Beneficial Use of Dredge Materials for the Improvement and Enhancement of Eastchester Bay Wetlands and the Water Based Economy of the Eastern Bronx

Draft Environmental Impact Statement

Technical Appendix

Public Notice #97-13010- Y2
Royal Marina Application

July 13, 1998

Submitted to:

- New York State Department of Environmental Conservation
- U.S. Army Corps of Engineers, New York District
- New York State Department of State

Prepared by:

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ENVIRONMENTAL IMPACT STATEMENT

Introduction: NEPA: Requirements for an Environmental Assessment/Environmental Impact Statement

The Council on Environmental Quality (CEQ), created pursuant to Section 202 of National Environmental Policy Act Procedures (NEPA), was charged with the responsibility to "develop and recommend to the President national policies to foster and promote the improvement of environmental quality to meet the conservation, social, economic, health, and other requirements and goals of the Nation." This charge resulted in the promulgation of Regulations on Implementing National Environmental Policy Act Procedures (40 CFR 1500-1508, as amended). These regulations and procedures are the basis upon which all Federal environmental documents related to major Federal actions are generated. The CEQ regulations and procedures are supplemented by guidelines, regulations and procedures developed by each Federal agency to comply with the purpose and provisions of NEPA. Federal actions for which environmental documentation is being prepared (EISs and/or EAs) must consider all applicable Federal, State, and local statutes and ordinances affected by the action.

These detailed statements have come to be known as Environmental Impact Statements (EISs) and Environmental Assessments (EAs). This EIS document is a technical appendix to the SEQR Draft EIS. It presents the scientific evidence reviewed to assess potential benefits for the use of dredged materials in wetland construction and habitat restoration.

1.0 Project Identification

Project Name: Beneficial Use of Dredge Materials for the Improvement and Enhancement of Intertidal Salt Marsh in Eastchester Bay along the Pelham Bay Landfill and Pelham Bay Park

Name and Address of Applicant: Royal Marina
c/o The Gaia Institute
99 Bay Street
City Island, NY 10464

Project Number: Public Notice #97-13010- Y2

Project Location: Eastchester Bay
Pelham Bay Park
Bronx, NY

1.1 Project Summary

The Applicant proposes to dredge sediments from Royal Marina, then beneficially use the dredged materials to create salt marshes around the Pelham Bay Landfill and the southern tier of Pelham Bay Park. Dredging of Royal Marina, and other marinas in the Eastchester Bay vicinity, is necessary to return water depth to prior navigable levels, restoring capacity to berth boats in existing slips, and again bring in larger vessels, which is no longer feasible at low tide.

This proposed beneficial use plan for dredged materials around Pelham Bay Landfill and the Southern Tier of Pelham Bay Park aims to restore, in total, about 30 acres of intertidal marsh as well as more than ten acres of rocky intertidal and subtidal rocky habitat through the building of a 4,000 foot long stone dike containment facility. The initial phase of this work, beginning with ≈ 1.5 acres of marsh and a 400 foot length of rock armor wall, will create more than a half acre of rocky intertidal and subtidal habitat, providing a prototype, at 1/20 scale, for evaluating the success of benthic macrophyte and faunal recruitment and development, as well as biochemical, geochemical, and geophysical contributions to water quality. This area, with appropriate controls, will be a primary focus of the research and development work of the Pelham Project (see below for a description of the latter).

By using locally dredged materials in local ecological restoration projects, dredging can contribute to the redevelopment of water based industries in the eastern Bronx through the lowering of maintenance dredging costs while enhancing water quality and fisheries production.

This creation of intertidal wetland including saltmarshes, mudflats and rocky subtidal and intertidal ecosystems will remove pollutants and chemicals of concern (COCs) from combined sewer overflow and stormwater discharges, leachate from the adjacent landfill, as well as from the dredged sediments themselves. The creation of a tidal wetland together with rocky subtidal and intertidal habitat of the stone dike containment facility will also contribute to the essential fish habitat of the region.

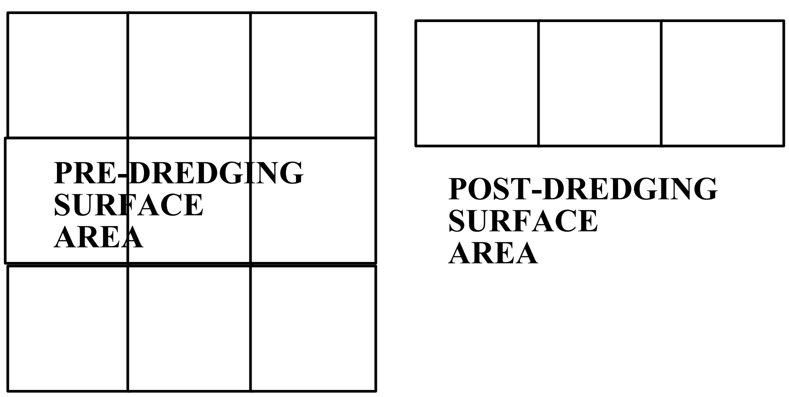
Dredged materials will be contained beneath the proposed tidal wetland. The contained volume will have less surface area than the present, pre-dredging distribution of sediments. Since contaminants are released through the sediment/water column interface, diminishing the surface area of this interface significantly reduces the scale of the pathway by which contaminants enter the ecosystem. Calculations characterizing the surface to volume ratio of the proposed containment configuration indicate that this structure will reduce the release of COCs contained in the dredged material to the water column by a factor of about three, i.e., a three fold reduction in the ratio of the sediment/water column interface to sediment volume will lead to about a threefold reduction in the movement of COC's through sediment surfaces (see Figure 1.). The biogeochemistry of the marsh microbial communities will provide an additional measure of protection to the water column through documented abilities to destroy and sequester major point and non-point source pollutants, including those found in dredge materials, landfill leachate, surface runoff, storm water, and combined sewer overflow (CSO) discharges. A review of this literature on salt marsh biochemical capacities and estimates on amounts sequestered, is presented in this document.

11. Pages 1 - 4 of the Technical Appendix focus on two primary means by which any contaminants will be reduced in effective concentration or eliminated: changes in gross interfacial geometry of dredged sediments within the containment facility; and, increased (bio)geochemical capacity of COC removal by containing sediments beneath the envelope of a developing saltmarsh rhizosphere, and by increasing the diversity of biogeochemical systems.

As stated on page 4:

"Calculations characterizing the surface to volume ratio of the proposed containment configuration indicate that this structure will reduce the release of COCs contained in the dredged material to the water column by a factor of about three, i.e., a three fold reduction in the ratio of the sediment/water column interface to sediment volume will lead to about a threefold reduction in the movement of COC's through sediment surfaces."

This will lead to a change in geometry as shown in Figure 1 in the Technical Appendix, and below, from sediments spread beneath an approximately three acre surface, to packed below approximately a one acre surface. Since contaminants are released through the surface, this step alone will diminish contaminant release.



While page four in the Technical Appendix does not address the assumption that sediment remaining in Royal Marina is clean, it does lay out the basic mechanism of interfacial geometry which is known to decrease and to regulate COC release, as well as the increasing the quantity and activity of the fundamental regulators of pollutant uptake and degradation: "The biogeochemistry of the marsh microbial communities will provide an additional measure of protection to the water column through documented abilities to destroy and sequester major point and non-point source pollutants, including those found in dredge materials, landfill leachate, surface runoff, storm water, and combined sewer overflow (CSO) discharges." Because of increases in oxidation/reduction potential and the scale of the air, water, and sediment interface, biogeochemical activity is substantially increased. The Pelham Project will document the behavior of these fundamental modification of the sediment/water column interface, as well as pore water activity.

The proposed project aims to renew an urban waterfront by dredging, increase the intensity of the water-based uses of this and nearby properties, and thus contribute to both state and local waterfront revitalization efforts. By demonstrating how water-based economic activities can be strengthened, at the same time increasing habitat diversity and ecological productivity of the area, the coupling of economic and ecological goals will have the following effects:

1) diminishing contaminant discharge by reducing the surface area of the sediments, and increasing biogeochemical activities which remove or sequester harmful constituents;

2) increasing habitat heterogeneity in northwestern Eastchester Bay by restoring historically prevalent diverse habitat types including intertidal marsh, mudflat, rocky intertidal, rocky subtidal zones, and creeks which were diminished, displaced or destroyed in recent years by landfilling much of the surrounding environment.

3) providing economically attractive dredge disposal options for western Long Island Sound and facilities in and around the eastern Bronx; &

4) intercepting and treating stormwater and CSO discharges from city streets and highway infrastructure as well as any flows of leachate from the landfill.

The redevelopment of marinas can also serve as a catalyst for related private investment in water-based industries in the area, providing economic incentives to refurbish maritime properties generally in nearby deteriorated sites, prevent further deterioration, improve the existing economic base of the local community, restore contiguity between regionally important habitat types, and improve the viability of integrated commercial and recreational uses of the area.

This proposed action is part of the Pelham Project: Developing Wetlands for the Disposal and Treatment of Dredged Material, a project of Columbia University. It is a collaboration of the Earth Engineering Center and the Lamont Doherty Earth Observatory of Columbia University, with the Gaia Institute. The Pelham Project will:

- design the dredge material containment stone dike wave break;
- investigate the development of marsh capacities to remove sediment contaminants;
- oversee dredging, saltmarsh construction and maintenance;
- stage a major interdisciplinary research effort on the marsh for at least three years, including investigations on hydrology and hydrodynamics, geophysics and sedimentology, biology, ecology, and geochemistry.

The project aim is to couple the structural engineering practices of containment facility construction with the ecological engineering of habitat construction and restoration. A primary outcome of the work will be design options which couple dredging project windows with modular containment facility cells. Orientation and arrangement of these cells will be influenced by the structure of existing salt marsh systems, and, where necessary, optimized for pollutant treatment and to make use of freshwater inputs. Details of this proposal of Columbia University are available upon request from Dr. Bud Griffis (Earth Engineering Center, 610 S.W. Mudd Bldg., Columbia University, New York, NY 10027, ph 212 854-8873, FAX 212 854-6267).

