Environmental Assessment
Appendix B:
Water Resources, Shoaling, Coastal Erosion

U.S. Army Corps of Engineers
New York District

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NEW YORK AND NEW JERSEY HARBOR DEEPENING PROJECT

HYDRODYNAMIC AND WATER QUALITY MODELING AND SEDIMENT TRANSPORT AND COASTAL EROSION EVALUATION

January 2004

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INTRODUCTION

B1.1 Hydrodynamic and water quality changes due to unconsolidated implementation of the Harbor Deepening Project (HDP) were documented in the *New York and New Jersey Harbor Navigation Study Feasibility Report – December 1999* (the Feasibility Report)[1]. Specifically, a three-dimensional (3D) model of NYNJ Harbor and surrounding waters was developed and used to evaluate changes in hydrodynamic and water quality dynamics under With (i.e., the Recommended Plan) and Without (i.e., authorized projects as of 1999) Project conditions. This model was developed by the *New York/New Jersey Harbor Partnership* (A Joint Venture of Moffatt & Nichol Engineers, Inc. and Lawler, Matusky and Skelly Engineers, LLP) for the New York and New Jersey Harbor Deepening Study[2]. The modeling scenario was developed on the basis that the separately authorized navigation improvement projects[3] (Predecessor Projects) would all be completed before deepening to 50 feet would begin.

B1.2 The US Army Corps of Engineers (USACE) New York District (NYD) has identified opportunities to increase efficiency of the ongoing deepening projects by consolidating vertical deepening in several locations (see details below). These locations would be deepened directly to 50 feet MLLW from existing depths. Therefore, alternatives considered in this study are the Without Project (i.e., No Action) and With Project (i.e., Proposed Action) alternatives.

B1.3 Because the final channel configuration and depths for the With and Without Project Conditions are the same, no long-term impacts are associated with the Proposed Action. The With Project Condition, however, may lead short-term impacts in the isolated areas of vertical consolidation (and other adjacent areas) during the interim condition when only those areas will be deepened to 50 feet. The purpose of the present study is to evaluate these short-term effects on hydraulics, salinity, temperature, and Dissolved Oxygen (DO) in the harbor until the 50-foot project is completed. In addition, a sediment transport evaluation with particular regard to shoaling rates changes in the vertically consolidated areas is presented.

B1.4 Short-term impacts attributable to the proposed consolidated implementation were only investigated for vertical consolidation efforts. No hydrodynamic, water quality or shoaling impacts are expected for horizontal consolidation efforts as these efforts affect the administration, procurement, contracting and sequencing of contract areas for the authorized project.

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[1] U.S. Army Corps of Engineers, *New York and New Jersey Harbor Navigation Study Feasibility Report*, (December, 1999). Hereinafter the shorthand reference "*Feasibility Report*" will be used to refer to this document and "Recommended Plan" to refer to the plan recommended in the *Feasibility Report* with the modifications that have occurred since the 1999 release of the *Feasibility Report*.

[2] Hereinafter the 3D model will be referred to as the Harbor Partnership Model (**HPM3D**).

[3] Specifically, the Arthur Kill Channel, Howland Hook Marine Terminal, New York and New Jersey; the Kill Van Kull and Newark Bay Channels, New York and New Jersey; and the New York and Adjacent Channels, Port Jersey Channel, New Jersey. They are designated AK-41/40, KVK/NB-45, and PJ-41, respectively, and hereinafter referred collectively to as the "Predecessor Projects". They are Predecessor Projects in the sense that their complete implementation was assumed as part of the most likely without-project future condition for the New York and New Jersey Harbor Deepening Study.

B1.5 This evaluation considers vertical deepening in three possible areas: Port Jersey Area 2b (PJ 2b) deepened directly from 12 ft to 50 ft; Kill van Kull Area 4b (KVK 4b) deepened directly from 40ft to 50ft; and Kill van Kull Area 5 (KVK 5) deepened under a separate authorization by the Port Authority of New York and New Jersey to obtain a 50ft depth prior to the surrounding areas.

B1.6 The purpose of the present study is to model the short-term impacts of consolidation implementation on salinity, temperature and DO, and compare those effects to the levels predicted for the completed 50ft harbor conditions. To that end, two modeling scenarios were constructed to represent the interim depths during completion of the vertical consolidation plan (With Project Condition) and the completed New York and New Jersey Harbor Deepening Project (Without Project Condition). Model depths for each scenario by project reach are listed in Table B0-1.

