of Norton Basin (South)

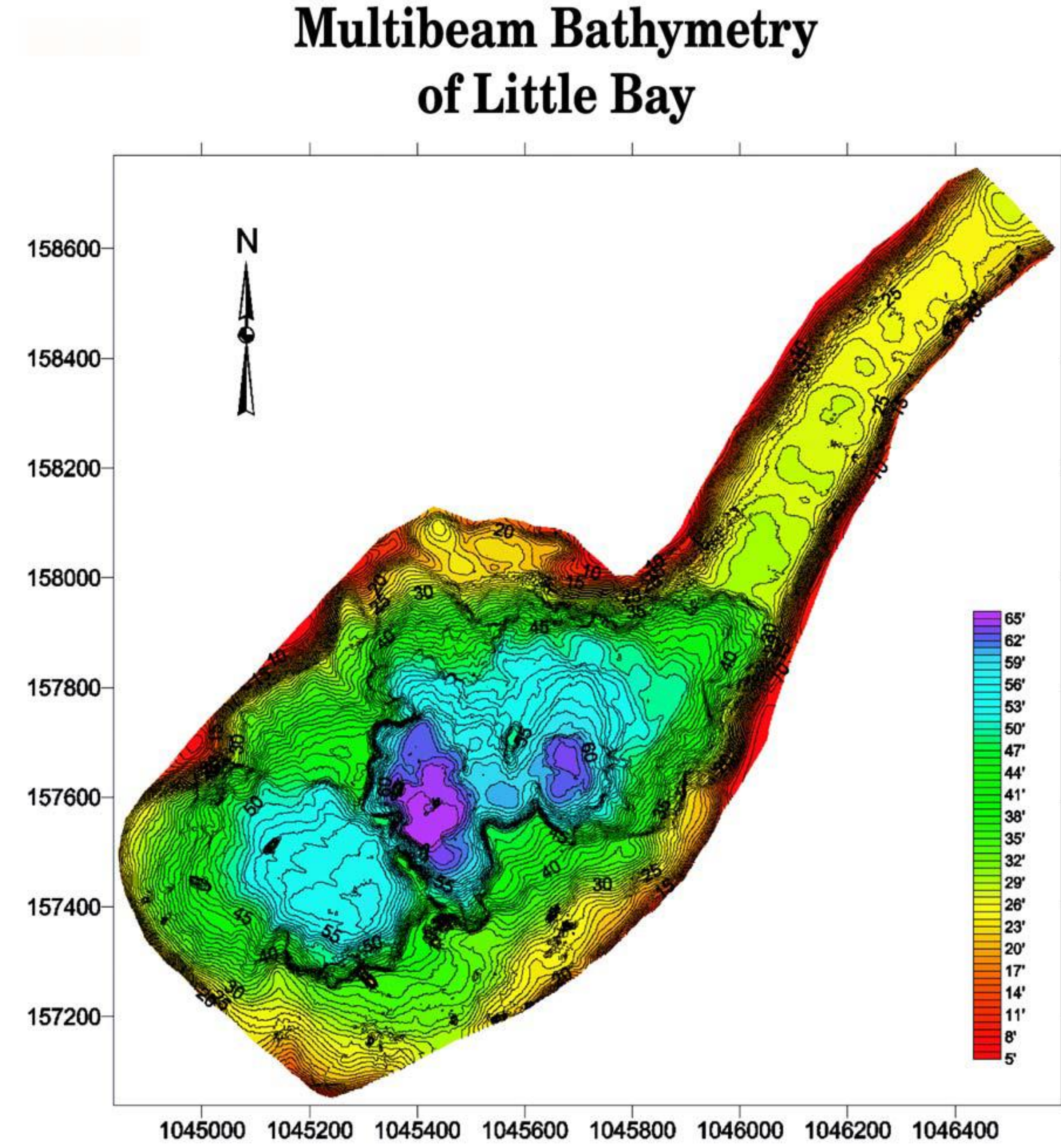

Figure 2c. Bathymetry of Little Bay

Table 1. Sediment Contaminant Comparison. Indicates the number of samples that exceed the stated criteria.