2.0 Purpose, Need and Benefits of the Proposed Action

Sediments fall out of suspension in quiescent waters around piers and docks, diminishing the value of these structures for commerce and recreation. This is the case at Royal Marina on City Island, and many of the docking facilities throughout the Borough of the Bronx, the City and the State. At the same time, extensive landfilling has eliminated most of the historic intertidal wetlands and sedimentary shallows in New York and other coastal cities, diminishing pollutant removal and fisheries production in the process. Contaminants in sediments have led to the ban on ocean dumping, effectively eliminating readily available, low cost disposal of dredgings. This regulatory framework requires new approaches to sediment decontamination and disposal which also include marsh creation.

It is fair to say that wetlands can treat the majority of kinds of contaminants in dredged materials (Kaklec & Knight 1996). The historic filling of wetlands in New York City has both removed a major sink for sediments in the area and at the same time a major sink for nutrients and contaminants. Two millimeters of sediments per year over the 45,000 acres of wetlands which have been filled historically in New York would have provided a sink for about a half million cubic yards of sediments ($\approx 4 \times 10^{11}$ grams), about a tenth of the annual dredgings in New York Harbor. It is interesting to note, by way of comparison, that, with a much lower ratio of marsh to open water than the historic New York City region, estimates of sediment removal for Chesapeake marshes are on the same order of magnitude as those provided above, $\approx 10^{11}$ grams per year (Nixon 1981).

2.1 Ecological Enhancement through Habitat Creation and Restoration

Habitat creation through human efforts has been carried on for decades to centuries through the use dams, dikes, structures for the aggregation of fish, and attachment surfaces for macrophytic algae and filter feeders such as oysters and mussels (Grove et. al. 1991). All of these are hydrologic modifications in that flow patterns, rates, or the distribution of velocity gradients are modified. These changes in turn impact on the niches of species and communities, from microbes to macrophytes and macrofauna, leading to changes in ecological structure. More recently, attempts have been made to utilize structural modifications to restore or create functional qualities of aquatic, wetland and other ecosystems for various purposes, including the mitigation of damage caused to other systems (National Research Council 1992; Cairns & Buikema 1982). Dredged materials have been used in the context of wetland and upland habitat creation, and, in all cases, attempts are made to establish the correct hydrological regime for the intended plant communities, and to copy the natural geomorphological features which protect plantings, suppress erosion, and lead to some sediment accretion (Kirby 1995). Much of the work in habitat restoration has focused on a specific effects in a group of organisms such as fin fish (Chipps et. al. 1997), or a specific habitat type, such as tidal flats (Kirby 1995). In a few cases, detailed comparisons have been made between constructed and natural systems (Okada et. al. 1997). A unique environmental enhancement/mitigation project aimed at integrating the construction/restoration of at least five different habitat types, including habitat for an endangered species (Proposed Batiquitos Lagoon Enhancement Project in the City of Carlsbad 1986).

The construction of intertidal salt marsh may be expected to reduce BOD (Hammer et. al. 1993; Kaklec & Knight 1996) and nitrate (Valiela, I. & JM. Teal. 1979a; 1979b; DeLaune et. al. 1989; White & Howes 199) in Eastchester Bay, thus providing a measurable, positive effect in the environment around the Pelham Bay Landfill and Pelham Bay Park.

12. NYS DEC's Record of Decision for the Pelham Bay Landfill states:

"The total amount of leachate generated from all areas of the landfill is projected to be reduced up to 70% through the placement of final cover and the installation of the trench along the southwest perimeter by Pelham Bay Park. The remaining significant source of leachate will be from the saltwater intrusion into the landfill, which is estimated to affect about a 125 foot width around the landfill that "touches" Eastchester Bay. It is estimated that the leachate that will be generated from this tidal flushing will be significantly "cleaner" because the leachate from the interior portion of the landfill will be drastically reduced by the capping and the leachate from the 125 foot perimeter area has been flushed for years; most of the contaminants in this area have been removed. Therefore, the contaminants in this leachate will decrease after closure" (pp 24-25).

The Pelham Project is the only effort on the horizon which can provide a verifiable quantitative evaluation for these assertions in the Record of Decision. This will, of course, require the very precise approach to analysis documented in the Pelham Project Proposal, since the quantities of materials in the leachate, as determined by Woodward & Clyde, are not high. As noted in the Technical Appendix (p 11), "Even the most problematic metals in the leachate, Fe, Cr, Pb, Ni, and Cu range from 4 to 0.003 mg/l (see discussion of test results in Appendix). The most highly concentrated pollutant discharged, from samples to date, is ammonia, ranging from about 10 to 1000 ppm (Woodward and Clyde 1993)." Woodward-Clyde reported a groundwater discharge of 80,000 gallons per day. The following discharges would occur at the above noted concentrations and mass flow:

metals concentration in ppm	metals* discharge in lbs/day	metals* discharge in lbs/yr.	ammonia concentration in ppm	ammonia* discharge in lbs/day	ammonia* discharge in lbs/yr.

max.					
4	2.67	973	10	7	2,433
min.					
0.003	0.002	1	1,000	667	243,324

* assuming 80,000 gpd of ground water derived leachate from the Pelham Bay Landfill

The addition of mounded leachate from precipitation prior to capping would multiply these estimates by a factor of less than 2, since one foot of infiltration over the 80+ acres of the landfill each year would generate somewhere between 50,000 and 100,000 gallons of precipitation-derived leachate each day. More refined estimates and measures will be provided by the Pelham Project, i.e., the determination of inputs and outputs, together with modeling transport and fate of contaminants. As noted in the Gaia Institute work for NYC DEP in the early 1990s, and also by collaborators in the Pelham Project, the presence of sediments and intertidal marshes around the landfill should diminish tidal inputs into the landfill and resist the flow of leachate out into Eastchester Bay. At the same time, biogeochemical processes in constructed marshes and sediments will contribute additional regulative mechanisms which will modify the flow of ammonia, DOC, metals, and other COC's.

The New York City Department of Environmental Protection has recognized the importance of wetlands to the ecological health and environmental quality of the area. The scope of work for The Pelham Bay Landfill Wetlands Investigation: An Evaluation and Analysis of the Contribution of Wetland Systems to Environmental Quality in Eastchester Bay, by NYC Department of Environmental Protection, states: *"Wetlands enhancement in Eastchester Bay through creation, restoration or augmentation of existing wetlands areas will be an integral part of New York City's remediation of the Pelham Bay Landfill."* Wetlands may here serve both as a remediation technology for landfill leachate, and a means for removing BOD and nitrate from stormwater and other non-point discharges, while creating essential fish habitat. A major thrust and purpose of the more recent Pelham Project is to quantitatively evaluate this constructed marsh and the containment facility rocky habitat communities on water quality, biodiversity, and ecological productivity. Aims of this project are detailed below.

By treating the chemicals of concern (COCs) from the landfill leachate, point and non-point source runoff, and contaminated sediments, the project aims to increase water and sediment quality in Eastchester Bay. While the wetland may be expected to increase the biogeochemical filtration and treatment within several months of planting, it must be recognized that moving, settling, stabilizing, and planting sediments will necessarily precede any enhancement. However, since the historic criticism of dredging has been that sediments are resuspended in the process, and especially through losses of low density materials during deep water disposal (reviewed in Kennish 1992), negative impacts of these prior steps can be minimized by mitigation measures during dredging and by the placement of sediments within a containment facility. Even if such sediment releases are diminished, however, the act of constructing a wetland cannot enhance environmental quality per se. This process must be measured against the plant and microbial uptake and removal of chemicals of concern from the sediments and water column which will follow marsh growth and development. While all the major features of this developmental sequence have not been well characterized to date, prior experience leads to the expectation that the marsh should begin to show environmental quality enhancement effects after six to eight weeks of growth (April to June), when the plant leaves have reached heights of about a half meter (Bergen et. al. 1996). When the plant community approaches this size class, water and sediment quality should increase sufficiently to begin to protect wildlife receptors.

The close proximity of intertidal rocky and marsh habitat with rocky subtidal and soft benthic habitat is expected to increase food availability and feeding habitat, together with protection from predators for fry and juveniles for fin and shell fish, thus increasing fishery productivity and biodiversity of Eastchester Bay. The proximity of diverse habitat types enhances larval, fry, and juvenile survival by allowing fish to minimize predation in structurally complicated habitats which provide cover, while optimizing foraging strategies in environments with high food abundances (Bohnsack et. al. 1991; Irlandi & Crawford 1997). While the archipelago on which the Pelham Bay Landfill is situated probably provided such habitat in historic time (see 1906 historic map of landfill and Royal Marina area on City Island in Figure 2.), the nearest environment with such structural diversity on the scale of acres of habitat is presently more than three miles away.

2.2 Economic Enhancement

In addition to measurable improvements to environmental quality, the proposed action coupling dredging with habitat restoration will serve the local economy. Because of the expense of dredging, many coastal economies have become derelict. A number of previously water oriented properties near the Royal Marina have fallen into disuse over the past several years. Interim uses, including staging areas for construction, are in no way water based.

The areas around the Royal Marina and Pelham Bay Park have high recreational value. Activities around these areas include fishing, boating, and swimming. Improved water and sediment quality will be more protective to human health in a number of ways. Contact with water is a means by which pathogens may be spread to bathers after combined sewer overflow or other sewerage discharges. Physical and chemical processes in tidal wetlands, as well as the activities of intertidal filter feeders can reverse this threat, cleaning water and making it more aesthetically pleasing in the process.

17. The Pelham project was devised to determine pre and post-construction water and sediment quality, and monitor, model, and predict specific outcomes (see specifics in Pelham Project Proposal). Since the mission of the Pelham Project is to demonstrate the feasibility, long term stability, and advantages of engineered constructed wetlands for dredge material treatment and disposal, the intrinsic aim of this work is to provide a

sound foundation to evaluate water and sediment quality results where dredged materials are used to construct intertidal wetlands.