Table B0-1: Channel Depths With and Without Project Alternatives

	With Project Condition	Without Project Condition
Channel	Interim Consolidated Project Depths (MLLW)	Completed HDP 50 ft. Project Depths (MLLW)
Ambrose Channel	45 ft	53 ft
Anchorage Channel	45 ft	50 ft
Bay Ridge Channel	40 ft	50 ft
Port Jersey		
Area 1	41 ft	50 ft
Area 2a	41 ft	50 ft
Area 2b*	**50 ft**	**50 ft**
Kill van Kull/Newark Bay		
Area 1	45 ft	50 ft
Area 2	45 ft	50 ft
Area 3	45 ft	50 ft
Area 4a	45 ft	50 ft
Area 4b*	**50 ft**	**50 ft**
Area 5*	**50 ft**	**50 ft**
Area 6	45 ft	50 ft
Area 7	45 ft	50 ft
Area 8	45 ft	50 ft
Arthur Kill		
Area 1	41 ft	50 ft
Area 2	41 ft	50 ft
Area 3	41 ft	50 ft
Area 4	40 ft	40 ft
Area 5	40 ft	40 ft
(*)indicates possible consolidated dredging areas considered in model		

B2 HYDRODYNAMIC AND WATER QUALITY MODELING

B2.1 The impacts of the Proposed Action on salinity, temperature, and dissolved oxygen in the harbor were assessed using HPM3D. This model was developed using MIKE3, a general 3D modeling system developed by the Danish Hydraulic Institute for a wide range of applications in oceans, coastal regions, estuaries, and lakes. The model simulates unsteady three-dimensional (3D) flows and accounts for bathymetric variations, density variations, as well as external forcing variables such as meteorology, tidal elevations, currents and other hydrographical conditions.

B2.2 The governing equations for MIKE 3 are the mass conservation equation, the Reynolds-averaged Navier-Stokes equations (including the effects of turbulence and variable density), and the conservation equations for salinity and temperature. The equation of state for seawater relates the local density to salinity, temperature and pressure. In addition the model solves the chemical and biological interactions between BOD nutrients, and bacteria that govern the concentrations of DO in the water. MIKE3 includes nested orthogonal grids, a bottom resolving (bottom-fitted) coordinate system, a mixed Smagorinsky/k-e turbulence model-closure model, wind-forcing, and time-dependent point source input. Spatial discretization within the model is based on the finite-difference technique.

B2.3 HPM3D includes New York Bight, Eastern Long Island and New York Bay, as well as the Hudson, Passaic, and Hackensack Rivers. A nested model was employed in order to accurately capture bathymetry and provide a detailed hydrodynamic and water quality description in NYNJ Harbor and the navigation channels. The nesting scheme allows model resolution to vary from a grid spacing of 2025 m in NY Bight to 75 m in the NYNJ Harbor channels. The model grid is illustrated in Figure B2-1.

B2.4 HPM3D was calibrated and validated with field data collected in 1991 and 1995, respectively. These data consist of measured elevations, currents, and water quality parameters at a number of locations within the project area. Results of these calibration and validation tests indicate that the model results reasonably match measured hydrodynamic and water quality measurements for both low-flow and high-flow freshwater conditions.

B2.5 A detailed model description, including governing equations, hydrodynamic and water quality parameters, sensitivity analysis, and calibration/verification results is included in the NYNJ Harbor Navigation Study Hydrodynamic and Water Quality Modeling report (USACE, 1999).