Criteria	Raunt	Grass Hassock	Norton Basin Pit	Little Bay Pit
Class A	7	3	2	1
Class B	2	6	7	5
Class C	0	0	0	3
ER-L	5	7	7	3
ER-M	0	1	1	6

Table 2: Summary Matrix

STATION	Norton Basin Pit	Norton Basin Ref.	Little Bay Pit	Little Bay Ref.	Grass Hassock	The Raunt
PARAMETER						
I. Water Quality						
A. Dissolved Oxygen	<3mg/l	>3mg/l	<<3mg/l	>3mg/l	>3mg/l	>3mg/l
	>50% Occurrence		100% Occurrence		Hypoxic on 4 occasions	
	June-October		Often Anoxic			
B. Temperature	Normal	Normal	<5°C below 25'	Normal	Normal	Normal
C. Nutrients	Normal	Normal	Indicative of anaerobic conditions	Normal	Normal	Normal
II. Sediment Quality						
A. Substrate Type	Fine	Mix	Fine	Fine	Mix	Mix
B. Contaminants	Low-Med	n/a	Med-Hi	n/a	Low-Med	Low
C. Bioaccumulation	Low	n/a	Low	n/a	Low	n/a
D. Acute Toxicity	no failures	n/a	1 failure	n/a	no failures	n/a
III. Benthic Community						
Total Mean Density (ind. m^{-2})	20,000	40,000-110,000	<10	<5,000	140,000	80,000
Mean # of Taxa (2002)	17	17-46	<1	9	28	36
IV. Finfish Community						
A. Trawl Total Catch	2-28	n/a	n/a	n/a	0-175	1-85
B. Trawl CPUE (g/min)	17-438	n/a	n/a	n/a	0.4-856	0-205
C. Gill Net Total Catch						
i. Surface	3-98	19-359	0-178	9-271	21-42	44-124
ii. Mid-water	1-85		0-51		8-162	
iii. Bottom	23-439		0-1		18-158	12-217
D. Gill Net CPUE (g/hr)						
i. Surface	29-901	419-1767	0-769	152-325	27-1598	361-663
ii. Mid-water	85-899		0-454		148-4038	
iii. Bottom	270-3115		0-11		530-6400	574-2801

References

Long, E.R., and L.G. Morgan. (1990). The Potential for Biological Effects of Sediment-Sorbed Contaminants Tested in the National States and Trends Program. National Oceanic and Atmospheric Administration (NOAA) Technical Memorandum No. 5, OMA52, NOAA National Ocean Service, Seattle, WA.

National Park Service-Gateway National Recreation Area and Aquatic Research and Environmental Assessment Center, Brooklyn College, CUNY. (2002). Jamaica Bay Ecosystem Research and Restoration Team (JABERRT) Final Report.

New York State Department of Environmental Conservation. (1993). Technical Guidance for Screening Contaminated Sediment, Division of Fish, Wildlife, and Marine Resources.

US Army Corps of Engineers, New York District. (1999). Dredged Material Management Plan for NY/NJ Harbor.

Wilk, S.J., Pikanowski, R.A., McMillan, D.G., MacHaffie, E.M. (1998). Seasonal distribution and abundance of 26 species of fish and megafauna collected in the Hudson-Raritan Estuary, January 1992-December 1997. Northeast Fish. Sci. Cent. Ref. Doc. 98-10;145 p.

Yozzo, D.J., J.M. Rhoads, P. Wilber, W.H. Nukols, III, L.A. Hollen, and R.J. Will. (2001). Beneficial Uses of Dredged Material for Habitat Restoration, Creation and Enhancement in NY/NJ Harbor, U.S. Army Corps of Engineers, New York District, New York, NY.