3.0 Site History and Description

3.1 Site Geology

Surficial and Bedrock Geology

Pelham Bay Park is underlain by highly metamorphosed and dissected crystalline bedrock. The eastern side of the Park is underlain by the Hartland schist formation, part of the larger Hutchinson River Group of schists and gneisses underlying much of Westchester County (CA Rich Consultants, Inc., 1985). Bedrock outcrops at the Eastchester Bay shore have been exposed by a combination of glacial erosion from ice advances during the last glaciation nearly 10,000 years ago and from the removal of glacial till (poorly sorted clays, silts, sands and gravels) by wave action.

Beach Sediments

Much of the intertidal zone consists of typical muck soils composed of accumulated upland sediments and organic debris from the decomposition of wetland plants. Sand is limited mostly to the northern areas of the site. These soils range from several inches to two feet deep. They are rich in organic matter and are underlain by loose sand derived from glacial moraine. (Malcolm Pirnie, 1988)

Soils

Upland soils just west of the intertidal zone are classified with the Riverhead Series; relatively deep, very fine sands and course silts with lenses of fine silts and coarse clays derived from glacial outwash. Gneiss and schist minerals such as quartz, orthoclase, and mica increase with depth as does the frequency of coarse sand and fine pebble-sized particles. The soils are well drained with moderate moisture holding capacity and moderately rapid permeability (NYCDPR, 1989).

There are two types of soils in the southern zone. Well-drained loam to sandy loams over deep tills and shallow, excessively well-drained coarse sandy loam to loamy sands on shallow tills.

Shallow soils which are less than 20 inches deep have poorly developed horizons and low moisture-holding capacity. The deeper soils (35-60 inches deep) have high moisture capacity and well developed horizon profiles.

At elevations below 50 feet, upland soils are generally deep and well drained with moderate moisture-holding capacity. Textures are generally fine sand and coarse silt and appear to be uniform. Lenses and layered strata of fine silt and coarse clay exogenous sediment are occasionally encountered in these soils. (NYCDPR, 1989)

3.2 Site Hydrology

Surface and Shoreline Hydrology: Surface drainage in Pelham Bay Park east of New York/New Hartford Railroad bed through the center of the Park is generally to the east toward Eastchester Bay with the exception of more localized drainage from small-scale topographic variations. Lowest surface flow is usually during August and September while higher flows occur during late winter and early spring.

Groundwater flow is toward the east. Near the shoreline, tidal fluctuations and difference in fluid density between fresh and salt waters may locally influence groundwater flow direction velocity. (CA Rich Consultant, Inc., 1985)

The hydrogeologic structures that characterize the subsurface hydrology include unconsolidated sand and gravel glacial deposits, and water-bearing fractured bedrock. The flow volume and direction from the fractured bedrock is highly variable.

Tidal Influence: The area around the Pelham Bay Landfill is tidally influenced, with water levels differing between 0 to 7.2 feet to 8.5 feet from low to hide tide. (Malcolm Pirnie, 1988)

3.3 Site Ecosystems

The New York State Department of Environmental Conservation, Division of Water Resources has classified and set water quality standards for Eastchester Bay as Class SB, suitable for primary and secondary contact recreation and any other use except shell fishing for marketing purposes (NYSDEC, 1985).

A comprehensive environmental characterization report entitled Pelham Bay Park Environmental Characterization Report, was completed by Malcolm Pirnie in 1988 (Malcolm Pirnie, 1988), for the City of New York , Department of Parks and Recreation (NYCDPR, 1989). This report was published as the Pelham Bay Park, Southern Portion, Bronx, NY: Site Analysis (NYCDPR, 1989). This report includes:

- Geology and Soils,
- Ecology/Plant & Animal Communities
- Hydrology, &
- Water Quality.

The Site Analysis concludes with a section of Findings and Discussion that summarizes the various overall health of the surrounding intertidal and subtidal ecosystems. The only significant changes in the subject site area, since this biological inventory was completed, is the re-grading and capping of the Pelham Bay Landfill. Therefore, the data presented, and their conclusions, are likely representative of the current ecosystem conditions at and near the proposed site.

The Pelham Bay Landfill Wetlands Investigation: An Evaluation and Analysis of the Contribution of Wetland Systems to Environmental Quality in Eastchester Bay (Gaia Institute, 1994), includes a detailed assessment of the site wetlands and the potential environmental impacts of wetland enhancement and restoration. This report provides a description of existing intertidal and subtidal structure and diversity, together with an assessment of the present operative scale of biogeochemical activities. Aerial extent of habitat types is used to generate a context in which to compare past, present and potential contributions of different habitat types to water quality in the study region. The PBL Wetlands Investigation also includes a quantitative and qualitative ecological and human health risk analysis of the various chemicals that are currently present at the subject site and the likely effects of wetland restoration on the chemical fate and transport of these chemicals.

Studies of the Eastchester Bay subject site to date, and inspection of historic and present day maps, suggest that intertidal salt marsh and intertidal and subtidal rocky habitat restoration will benefit the local ecological system. These kinds of habitats have been greatly diminished or destroyed by recent human activity, while in the past, they were predominant. The only 'measure' we have of former ecological integrity may be gleaned from the written reports of the productivity of the fishery:

"The Pelham Bridge, over the mouth of the East Chester Creek, has long been famous for the size and quality of fresh fish taken in and around the waters of the Bay and River".

These words of the Reverend Charles E. Lindsley are quoted in Scharf's History of Westchester County (vol. 1, p 706). Conditions from past centuries included many differences from the present, but evidence indicates that at least an order of magnitude of marsh area was lost, and perhaps more rocky intertidal and subtidal habitat in the immediate vicinity of the Pelham Bay Landfill. Since the proposed wetland construction will displace some benthic habitat with a mosaic of intertidal wetlands plus rocky intertidal and benthic habitat, these constructed tidal wetlands will provide structural complexity which supports essential fish habitat. As a case in point, the same source noted above tells us that, although fishing had declined in the area even then:

"Still, within the past twenty years, bass of large size and weighing from 50 to 60 pounds, have been taken with the hook in this vicinity. Black fish are still numerous around the rock and reefs along the shore".

Striped bass have been caught in the 30 to 40 pound range by Turtle Cove and around the City Island Bridge in recent years, but blackfish rarely if ever are taken from the far side of Eastchester Bay, because much of the rock and reef habitat here has been landfilled. Rocky habitat restoration, the colonization of bladder wrack and similar blackfish habitat around the landfill is expected to reverse this trend. The increased biological complexity of a mosaic of different habitat types and ecological communities is expected give rise to a robust, persistent and resilient ecological system - where currently small patches of such systems represent fragments of the previously contiguous community structure.

3.4 Site History

The western tier of Pelham Bay Park is located in the Borough of the Bronx south and west of the Pelham Bay Landfill. The Landfill and this section of the Park mark the western and northern edges of Eastchester Bay. The latter was adjacent to and, according to the 1897 USGS map, tidally connected to Pelham Bay by the impoundment which is now called Turtle Cove. Inspection of the remnants of the original road to City Island of more than a century ago through the middle of the marsh in Turtle Cove indicates that the gravel and rock footings of this road would have blocked the connection between Pelham and Eastchester Bay's to some degree. The present main road to City Island crosses the southern discharge of Turtle Cove into Eastchester Bay, diminishing tidal exchange. Recent work has removed collapsing concrete footings which had impeded tidal exchange, and greatly increased drainage rates and input and output quantities. No work, however, is scheduled to address the northern input into Turtle Cove which had provided tidal throughput from Pelham to Eastchester Bay which is completely blocked by the road to Orchard Beach, constructed in the 1930's.

The geomorphological diversity in aspect and orientation of the archipelago of the Eastern Bronx provided high energy rocky intertidal and benthic habitat, low energy intertidal salt marsh and mud flat environments, soft silty subtidal, and muddy and sandy creek and river bottom habitat. Low lying flats, rock outcroppings, and rocks of the archipelago also provided relatively easy places to span these waterways, as occurred in previous centuries with the building of what is now Shore Road, as well the coastal rail line of the northeast corridor. More recent history brought the Hutchinson River Parkway, I 95, CoOp City, a high school and a hospital which, together with other development, reduced some 2,000 acres of tidal wetland in the northeastern Bronx to about 250.

Decline in the region thus started well before the Pelham Bay Landfill with wetland destruction, together with pollution and over fishing, erosion and runoff compromising the health and diversity of the estuary. Sewage was discharged directly into the Hutchinson River, and Eastchester and Westchester Creeks further degraded the environment. The Hunts Point and Wards Island waste water treatment plants improved the quality of the discharge, and the upgrading of these plants has allowed for a substantial comeback of oyster reefs from Clason's Point to City and Hunter Islands.

While the Pelham Bay Landfill has now been capped, only leachate from the southwest corner of the landfill is pumped to the Hunts Point wastewater treatment facility, potentially leaving other leachate mounded under the cap, to migrate through the eastern and northern reaches of the rock armor wall. A large rock lined stormwater discharge, positioned near where historic maps indicate a former arm of Westchester Creek connected to Eastchester Creek, enters the cove just north of the landfill from the direction of I 95 and the Hutchinson River Parkway. Smaller discharges (5' diameter and less) occur through the adjacent section of Pelham Bay Park, carrying water which supports green films of <u>Enteromorpha,</u> a weedy green algae often indicative of high nitrogen inputs.

13. The requirements of the principle of continuity, as defined in the physics of flow, must be met by leachate or any other incompressible fluid. This means that the product of fluid velocity and sectional area is the same for the same fluid moving between any two points[1]. This does not mean, however, that the hydrostatic head under the cap would lead to uniformly equal flow rates in all directions. Layers of garbage of various ages and compositions covered by layers of cover material with varying hydraulic properties act to create a complicated two and three dimensional structure. This three dimensional, discontinuous layer cake structure is further complicated by the even higher dimensional interactions of pressure and flow. There is even variability in the former parameter, i.e., pressure, through monthly and yearly oscillations of the tidal cycle which modify the total head of the leachate mound by changing the boundary conditions. Added to this are stochastic events such as storm surges and internal changes with layers through further microbial action turning cellulosic materials into more gel-like materials. In short, how the heterogeneous materials beneath the landfill behave is a matter which can only be described through the specific empirical studies outlined in the Pelham Project . While the force main to Hunts Point WWTP is still in operation, unless leachate is removed equally from all sectors of the water table beneath the landfill, forces acting to move water outward from the hydrostatic head are likely to be quite different in different places.