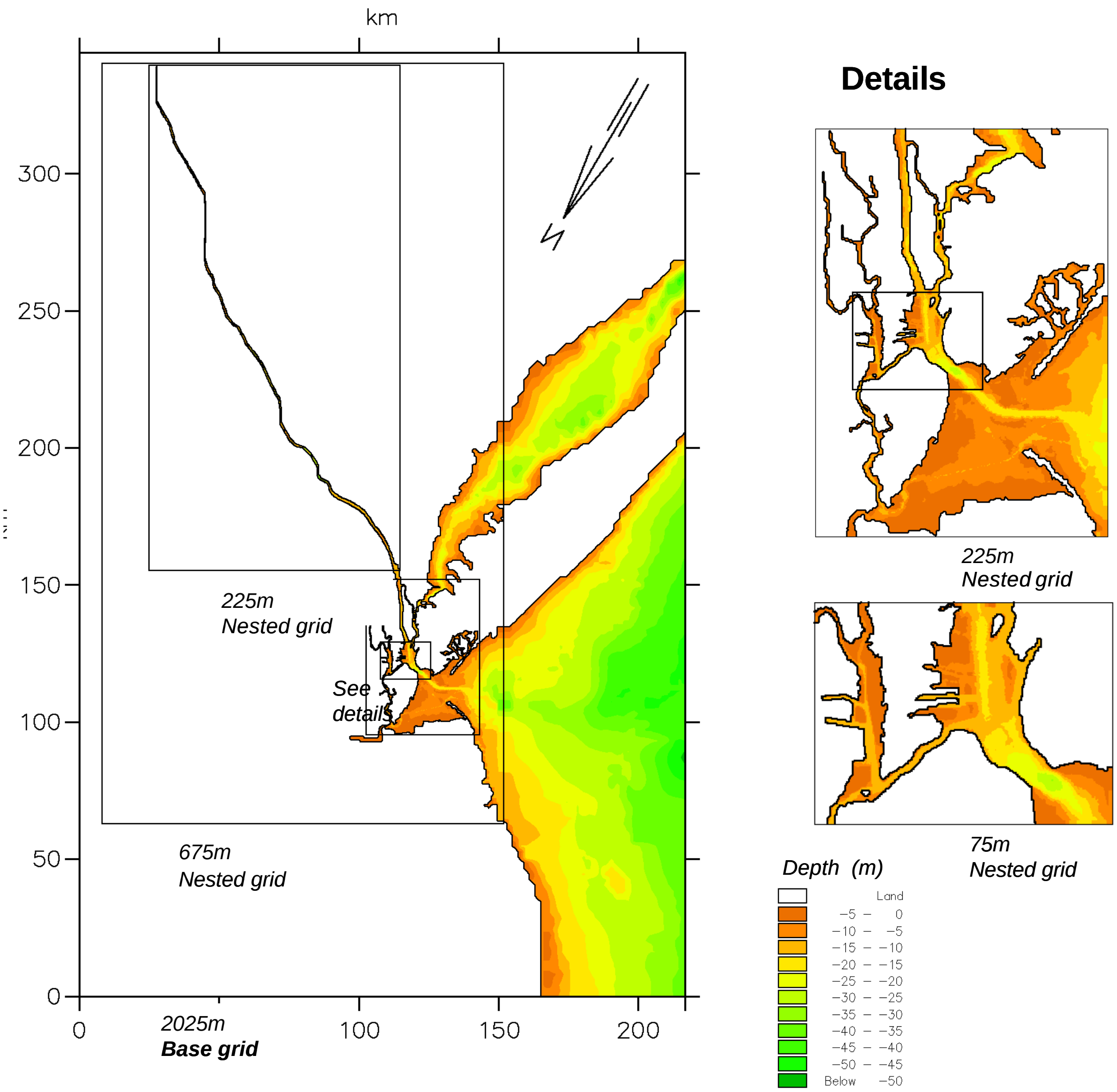

Figure B2-1 HPM3D Bathymetry and Grid Nesting in NY

LOW FRESHWATER FLOW SIMULATION

B2.6 The impacts of the consolidation project were evaluated under critical water quality conditions: high salinity concentrations, high temperatures, and low levels of dissolved oxygen. These conditions typically occur during late summer months when there is low freshwater flow and water temperatures reach their annual peak. Low flow conditions for evaluating the consolidation scenario are based on the "30Q10" criteria. The 30Q10 is defined as the lowest 30-day average flow that occurs on average once every 10 years. The 30Q10 low flow condition is commonly used by the EPA to define a critical low flow condition for evaluating effluent discharges when available water for dilution is at a minimum.

B2.7 The streamflow records for the Hudson River at Green Island, just north of the dam at Troy, run from 1947-2001. Table B2-1 displays, the annual minimum 30-day average flow rates. Based on these values a 10-year (10%) exceedance level was computed, resulting in a 30Q10 of 3400 cfs.