Appendix

1. Barry A. Vittor & Associates, Inc., (2001a). Norton Basin/Little Bay Restoration Project: Historical and Environmental Background Report.
2. Barry A. Vittor & Associates, Inc. (2001b). Norton Basin Restoration Project, Baseline Data Collection at Project and Reference Sites - 2000. Final Report to U.S. Army Corps of Engineers, New York District. Barry A. Vittor & Associates, Inc., Kingston, NY.
3. Barry A. Vittor & Associates, Inc. (2002a). Sediment Profile Imagery: Norton Basin, Little Bay, Grass Hassock Channel, and the Raunt, prepared by (Interim report on SPI sampling conducted May 2002).
4. Barry A. Vittor & Associates, Inc. (2002b). Sediment Sampling and Analysis Reports: Norton Basin, Little Bay, Grass Hassock, and The Raunt. (Interim report on sediment characterization and contaminant analysis conducted May 2002).
5. Barry A. Vittor & Associates, Inc. (2002c). Bioassay analyses conducted on sediments collected from Jamaica Bay, Far Rockaway, New York, June 2002. Final Report to the Port Authority of New York and New Jersey and the New York State Department of Environmental Conservation. Barry A. Vittor & Associates, Inc., Mobile, AL.
6. Barry A. Vittor & Associates, Inc. (2002d) Gill Net & Otter Trawl Sampling: Norton Basin, Little Bay, Grass Hassock Channel, and The Raunt. (Interim report on fish sampling May/June 2002).
7. Barry A. Vittor & Associates, Inc. (2002e) Gill Net & Otter Trawl Sampling: Norton Basin, Little Bay, Grass Hassock Channel, and The Raunt. (Interim report on fish sampling August 2002).
8. Barry A. Vittor & Associates, Inc. (2003a). Norton Basin/Little Bay restoration project: Baseline data collection at project and reference sites - 2001. Final Report to U.S. Army Corps of Engineers, New York District. Barry A. Vittor & Associates, Inc., Kingston, NY
9. Barry A. Vittor & Associates, Inc. (2003b). Benthic Macroinvertebrate Sampling, Norton Basin, Little Bay, Grass Hassock Channel, and the Raunt. (Interim report on benthic macroinvertebrate surveys conducted June and October, 2002).
10. Barry A. Vittor & Associates, Inc. (2003c). A Supplemental Bioaccumulation Study Conducted on Sediments Collected from Jamaica Bay, New York, May 2003. Final Report to the New York State Department of Environmental Conservation and the Port Authority of New York and New Jersey. Barry A. Vittor & Associates, Inc., Mobile, AL.
11. Barry A. Vittor & Associates, Inc. (2004a). Multivariate Benthic Community Analysis: Norton Basin/Little Bay Restoration Project.

12. Barry A. Vittor & Associates, Inc. (2004b). Norton Basin/Little Bay Baseline Data Collection - 2002: Fisheries, Benthic Communities, and Sediment Profile Image Analysis. Final Report to the New York State Department of Environmental Conservation. Barry A. Vittor & Associates, Inc., Lake Katrine, NY
13. Continental Shelf Associates, Inc. (2001). Initial survey of current speed and direction by acoustic Doppler current profiler for the Norton Basin Baseline Study. Final report to Barry A. Vittor & Associates, Inc. Continental Shelf Associates, Inc., Jupiter, FL.
14. Continental Shelf Associates, Inc. (2002). Acoustic Doppler Current Profiler Survey of Current Speed and Direction for the Norton Basin Baseline Study.
15. Continental Shelf Associates, Inc. (2004). 2002 Water quality and current surveys in the Norton Basin/Little Bay complex. Final report to Barry A. Vittor & Associates, Inc. Continental Shelf Associates, Inc., Jupiter, FL.
16. CR Environmental, Inc., (2001). Multibeam and Seabed Classification Surveys: Little Bay, Norton Basin, Grass Hassock Channel, and The Raunt, Jamaica Bay, New York. Final Report to Barry A. Vittor & Associates, Inc., Falmouth, MA
17. Great Eastern Ecology, Inc. (2003). Norton Basin/Little Bay Statistical Analysis: Preliminary Project Report and Summary of Data Analyses.
18. New York State Department of Environmental Conservation. (2003). Jamaica Bay Borrow Pit Evaluation Project - NYS DEC Water Quality Monitoring Report 2000-2002.