The New York City Department of Parks and Recreation has built valuable freshwater wetlands in the Park adjacent to the Landfill, protected from the inflow of leachate by a slurry wall. Only small salt marsh restoration projects have been attempted in this section of Eastchester Bay to date, however, which, because of their scale, cannot have significant impact on water quality or the establishment of essential fish habitat.

3.5 Pelham Bay Landfill-History:

The former New York City Department of Sanitation (DOS) municipal landfill covers

14.The text has been amended to read 89.3, as opposed to the pre-closure approximation of 81 acres.

It appears on the New York State Inactive Hazardous Waste Site List because of illegal dumping of hazardous materials such as industrial waste and waste oil. The responsibility for closure and remediation at the Landfill was transferred in 1990 from the DOS to the New York City Department of Environmental Protection (DEP). Once properly closed, the landfill will be incorporated into Pelham Bay Park. Intermediate cover material was placed on the landfill when solid waste dumping ceased and subsequently was closed and remediated in accordance with the regulations of the New York State Department of Environmental Conservation (DEC) and the U.S. Environmental Protection Agency (EPA). At the time of this writing, the impermeable

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[1] Elementary Mechanics of Fluids, by H. Rouse. 1946, Constable & Co., Ltd., London. pp 13-16.

cap currently covering the landfill is beginning to support a uniform vegetation cover, and thus meet closure specifications. During significant storms, however, large plumes of suspended sediments and solids are still discharged into Eastchester Bay. After the storm of 13 June, 1998, a plume ten meters in width and tens of meters long was discharging for hours from the Landfill stormwater outfall, just East of the Shore Road Bridge (personal observation of PSM).

Formerly, collection and drainage infrastructure directed leachate into Eastchester Bay. Because of this, the City of New York was found to be in violation of Clean Water Act Statutes in a suit filed by the New York Coastal Fisherman's Association. This lawsuit may have served to hasten closure work on this landfill.

In preparation for closure, leachate and sediments were examined by the consulting firm of Woodward and Clyde in 1992 and 1993. Major chemicals of concern (COCs) were found to be lead, benzene, and various polycyclic aromatic hydrocarbons (PAHs) derived from petroleum products (Woodward and Clyde 1993), as well as high concentrations of ammonia and BOD. While sediment samples indicate several 'hot spots' for hydrocarbons and metals, the metal levels in leachate appears relatively low. Even the most problematic metals in the leachate, Fe, Cr, Pb, Ni, and Cu range from 4 to 0.003 mg/l (see discussion of test results in appendix). The most highly concentrated pollutant discharged, from samples to date, is ammonia, ranging from about 10 to 1000 ppm (Woodward and Clyde 1993). While total variability and stability patterns of this signal are not well characterized by sampling to date, the Pelham Project will aims to redress this. These compounds can pose significant threats to the health of humans and/or wildlife when present at significant concentrations.

Human health issues are all the more critical because of the siting of the Pelham Bay Landfill adjacent to several communities, including Throgs Neck, Country Club and City Island. It is also near Orchard Beach, one of the most popular bathing beaches in New York City. Bronx citizens have been concerned about the environmental impacts of the Pelham Bay Landfill from its beginning in 1963. The Talliposa Site, as it is known locally (and was, in former times, by the Native Americans), together with nearly 3,000 adjacent acres in Pelham Bay Park, were marked to be landfilled with New York City garbage for decades following the opening of the dump in the mid-1960's. Public opposition changed the City's plans, and Fresh Kills was eventually chosen to be the large New York City Landfill. While the flow of contaminated water into Eastchester Bay remains an issue for a number of Bronx residents, many continue to fish and swim in the vicinity of the landfill, often on the landfill itself, regardless of official prohibition.

The question remains as to whether the capacity of this environment to protect human health and ecological integrity will be increased or decreased by dredging or the no action plan, and as to whether the water based economy of the region is sustainable.

4.0 Required Components of an EIS

According to regulations (40 CFR 1502), an **EIS/EA must describe the purpose and need for the action that is being proposed, and identify all reasonable and practicable alternatives to the proposed action. The EIS/EA must include a detailed description of the biological, physical, and sociocultural environment that would be affected by the proposed action.** Following this directive, an analysis was produced of the environmental consequences that would result from the implementation of the proposed dredging from Royal Marina and the Western Sound, containment facility and marsh construction around the Pelham Bay Landfill and the Southern Tier of Pelham Bay Park, and possible alternatives to these proposed actions. This description of environmental consequences includes the following:

- any adverse environmental effects that cannot be avoided by the proposed action or no action alternative;
- the effects on short-term uses of the environment and long-term productivity by both action and no action alternatives;
- any irreversible or irretrievable commitments of resources inherent in action or no action alternatives; and,
- the direct, indirect, and cumulative effects of action and their significance.

The purpose and need for dredging of Eastchester Bay and the construction of wetlands within a containment facility around Pelham Bay Landfill and the southern tier of Pelham Bay Park is to minimize the costs of water-based industries and to maximize ecological benefit, or, as stated in the Federal Coastal Zone Management Act of 1972, to "preserve, protect, develop, ...restore or enhance the resources of the Nation's coastal zone". The analysis presented below indicates that the only way to accomplish these multiple ends is to couple ecological with economic enhancement.

Both dredging and wetland construction on dredged sediments within containment facilities are essential to meet the stated purpose of preserving, protecting, developing, restoring and enhancing the resources of the nation's coastal zone. The potential impacts of dredging or not dredging on economic activity and environmental quality may already be described as very large in local, regional, and national terms. Dredging directly affects economic and environmental costs of water access infrastructure and transportation. For this reason, the reply to comments for the dredging of Royal Marina in Eastchester Bay is presented in the form of an Environmental Impact Statement so that positive and negative outcomes of dredging and no action alternatives may be compared directly in economic, environmental and ecological terms.

Provided below is a description of impacts of the proposed action, and of available mitigation measures for minimizing adverse environmental effects, together with a comparison of alternative actions. Effects of the proposed actions and possible alternatives are identified and analyzed in terms of their effects and environmental impacts, as required by the EIS/EA process.

4.1 Environmental impact of the proposed action;

a) Dredging will have the following impacts at the Royal Marina site:

Disturbance of benthic habitat beneath the Royal Marina. While the most quiescent of these environments may be depleted of oxygen during parts of the tidal cycle, especially during warmer months, the higher energy, more oxygenated depositional areas are likely to be habitat for estuarine worms (polychaetes of the genus Nereis, inter alia.), mollusks and arthropods. This habitat, and the organisms which occupy it, will be destroyed during dredging.

The presence of a black organic matrix on top of coherent, gray clays (gleys) suggests that the environment may be too low in oxygen during critical warm weather periods for species of soft shell clam, such as *Mya arenaria*. While sampling (see Sampling Protocols and Results Appendix for a discussion of method)**.** brought up a matrix of blue mussel (Mytilis edulis) shells from a depth of several inches to a foot or more (which appear to be shed from the marina's pilings), no living worms or other invertebrates were found in the sediments. This is far from conclusive evidence, however, since benthic organisms are notoriously difficult to sample. Hand dredging, in fact, has captured periwinkles and tunicates, indicating that the sediment surface supports macrofaunal elements.

Sedimentation Rates and Resuspension of fine grain sediments. The Royal Marina is situated in a quiescent embayment where channel width increases threefold for water moving through the confines of the neck of land and the abutments of the City Island Bridge, with corresponding deceleration in water velocity. In technical terms, the pilings of rows of piers dramatically reduce the Reynolds number, further contributing to decreased water velocity here by breaking up the flow, decreasing turbulence, and increasing sediment deposition.

Some of the organics and clays have sedimentation rates on the order of a meter per day or less. By standard column testing (Montgomery 1978), minimum sedimentation rates were measured and found to be in the half meter per day range. This would place the size classes of the finest sediments at somewhat less than 0.01 mm (interpolated from Table 4.1 Settling velocities of various size particles on p 121 of Environmental Engineering, Peavy et. al. 1985). While algae and some suspended carbon compounds are capable of flocculating these and finer grained sediments in estuaries, such suspended sediments may impact attached filter feeders for a distance of tens to hundreds of linear feet. Estimates of duration of impact are a few days to approximately a week during and after dredging.

b) Constructing salt marsh within a confined containment facility will have the following impacts on the area around the Pelham Bay Landfill and the southern tier of Pelham Bay Park:

Removal of benthic habitat. The four foot diameter rock of the containment facility will displace the majority of the soft sedimentary benthic habitat with rocky benthic habitat.

Depending upon the settling pattern of the rock, a few to a maximum of approximately 15 percent of the soft sedimentary benthic habitat may remain exposed in the spaces between where the stone dike of the containment facility rests on the benthic sediments (see Figure 3.). Approximately 1 1/4 to 1 3/4 acres of benthic soft sedimentary habitat within the containment facility will be covered with dredged sediment within the initial containment facility cells. Approximately 30 acres would be covered in the full scale containment facility.

18. Bathymetry

Introduction. A bathymetric survey of Eastchester Bay around the Pelham Bay Landfill and the southern tier of Pelham Bay Park was carried out on 17 January 1999 by Roelof Versteeg from Lamont-Doherty Earth Observatory of Columbia University. The area surveyed extended from about 500' south and west of the Shore Road Bridge to the southern reach of Pelham Bay Park, due east of the eastern terminus of Watt Avenue. The survey vessel tracked an envelope of from 300' to more than 700' around this zone.

Methods & Materials. Bathymetry was collected using a Furuno LS6000. Bathymetric data (in feet) were recorded every second. Data were coregistered with time, latitude and longitude, which were obtained from a Trimble Ag132 DGPS with satellite provided differential correction. Survey tracklines were monitored using Visual Series from Nobeltec. Tracklines followed the shore line, and were spaced approximately 10 feet apart, with the first trackline within 10 feet of the shore line. During the survey several points were sampled multiple times to ensure data consistency.