Table B2-1: Annual Minimum 30-day Average Flow Rate at Hudson River

Year	Flow (cfs)	Year	Flow (cfs)	Year	Flow (cfs)	Year	Flow (cfs)
1947	5087	1962	3346	1977	5020	1992	5097
1948	3861	1963	3724	1978	4500	1993	4607
1949	3464	1964	2811	1979	4402	1994	5533
1950	4776	1965	2655	1980	4042	1995	2773
1951	5587	1966	3421	1981	4050	1996	3673
1952	5080	1967	4934	1982	4005	1997	4380
1953	3924	1968	4129	1983	4253	2001	3453
1954	4297	1969	4079	1984	4520		
1955	4207	1970	3859	1985	3521		
1956	4704	1971	5590	1986	6129		
1957	3539	1972	6224	1987	3916		
1958	3997	1973	4033	1988	3463		
1959	3712	1974	4744	1989	5037		
1960	4041	1975	7260	1990	5130		
1961	3745	1976	9136	1991	3909		

B2.8 For this study, the 30Q10 model scenario was developed based on freshwater discharge records from a 30-day period from the historical record with an average Hudson River discharge similar to the computed 30Q10 flow.

B2.9 The 2001 minimum 30-day average flow of 3453 cfs closely approximates this value. This minimum 30-day average occurred between 20 August and 19 September. To model the 30Q10 condition, measured 2001 discharges for each river during this period were applied. If data for a specific river was unavailable, flow rates were scaled proportionately to a nearby river based on historical streamflow records.

B2.10 A 30-day spin up period was simulated to establish initial salinity and water quality conditions in model. The overall simulation of the low flow event therefore covers the period 20 July 2001 – 19 September 2001, 60 days total. The first 30-day period is used to diminish any potential effects of initial conditions. The second 30-day (from 20 August to 19 September2001) period is used to compare individual alternatives.

B2.11 Contour plots comparing parameter concentrations for the interim consolidated condition (With Project) and the completed New York and New Jersey Harbor Deepening Project condition (Without Project) are presented in figures B2-2 to B2-7. Contours were generated by averaging the parameter (salinity, temperature, and DO) over a 24-hour period, thereby comparing changes in average daily concentration. While model evaluations considered potential consolidated deepening at both Port Jersey (Area 2b) and in the Kill Van Kull (Area 4b/5), model results from these two areas may be considered independently.

CHANGES IN SALINITY

B2.12 Figures B2-2 and B2-3 show surface and bottom contours of salinity concentration averaged over the 24-hour period with the highest salinity levels in Newark Bay during the simulation, 14 September to 15 September 2003. However, it should be noted that the relative differences in salinity concentration between the two scenario runs remain essentially unchanged, regardless of the 24-hour period selected for analysis. Each figure shows contours for the interim consolidated condition and for the completed Recommended Plan. Table B2-2 presents the maximum 24-hr average modeled salinity concentrations at the vertical consolidation areas.

Table B2-2: Changes Maximum Daily Average Salinity Concentrations

	Surface Salinity (PSU[4]))		Bottom Salinity (PSU)	
	Interim Consolidated	Completed HDP 50 ft.	Interim Consolidated	Completed HDP 50 ft.
PJ Area 2b	25.3	25.4	28.7	29.4
KVK Area 4b/5	24.3	24.7	25.1	25.6

B2.13 **Surface Changes:** Figure B2-2 and Table B2-3 indicate that surface salinity intrusion in the harbor is no greater under the interim consolidated condition than under the completed New York and New Jersey Harbor Deepening Project condition. In the two areas of vertical consolidation, surface salinity is no higher under the consolidated implementation.

B2.14 **Bottom Changes:** Figure B2-3 and Table B2-2 indicate that bottom (i.e., seabed) salinity intrusion in the harbor is no greater under the interim consolidated condition than under the completed project New York and New Jersey Harbor Deepening Project. More importantly, in the two areas of vertical consolidation, bottom salinity is no higher under the consolidated implementation scenario.