Post acquisition the data were checked and quality controlled to eliminate inconsistencies (e.g. during several minutes the differential correction was lost). After this the data were corrected for the tide cycle elevation. This correction was based on the available tide charts as no tide gauge was in place during this survey. The resulting data were gridded and contoured. For this contouring, areas with no data outside the survey were assigned a value of 0 depth. The resulting map has depth units of feet and dimensions of meters relative to the starting point of the survey.

The resulting map is in very good agreement with the existing NOAA map of this area, and with an independent depth sounder on the vessel which was used for this survey.

Results. The sediment surface of the area of Eastchester Bay surrounding the Pelham Bay Landfill and southern tier of Pelham Bay Park has very low relief. Over most of the area surveyed, depth is stable within a two foot isocline over tens to hundreds of feet (see Figure below). The apparent slope of much of the 30+ acres surveyed is one to a few percent. This uniformity in sediment grade, together with an apparent lack of benthic features, acts to minimize habitat types in this area.

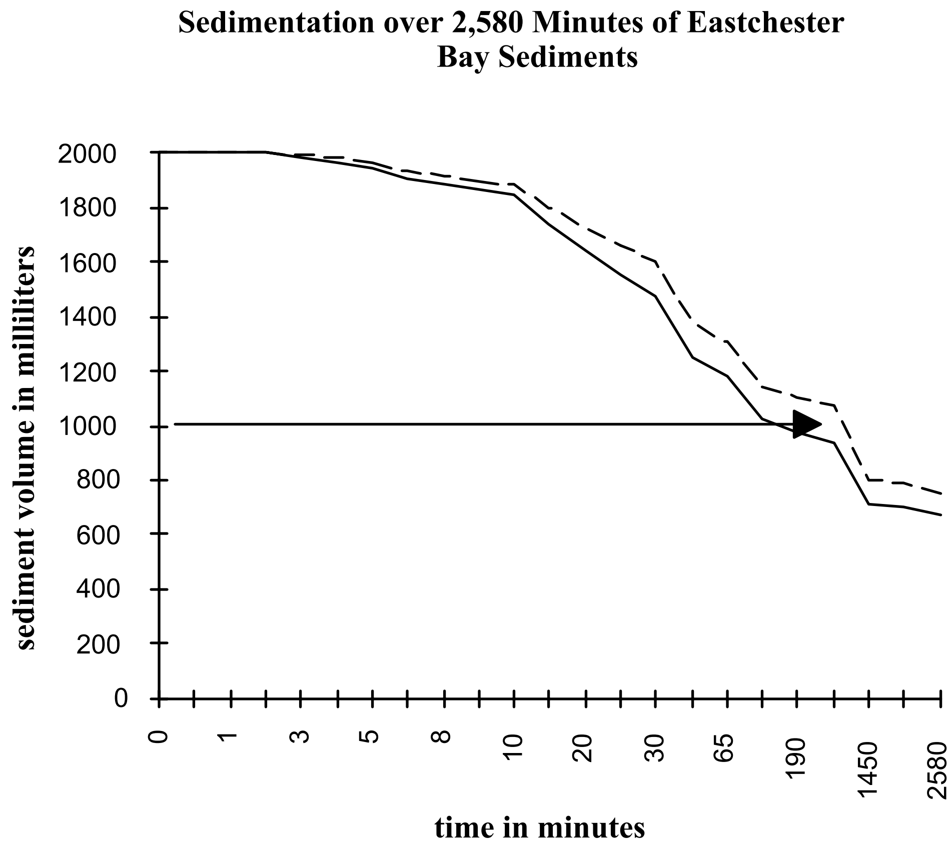
Benthic Habitat: Sediments

Introduction. Sediments from the area of the proposed confined containment facility adjacent to the Pelham Bay Landfill and the southern Tier of Pelham Bay Park were sampled on two occasions: January 17, 1999 & April 8, 1999. The first set of five samples were collected during the bathymetric survey on 17 January 1999. Here sediments and benthic organisms were screened from materials collected by Gaia Institute staff. Analyses followed to assess wet weight per sample, and a preliminary survey of benthic invertebrates and their by-products was carried out by GI staff with the assistance of the Ecological Engineering graduate students at Queens College. The sediments were analyzed using two methods, sedimentation rate and light scattering, by Maurizio Marezio-Bertini, a graduate student in the Earth and Environmental Engineering Department of the Henry Krumb School of Mines at Columbia University. A second set of three samples was collected on 8 April 1999. One of these samples was screened, while the remaining two were left unscreened prior to analysis (the latter carried out by R. Prezant and E. Chapman, Marine and Aquatic Biology Laboratory, Queens College of CUNY).

Methods and Materials. A ponar dredge with a sampling area of 230 cm^2 was dropped at five locations offshore from the southern tier of Pelham Bay Park and the Pelham Bay Landfill on 17 January (n=5), and again on 8 April (n=3). Samples from Eastchester Bay were processed through a three gallon Sieve Bucket lined with 30 mesh brass wire cloth. For the 17 January sample, materials which remained on the screen were shaken dry and weighed. Replicate sediment samples were then subjected to the standard sedimentation rate tests described immediately below. Benthic invertebrate data follows this sediment data.

Before running sedimentation tests, samples were blended and homogenized. After blending and homogenization, samples were introduced in sedimentation jars. Then, the jars were filled with distilled water up to the reference mark. Two different jars were used: jar #1 had a height of 34.4 cm and an internal diameter of 8 cm; jar #2 had a height of 41 cm and an internal diameter of 8.9 cm.

Before starting the sedimentation test, the jars were shaken for five minutes to ensure a satisfactory suspension of the sediments. After shaking, the jars were put on the vertical position and time was started. Readings were take every minute for the first ten minutes, every five minutes after the first ten minutes and in between the first hour. After the first hour, readings were taken at intervals of 40 – 60 minutes. After the first day of testing, readings were taken three times a day for the second day, and once a day for the following days. The tests were run for five days (results for about two days are shown below).



The data obtained were plotted in a linear X-Y plot, where the X-axis represented time and the Y-axis represented the decrease in height of the suspended column. The arrow points to the midpoint in settling, approximately 225 minutes (3 hr, 45 min) after initiation.

Time	I ml	II ml	I cm	II cm	Time	Sample 3	Sample 4	Time
0	2000	2000	36.40	41.00	0	36.40	41.00	0
0.5	2000	2000	0.00	0.00	0.5	36.40	41.00	0.5
1	2000	2000	0.00	0.00	1	36.40	41.00	1
2	2000	2000	0.00	0.00	2	36.40	41.00	2
3	1980	1990	0.00	0.00	3	36.04	40.80	3
4	1960	1980	0.00	0.00	4	35.67	40.59	4
5	1940	1960	0.00	0.00	5	35.31	40.18	5
7	1900	1930	0.00	0.00	7	34.58	39.57	7
8	1880	1910	0.00	0.00	8	34.22	39.16	8
9	1860	1890	0.00	0.00	9	33.85	38.75	9
10	1840	1880	0.00	0.00	10	33.49	38.54	10

15	1740	1800	0.00	0.00	15	31.67	36.90	15
20	1640	1730	0.00	0.00	20	29.85	35.47	20
25	1550	1660	0.00	0.00	25	28.21	34.03	25
30	1470	1600	0.00	0.00	30	26.75	32.80	30
50	1250	1380	0.00	0.00	50	22.75	28.29	50
65	1180	1310	0.00	0.00	65	21.48	26.86	65
150	1020	1140	0.00	0.00	150	18.56	23.37	150
190	980	1100	0.00	0.00	190	17.84	22.55	190
225	940	1070	0.00	0.00	225	17.11	21.94	225
1450	710	800	0.00	0.00	1450	12.92	16.40	1450
1610	700	790	0.00	0.00	1610	12.74	16.20	1610
2580	670	750	0.00	0.00	2580	12.19	15.38	2580
4180	660	730	0.00	0.00	4180	12.01	14.97	4180
5760	650	730	0.00	0.00	5760	11.83	14.97	5760

1) The test was started on 2/12 at 3:25 pm.
2) After 225 min the heights of the columns were reduced to 47% for #3 and 53% for #4 of the initial height.
3) After 4 days of monitoring, the height of the columns has decreased to about 70% of the initial height in both cases.
4) A fairly clear supernatant was obtained in both cases as soon as the supernatant formed.

These results are commensurate with a particle size distribution consisting of silts in smaller size class ranges (see below).

Particle size analysis by light scattering

Methods & Materials. Particle size analyses were run with two samples (Lot 4051-449/7348-752 #3, #4), by light scattering. A MICROTAC 7995 Particle Size Analyzer was used to carry out the analyses.
The samples were introduced into the mixing chamber to obtain a stable suspension. The suspension was then introduced into the analyzer equipped with a laser beam. The scattered light of the laser beam was recorded and analyzed by the internal computer and a printout of the particle size distribution was obtained. In particular, the printout contained the 16, 50 and 84 percentiles, which were used to characterize the particles of the samples. The results are summarized in Table 1.

Table 1: Particle size distribution obtained by light scattering.

Percentile	Sample #3	Sample #4
16%	0.00142	0.00136
50%	0.00427	0.00443

84%	0.01173	0.01469
Max	0.02700	0.02700

The results show that in both samples only 16% of the particles are smaller than 0.00142 mm and 0.00136 mm, respectively. They also show that 84% of the particles are less than 0.00427 mm and 0.00443 mm, respectively.

It can be concluded from the results that the sediments have particles in the silt range (>0.002 mm , <0.075 mm), with the smaller particles in the clay range (<0.002 mm). No particles in the sand range (>0.075 mm, <2 mm) were detected.

Benthic Habitat: Invertebrates

To evaluate benthic invertebrate taxa and frequency, screened material was inspected macroscopically, and under a dissecting microscope. The three samples from Eastchester Bay within the area of the proposed confined containment facility were dominated by amphipods, especially two congeners of ampeliscids. There are also many tube dwellers in the samples. These organisms are probably able to stay near the sediment/water column interface, despite apparent unconsolidated structure of the sediments. A few tube dwelling polychaetes were found (spionids) and some "free living" species (*Eteone* and *Nereis*). A very few, small juvenile clams were also found in the samples. These are probably young of the year spat. Given habitat structure, it is unlikely that these organisms would survive long.

Eastchester Bay/Pelham Bay Landfill & Southern Tier of Pelham Bay Park Benthic Species List, April 1999 (identified by Eric Chapman & Robert Prezant, Marine and Aquatic Biology Laboratory, Queens College of CUNY):

Crustacea:	
Amphipoda	
Ampelisca agassizi	42
Ampelisca vadorum	78
Melita nitida	6
Cumacea	
Leucon americanus	1
Mollusca	
Bivalvia	
Donax variabilis	1
Spisula solidissima	2
Annelida	
Polychaeta	
Autolytus cornutus	1

Eteone heteropoda	4
Nereis virens	5
Paraprionospio pinnata	8
Polydora ligni	1
Scoloplos fragilis	2

Total Taxa	12
Total organisms/3 samples (690 cm2)	151
Total organisms/m2 (extrapolated)	729

These data are similar to data from benthic samples from Western Long Island Sound published elsewhere (shown below). The 12 taxa found in approximately a 700 cm^2 sample are comparable to the ≈ 21 species per sample reported by EPA for the NY/NJ Harbor Estuary[2] . With 151 organisms per this sample area, however, the abundance, by extrapolation, is somewhat low for the Harbor Estuary, as indicated in the table below:

	Harbor	Jamaica Bay	Newark Bay	Lower Harbor	Upper Harbor	W. LI Sound	Bight Apex
Abundance (# of organisms/m^2	40,000	39,000	11,000	51,000	12,000	19,000	32,000
S.D.	14,000	15,000	4,700	22,000	3,600	7,400	8,200
Species Richness (#spec/sample)	19.2	17.7	14.1	20.6	17.1	20.6	28.9
S.D.	1.7	2.7	2.6	2.6	2.3	2.8	3.6
Pollution Sensitive Species (%)	13	3.6	0.3	18	6.8	8.1	50
S.D.	5.6	2	0.3	8.6	5.67	4.7	9.2
Pollution Indicative Species (%)	31	46	65	20	49	28	3
S.D.	3.5	8.4	7.1	5.O	6.3	8.3	1.O
Biomass (g/m^2)	31	10	5.4	50	56	22	29
S.D.	11	5.1	2	31	35	7.4	15
Species Diversity	2.3	2.1	2.1	2.4	2.5	2.4	2.3
(Shannon-Wiener) S.D.	0.17	0.2	0.3	0.26	0.15	0.29	0.23

Standard Deviation given as

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[2]Sediment Quality of the NY/NJ Harbor System: An Investigation under the Regional Environmental Monitoring and Assessment Program (R-EMAP). 1998. Adams, D.A., J.S. O'Connor, & S.B. Weisberg. EPA/ 902-R-98-001. March 1998. Table 6-2.

as +/- 90% confidence
interval

There are some differences between the sites sampled, with 16 taxa at the Watt Avenue southern terminus of the area, and 4 and 7 taxa along the southern and western faces of the landfill, respectively. Total taxa vary between 53 and 47, with the highest density collected due east of Watt Avenue. These results are presented below.

Site A. 150 Feet Due East of Watt Avenue

Crustacea:			
Amphipoda			
Ampelisca agassizi			16
Ampelisca vadorum			18
Melita nitida			2
Mollusca			
Bivalvia			
Spisula solidissima			2
Annelida			
Polychaeta			
Autolytus cornutus			1
Eteone heteropoda			4
Nereis virens			3
Paraprionospio pinnata			6
Scoloplos fragilis			1
polychaete fragments			7
	Total Taxa	16	
	Total organisms per 690 cm2 sample		53
	Abundance (organisms/m^2, extrapolated)		768

Site B. 200 Feet from Southern Face of Pelham Bay Landfill

Crustacea:			
Amphipoda			
Ampelisca vadorum			17
Amelisca agassizi			26
Melita nitida			3
Cumacea			
Leucon americanus			1
Annelida			
Polychaeta			
polychaete frags			7
	Total Taxa	4	
	Total organisms per 690 cm2 sample		47

Abundance (organisms/m^2, extrapolated) 681

Site C. 600 Feet North of Point & 200 Feet East of Pelham Bay Landfill

Crustacea:	
Amphipoda	
Ampelisca vadorum	43
Melita nitida	1
Mollusca	
Bivalvia	
Donax variabilis	1
Annelida	
Polychaeta	
Nereis virens	2
Parprionospio pinnata	2
Polydora ligni	1
Scoloplos fragilis	1
polychaete frags	6
Total Taxa	7
Total organisms per 690 cm^2 sample	51
Abundance (organisms/m^2, extrapolated)	739

In sum, while organisms were present in all of sediment samples collected in the area of the proposed confined containment facility (n = 8), the structure and behavior of these sediments indicates a very high silt/clay content as well as low bulk organics (i.e. very little to no visible detritus). The structure and behavior of these sediments are thus indicative of a very low energy regime.

Available evidence indicates that this area does not afford essential fish habitat for bottom dwelling organisms such as winter flounder, *Pseudopleuronectes americanus*.

<u>Change in circulation in Eastchester Bay.</u> While the Pelham Project plans to utilize hydrodynamic models to evaluate changes in circulation around the wave wall along the mouth of the Hutchinson River and Eastchester Bay, an initial look using standard analytical tools indicates that the structure will change circulation in Eastchester Bay as measured by Reynolds and Froude numbers.

At the north end of the Pelham Bay Landfill rock armor, where the Hutchinson River moves under the Shore Road Bridge, the ship channel and water flow is constrained to the south west by bedrock outcroppings. While the wave wall in this region will constrain the flow, the Reynolds number, $Re = lU/\mu$ (or discharge width times velocity divided by viscosity), the ratio of inertial to viscous forces, might only change by a factor of two to eight, since the river width would be reduced by half or less, leading to an increase in Re by a factor of 2, and most of the velocity of the river flows down the ship channel at present (because of the resistance of the bedrock at the channels edges), the wave wall might only increase this by a factor of 2, during normal flows. Storm flows may double this estimate. Within a few hundred yards from the mouth of the Hutchinson River, the width of Eastchester Bay increases to 300 and then 500 yards, so the constriction of the wave wall could amount to a velocity increase of about a third to a fifth, with much less effect on turbulence of the moving water mass than nearer to the bridge. This increased rate of river flow and tidal movement would, however, bring more oxygenated water into contact with the rocky intertidal and benthic habitat on the wave wall, increasing growth and development rates, as well as feeding rates by filter feeders which become associated with these structures.

At the southern end of the landfill and along the Southern Tier of Pelham Bay Park, the width of the wave wall falls to a fifth and less of the length and width of Eastchester Bay, contributing little to velocity changes in these areas of the Bay. A different key measure of estuaries is often used at this scale to evaluate changes in water movement, the Froude number, the ratio of inertial to gravitational forces, $F = V^2/gl$. Since l, the length term, is in the denominator here, as opposed to the Reynolds number where it is in the numerator, its increase or decrease has the opposite effect as in the Reynolds number. Since the contribution of the wave wall would be $\leq 1/5$ of the length and width of Eastchester Bay, it appears that circulation, as measured by the Froude number, would be affected by this construction in the range of about 20%. Specific scenarios would have to be evaluated, however, to predict what effects this may have on the flora and fauna of there area, which the Pelham Project aims to do with hydrodynamic modeling.

15. Analysis of circulation changes for Eastchester Bay are proceeding through standard steps. A first order approximation has already been generated, based on the evaluation of changes in the geometry of flow around a confined containment facility constructed around the Pelham Bay Landfill. This indicates that such constructions will have no significant impact on the circulation of Eastchester Bay. These results are based on a quantitative analysis using standard tools in fluid dynamics: the Reynolds and Froude numbers.

The Pelham Project will go further in this analysis (and already has, in performing a bathymetric and benthic survey, see below). To our knowledge, no baseline data presently exists on circulation in Eastchester Bay. The Pelham Project will need to generate this knowledge-base before comparative empirical studies can be initiated. Towards this end, the Pelham Project has already mapped the bathymetry of the sections of Eastchester Bay around the Pelham Bay Landfill and southern tier of Pelham Bay Park.

Circulation studies necessarily focus on the properties of flow. Specific measures of actual flow patterns and velocities are central to the research program of the Pelham Project, and these will be used in conjunction with fluid dynamics analyses to characterize flow. Systematic changes in Reynolds and Froude numbers will be investigated by calculating how these numbers change with changes in the scale of flow caused by construction of the stone dike, compared to the no-build alternative. These changes can then be used to chart changes in inertial compared to viscous and gravitational forces. These are basic indicators of the structure and behavior of fluid systems, intrinsic to scientific and engineering studies of fluids. Analyses for the following two zones are shown below:

a) Building a 300' wide containment facility in the constricted area of the Hutchinson River between the Shore Road Bridge to the spit of land at the western shore of the opening of Turtle Cove would decrease the width of the outlet by about one third. Decreasing the sectional area of the width of the water flow path by a third will increase the velocity by a factor of 1.5. Since the Reynolds number is proportional to the product of the characteristic dimension (depth) and the flow velocity, there will not be a significant change in the corresponding Reynolds number before and after construction. While it is quite common for the Reynolds number of a dynamic section of an estuary to vary over orders of magnitude, the structural change imposed by stone dike construction will have a low impact on the ratio of inertial to viscous forces at work in Eastchester Creek-Hutchinson River.

b) Opening of Eastchester Bay west and south of the Turtle Cove spit of land to Rodman's Neck, where width of the discharge of the Hutchinson River into Eastchester Bay increases from about 900' to 1,300', so the width, L, would change in proportion to the distance from the shore to the stone dike divided by the width of the Bay at that point, L, or 300'/900' to 300'/1300',- that is, from a quarter to about a third, constricting the channel and thus increasing velocity and the Reynolds number. The smaller coefficients in this downstream case would make this impact on the Reynolds number even smaller than that in the narrower section of the estuary discussed above.