[4] PSU stands for Practical Salinity Units

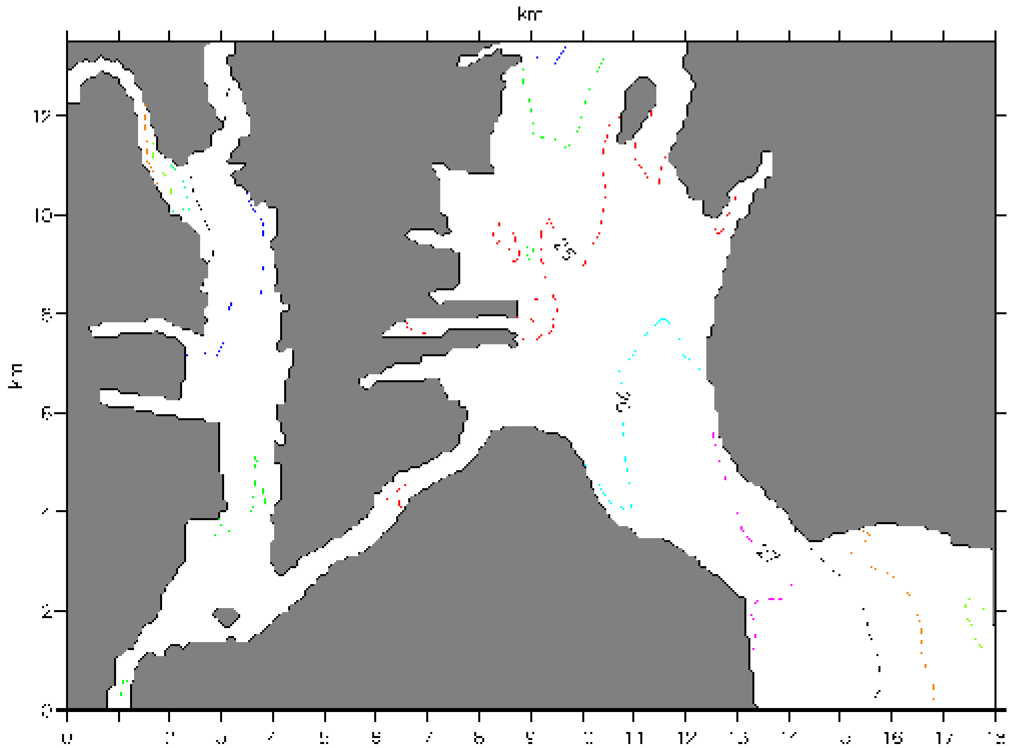

Figure B2-2 Surface Salinity (PSU): Interim Consolidated (solid) vs Completed Project (dashed)

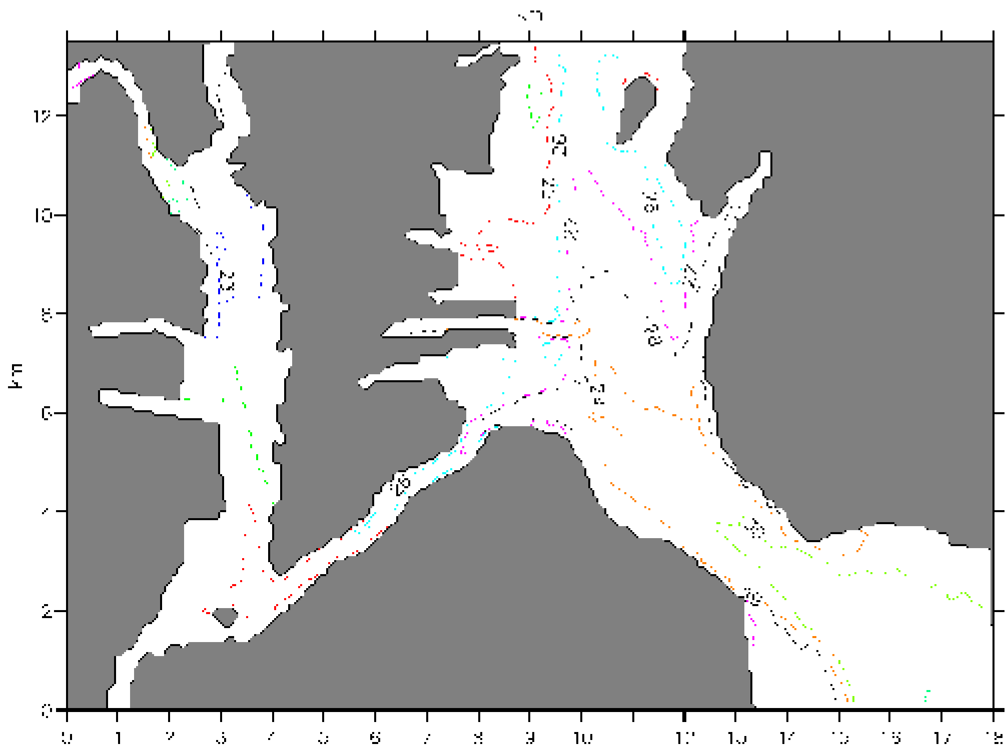

Figure B2-3 Bottom Salinity (PSU): Interim Consolidated (solid) vs Completed Project (dashed)

CHANGES IN TEMPERATURE

B2.15 Figures B2-4 and B2-5 show surface and bottom contours of temperature averaged over the 24-hour period, 14 September to 15 September 2003. Daily mean temperatures were declining throughout the simulation period; therefore the 24-hour period chosen for comparison coincides with the period of highest average salinity. However, the relative differences in temperature between the two scenario runs remain essentially unchanged, regardless of the 24-hour period selected for analysis. Each figure shows contours for the interim consolidated condition and for the completed New York and New Jersey Harbor Deepening Project condition. Table B2-3 presents the relative differences in temperature at the vertical consolidation areas.