Eastchester Bay Reynolds & Froude numbers

Reynolds number, the ratio of inertial to viscous forces, F = lV/v.
Froude number, the ratio of inertial to gravitational forces, F = V2/gl.

	kinematic viscosity	Length/depth characteristic dimension	velocity	Reynolds	
	m^2/s	m	m/s	number	
pre-construction	1.047E-06	3	0.01	28,653	
	1.047E-06	3	0.1	286,533	
	1.047E-06	3	1	2,865,330	
	1.047E-06	3	5	14,326,648	
post-construction, assuming an increase in velocity by a factor of three					
	1.047E-06	3	0.03	85,960	67%

	1.047E-06	3	0.3	859,599	67%
	1.047E-06	3	3	8,595,989	67%
	1.047E-06	3	15	42,979,943	67%

Shore Road to Rodmans Neck	gravitational constant m/s^2	width/ characteristic dimension m	velocity m/s	velocity squared m^2/s^2	Froude number (dimension-less)	% differ-ence
before	9.807	300	0.01	0.00	3.39893E-08	
	9.807	300	0.1	0.01	3.39893E-06	
	9.807	300	1	1.00	0.000339893	
	9.807	300	5	25.00	0.008497332	
after	9.807	200	0.01	0.00	5.0984E-08	33%
	9.807	200	0.1	0.01	5.0984E-06	33%
	9.807	200	1	1.00	0.00050984	33%
	9.807	200	5	25.00	0.012745998	33%
Rodmans Neck to southeast extent of the Pelham Bay Landfill						
before	9.807	600	0.01	0.00	1.69947E-08	
	9.807	600	0.1	0.01	1.69947E-06	
	9.807	600	1	1.00	0.000169947	
	9.807	600	5	25.00	0.004248666	% differ-ence
after	9.807	500	0.01	0.00	2.03936E-08	17%
	9.807	500	0.1	0.01	2.03936E-06	17%
	9.807	500	1	1.00	0.000203936	17%
	9.807	500	5	25.00	0.005098399	17%

The interaction of tidal currents with the boundary conditions, the confining borders of Eastchester Bay, determine and constrain a large number of physical, chemical, and ecological phenomena. One of the means for evaluating potential changes in behavior of Eastchester Bay due to the construction of a containment facility/salt marsh is to quantify any such modifications in terms of the Froude number, that is, the ratio of inertial to gravitational forces (F = V2/gl). Viewed as the distribution of momentum along the linear run of water movement, since widths will be decreased from the Shore Road Bridge to

Rodman's Neck by a quarter to a third. This constriction will, as noted above, increase velocity. It will have an even more pronounced effect on momentum, a function of the square of velocity. This is likely to increase the intensity of circulation in the nearshore area around the stone dike (see accompanying aerial photograph figure and spread sheet). Given the apparent low biodiversity and biomass (see benthic survey below) of this habitat at present, an increase in velocity gradients is likely to increase mass exchange between the water column and sediments, and, therefore, increase the diversity of benthic habitat types and, thus, secondary productivity and biodiversity. The Pelham Project will describe expected outcomes in the post-construction environment based on hydrodynamic changes. The relationship between these hydrodynamic changes and habitat diversity will also be detailed. Post-construction monitoring will evaluate these inferences.

<u>Scale of benthic habitat removal by the containment facility</u>. The containment facility design calls for a 2:1 base-to-height ratio. Since it is expected that the containment facility will be between 11 and 18 feet tall, each leg of this triangle will be between 22 and 36 feet. The total base length then, including both legs of the triangle will thus be between 44 and 72 feet. Since the landward half of this triangle will be filled with sediments, in this sector, the entire soft sedimentary benthic habitat will be covered. While a few to several percent of the other half of the rock armor structure may remain as soft sedimentary habitat, the use of this habitat by benthic suspension, sediment, and filter feeders will depend on how much oxygenated water moves into the water column above this sediment.

Pathways between the boulders will range from a few to several inches in diameter, with an average diameter of the open passages being around a third of a foot. Water current velocities and wave activity in the surrounding waters of Eastchester Bay should induce flow so that oxygenated water moves into the interstices between the rock armor blocks. While details of flow will partly depend on edge effects and the orientation of the rock armor to circulation and wave activity in Eastchester Bay, the rough surfaces provided by the rock armor should partition flow such that oxygenated water is moved one to several block diameters into the containment structure. Rock armor placement will be modeled, and its effects measured in order to explore how this effect may be maximized in the Pelham Project.

In the case of the eleven foot height structure, there will only be one layer of three to four blocks, on average, stacked one on top of another. In this case, it is expected that the only likely area of depressed oxygen will be next to the central core of the rock armor structure, extending about two to three rock diameters from the center in the case of the 11' X 22' configuration, and some three to five block diameters in the larger, 18' X 36' configuration (see Figure 4.).

The geometry of the rock armor described will displace the majority of soft benthic habitat with benthic rocky habitat. For the 11' high containment facility, total habitat area, however, will actually increase by a factor of four. This follows, since each boulder has a surface area of approximately 50 square feet, and the 4' X 4' sedimentary benthic habitat it rests on has a surface area of 16 square feet. About half of this surface area increase would be subtidal, and half intertidal, thus doubling the area of benthic habitat, while adding two times the benthic habitat area in intertidal rocky habitat. In the case of the 18' height structure, the effective, oxygenated surface area of the benthic subtidal and intertidal community would increase by a factor of 7 following similar assumptions, increasing rocky subtidal habitat by a factor of about 5, and creating about twice the displaced benthic area with rocky intertidal habitat. Actual effects will need to be measured, but a dramatic increase in benthic surface area is expected on geometric grounds.

<u>The Ratio of Restored and Created Benthic Habitat to Benthic Habitat Removed</u>. The planned containment facility/constructed marsh will be approximately 300 feet in width, from the shore to the center of the rock armor containment wall. For the sake of comparison, each four foot strip, comparable to the area under the rock armor blocks, will have an area of 4' X 300' or 1,200 square feet. The 22 foot length of rock armor extending into Eastchester Bay will contain a minimum of about 12 boulders, each with a surface area of 50 square feet, or 600 square feet total, about half of the total surface area removed under the corresponding 300' width. About half of the total area of soft benthic habitat covered under salt marsh would be created by the stone dike containment facility as subtidal rocky benthic habitat, and half as rocky intertidal habitat. In other words, the 11' X 22' configuration would increase habitat surface by about 40% while creating three habitat types: intertidal salt marsh; intertidal rocky habitat, and subtidal/benthic rocky habitat, as noted in the table below.

11' by 44' stone dike	existing sedimentary benthic habitat 4' by 22'	stone dike containment facility, (12) 4' diameter rock (4' by 22')	benthic area covered under 4' wide 300 ft. long containment facility	total habitat displaced under dike & containment facility	
Surface Area in square feet	88	603	1,200	1,288	
	created rocky benthic habitat	created rocky intertidal habitat	created salt marsh habitat	total habitat created	percentage of habitat increase with the 11' stone dike
Surface Area	302	302	1,200	1,803	40%

in square
feet

For the 18' high 36' length, about 30 boulders would add a surface area of 1,500 square feet, about 1,000 square feet of which would be subtidal, or about 80% of the benthic habitat displaced. As indicated in the table below, about 500 square feet of rocky intertidal would be added, about 30% of the area of the covered soft benthic habitat. Since the rocky subtidal and intertidal as well as marsh habitat were displaced by landfilling, the overall environmental impact of the proposed project would be to move the surface area and the diversity of the components of the system towards their historic pre disturbance ratios.

18' by 72' stone dike	existing sedimentary benthic habitat 4' by 36'	stone dike containment facility, (12) 4' diameter rock (4' by 22')	benthic area covered under 4' wide 300 ft. long containment facility	total habitat displaced under dike & containment facility	
Surface Area in square feet	144	1,508	1,200	1,344	
	created rocky benthic habitat	created rocky intertidal habitat	created salt marsh habitat	total habitat created	percentage of habitat increase with the 11' stone dike
Surface Area in square feet	1,005	503	1,200	2,708	101%

The environmental impact on the biota must also be addressed, since the kinds of habitat which remain today are very different from historic configurations, and also differ significantly from habitat known to support water quality enhancement and fisheries development. From maps of a hundred years ago, it is apparent that the Eastern Bronx was constituted by an archipelago of rocky islands, high energy intertidal and subtidal rocky habitat, and, leeward of these landforms, thousands of acres of depositional and soft sedimentary habitat of salt marsh and mudflat. Most of the rocky and salt marsh intertidal habitat has been removed (see Figure 5.). In addition, the construction of housing, lawns, and roadways has caused accelerated runoff which, with the coastal creeks, has been incorporated into stormwater infrastructure. Most of the tidal creeks have thus been turned into intermittent discharges carrying hydrocarbons, BOD, nitrogen, and suspended solids into Eastchester Bay. One of the aims of the Pelham project is to recreate these creeks by opening up these stormwater structures, allowing storage and treatment to groundwater and stormwater in ponds and creeks, delivering more constant flows of freshwater into Eastchester Bay, and recreating historic and essential fish habitat.

19. Stormwater presently enters Eastchester Bay along the eastern margin of the southern tier of Pelham Bay Park. At times, these discharges provide substantial volumes of water, but any non-point pollutants such as nitrogen and BOD are discharged without treatment into Eastchester Bay/Western Long Island Sound. Four discharges occur along the section of Pelham Bay Park along Eastchester Bay which provide opportunities for the restoration of three to ten acres of freshwater pond and wetland habitat.

As indicated in the accompanying figure, these ponds and wetlands would be created by redistributing fill along the margin and inland from Eastchester Bay. Much of the stormwater and walkway infrastructure in this section of the park is in a degraded condition which includes potentially serious liabilities for the City of New York. This would be repaired and replaced. Ecologically, these ponds and wetland habitats and fringes would increase biodiversity and ecological productivity, since much of the upland habitat which would be displaced by restored ecosystems is now occupied by mugwort, with some *Phragmites* . By redistributing between 15,000 and 50,000 cubic yards of material, these areas would be refurbished as wetland and pond habitat. From measured flow rates of a one to 10 plus cubic feet/second of stormwater and dry weather discharge, hydroperiod for treatment of this water would vary between about a day to a couple of hours.

Grading such freshwater ponds would be done to maximize fringing wet areas. Fine grading would include a diversity of submerged, emergent, and mesic habitat, as indicated in the plan below. Plantings would include species from the list below.

Plant List (adapted from NYCDPR/NRG): Stormwater Wetland, Pond & Creek Restoration-Pelham Bay Park

Dry
Mesophytic
Intermittent
Wet Shallow
Wet Deep

	Latin name	common name	D	M	I	WS	WD	soil type
	Deep Emergent Marsh							
Graminoids								
	Pontederia cordata	Pickerelweed				x		saturated
	Sagittaria latifolia	Arrowhead				x	x	saturated
	Shallow Emergent Marsh							
Ferns								soil type
	Onoclea sensibilis	Sensitive Fern			x	x		moist to wet
	Osmonda cinnamomea	Cinnamon fern			x	x		wet
	Osmonda regalis	Regal fern			x	x		wet
Graminoids								

	Andropogon virginicus	Broomsedge				x		sat-unsaturated
	Calamagrostis canadensis	Bluejoint			x	x		moist-wet
	Carex crinita	Crinkled sedge			x	x		wet-saturated
	Carex stricta	Tussock sedge				x		wet-saturated
	Deschampsis cespitosa	Tufted hairgrass				x		wet-saturated
	Juncus canadensis	Canada rush				x		wet-saturated
	Juncus effusus	Soft rush				x		wet-saturated
	Leersia oryzoides	Rice cutgrass		x	x	x		wet to dry
	Scirpus atrovirens	Black bulrush				x		wet-saturated
	Scirpus cyperinus	Woolgrass		x	x			wet-saturated
	Scirpus pungens	Common threesquare		x	x	x		wet-saturated
	Scirpus validus	Great bulrush				x	x	saturated
Forbs								
	Asclepias incarnata	Swamp milkweed		x	x			wet-saturated. ave. fert.
	Aster novae-angliae	New England aster		x	x			well drained to sat
	Aster novi-belgii	New York aster			x	x		tolerates satur-brackish
	Caltha palustris	Marsh marigold		x	x			wet, tol satur
	Chelone glabra	Turtlehead			x	x		requires saturation
	Eupatorium maculatum	Spotted Joe-Pye weed		x	x			tolerates saturation
	Eupatorium perfoliatum	Boneset		x	x			tolerates saturation
	Hyelenium autumnale	Common snezeweed		x	x			tolerates saturation, req. organics
	Helianthus angustifolius	Swamp sunflower		x	x			tolerates saturation
	Helianthus giganteus	Giant sunflower		x	x			
	Hibiscus moscheutos	Rose-mallow	x	x				pond edge
	Iris versicolor	Blue flag				x		
	Liatris spicata	blazing star			x	x		well drained, rich
	Lobelia cardinalis	Cardinal flower		x	x			organic
	Lobelia siphilitica	Great lobelia	x	x				
	Pontederia cordata	Pickerelweed				x	x	
	Sagittaria latifolia	Arrowhead			x	x		pond edge
	Tradescantia virginiana	Spiderwort		x	x			pref rich humus
	Veronia noveboracensis	New York ironweed		x	x			tolerates saturation
	Meadow edge/shallow emergent marsh							
Ferns								soil type
	Athyrium filix-femina	Lady fern		x	x			rich, variety
	Onoclea sensibilis	Sensitive Fern			x	x		moist to wet
Forbs								
	Eupatorium purpureum	Purple Joe-Pye weed		x	x			any
	Helianthus giganteus	Giant sunflower		x	x			
	Monarda didyma	Oswego tea		x				fertile, muched, composted

Pond sites will be surveyed with ground penetrating radar to identify areas of fill and saturated zones in the substratum. A global positioning system and surveying equipment will be utilized optimize aerial extent and minimize damage to existing vegetation. These methods, together with core samples, will be utilized to integrate this freshwater pond, wetland, and creek construction with on-site wetlands already established by NYC DPR. The Pelham Project team will analyze width, depth, length, and head of these creeks to minimize sediment transport to maintain habitat in the freshwater and tidal sections of these restored creeks.

Potential Erosion of Dredged Sediments from the Containment Facility. Placing dredging within the containment facility to a level near the average mid-tide mark is likely to lead to the formation of creek-forms through the marsh. While there is an apparent threat of erosion, the placement of sand, gravels, and shells in these areas will minimize this activity. Creek formation itself, and the ecological and biotic components of this process, provides an opportunity to utilize the structure of the salt marsh and the biota of the creek bottom to increase productivity and thus stabilize these hydrodynamic structures and prevent. By introducing ribbed and black mussels connected to Spartina *alterniflora* wind throws in a few areas along the creek edge, the aim is to provide larval stages of these organisms with maximal access to colonization of creek edges and the bases of emerging *Spartina* stems (Bertness & Ellison 1987; Bertness 1992). Along similar lines, oyster reefs have been found to be stabilizing structures in creek formation and behavior (Keck et. al. 1973; Dame 1987). To attain these structures as early as possible in the development of this system, oysters and shells, which are attractors for spat, oyster larval settlement, will be placed in the creeks as they are developing.

20. As stated in the DEIS Technical Appendix, the aim of the Pelham Project is to create habitat which sustains the growth and development of those components of the biota which act to stabilize sediments against perturbations. The performance criteria for planting success include coverage and survival. Together these are good predictors of resistance to storm driven wave disturbance and other perturbations. Marshes of substantial scale, where the flow of tidal exchange is organized into creek forms, demonstrate unique features of sediment stabilization. As noted in the DEIS Technical Appendix (p 17), velocity gradient of differing scalar values are regulated by different structures with these systems: low velocity flows in the ten centimeters per second range are regulated by Spartina stems plus mussel beds knit together with roots and byssal strands at the creek edges. Creek beds where flow velocities achieve tens of centimeters per second are regulated and stabilized by oyster beds and reef development. As noted in the Technical Appendix, these structures appear in conjunction with the higher current velocity zones on the concave side of creek bends. Since the forces of physics will propagate the bends of creeks and creek beds through new sediment banks[3], physical forces, by themselves, run counter to regulatory intent in terms of the stabilization of sediments in containment facilities. As pointed out in the Technical Appendix, since creek edge cord grass, mussel bed, and oyster reef development together act to both

[3]Dingman, SL. Fluvial Hydrology. 1984. WH Freeman, NY. pp 133-179.

decrease scour and distribute tidal and storm surge forces in a manner which maximizes filtration and sediment bed stability, the development of these systems is commensurate with the best management of dredged sediment stabilization, and noted in the Response to Comments of NYC DEP on the public notice section of the DEIS (pp 14-15).

As noted in the SEQR EIS (p 7), oyster beds have returned to much of the area around Eastchester Bay, expanding from long-standing populations in Pelham Bay Lagoon (T. Kazimiroff, per comm.), to presently occupying areas along the shores Eastchester Bay, Palmer Inlet, Weir, Westchester, and Pugsley Creeks (PSM, per. observ). Patches of these organisms stabilizing dredged sediments, together with already widespread mussel beds, will add about 1% or less to the area of extant 'attractive nuisance' distributions of these organisms. On the other hand, the Pelham Project would distribute information and produce signage on how mussel beds and oyster beds and reefs may play a large role in increasing biodiversity, acting as refugia for larval and juvenile fish and invertebrates, as well as nitrogen removal and protection from hypoxia. Thus habitat recreation and restoration can allow for the redevelopment of interacting species guilds which the public, through the development of a citizens watchdog and monitoring program, will find it worth their while to protect. As noted below, this one step would increase the level of surveillance and protection of shellfish beds many-fold. The program at once serves as a means for increasing public health protection by stabilizing dredged sediment, researching and informing the public of health risks and protections associated with local shellfish, and empowering citizens groups to enforce the protection of shellfish in closed beds. With only two state enforcement officers presently available to make such observations and enforcements, this program would immediately increase the protection of the citizens of New York some several to a hundred times or more, based on the number of observations of suspicious activities around closed shellfish beds. This could be achieved with a minimal or negligible increase in attractive nuisance shellfish beds in the western Sound.

<u>Environmental Impact of Restored Marsh in Terms of Nitrogen, Carbon, Hydrocarbons, Pathogens, & Metals Removal</u>. The thirty acre marsh restoration on fine grained sediments from Royal Marina and other nearby marinas and channels encompassed by this whole plan is expected to have beneficial effects on nitrogen and carbon balance of Eastchester Bay. Although pollutant uptake by salt marshes is partitioned between the sediments and the living plant material, the majority of pollutants, particularly metals, are sequestered by the sediments themselves, and not the plant matter, and hence would not be re-released as vegetation decays during winter, with exceptions noted below. Quantifying the fates of these pollutants throughout the seasons, however, will be a major thrust of research associated with this project.

In brief, established saltmarsh environments can break down, remove or sequester pollutants, nutrients or pathogens in substantial quantities. While a lag in the development of removal capacity is to be expected, the literatures on saltmarsh and constructed fresh water wetlands point towards specific ranges which can be expected in constructed saltmarshes around the Pelham Bay Landfill. Commonly available materials like the simpler carbon sources characterized as BOD should be broken down in the tons to tens of tons per acre per year range. Simple hydrocarbons are expected to be mineralized at rates in the hundreds of pounds per acre per year. More complicated ring compounds are broken down at lower rates, in tens of pounds to parts of a pound per acre per year. Nitrate, which plays the role of a terminal electron acceptor in saltmarsh sediments, can be converted to nitrogen gas and removed from the water column at rates in the tens of pounds per acre per year. Other mechanisms of nitrogen removal can operate at or above this rate, but their variability in published work to date will require further study in the course of the Pelham Project. Metals, specifically cadmium, chromium, zinc, lead, and nickel, in the tens or parts per billion range are reduced by an order of magnitude and sequestered in marsh sediments. Higher loadings are more variable in their behavior. Pathogens in constructed freshwater wetlands are reduced by about two orders of magnitude when influent sources contain hundreds of thousands to tens of millions of bacteria per 100 ml. Evidence from studies on saltmarsh filter feeders suggests that this may be a low estimate for these environments when where mussels, oysters and clams achieve about a 1% coverage of surface marsh area. These estimates are documented below.