Table B2-3: Changes in Daily Averaged Temperatures

	Surface Temperature (°C)		Bottom Temperature (°C)	
	Interim Consolidated	Completed HDP 50 ft.	Interim Consolidated	Completed HDP 50 ft.
PJ Area 2b	23.7	23.7	23.5	23.4
KVK Area 4b/5	23.8	23.8	23.9	23.9

B2.16 **Surface Changes:** Figure B2-4 shows that surface temperature in the Upper New York Harbor is lower under the completed New York and New Jersey Harbor Deepening Project condition than under the interim consolidated conditions, due to a deeper channel connecting to naturally deep water in the completed project condition. However, in the consolidated areas model results presented in Table B2-3 indicate that there is virtually no difference in surface temperatures between the two scenarios.

B2.17 **Bottom Changes:** Figure B2-5 shows that bottom temperature in Upper New York Harbor is lower under the completed New York and New Jersey Harbor Deepening Project condition than under the interim consolidated conditions, due to the a deeper channel connecting to naturally deep water in the completed H50 project condition, but over most of the model domain temperatures are the same. Table B2-3 indicates that the consolidated areas there is virtually no difference in bottom temperatures between the two scenarios.

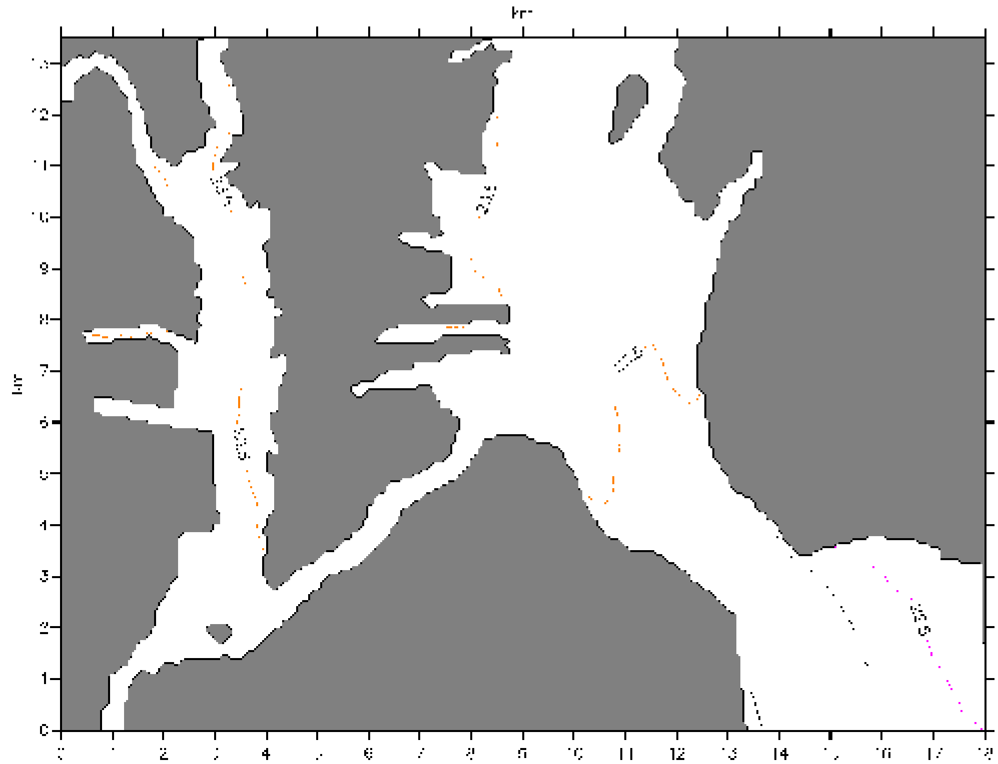

Figure B2-4 Surface Temperature (°C): Interim Consolidated (solid) vs Completed Project (dashed)

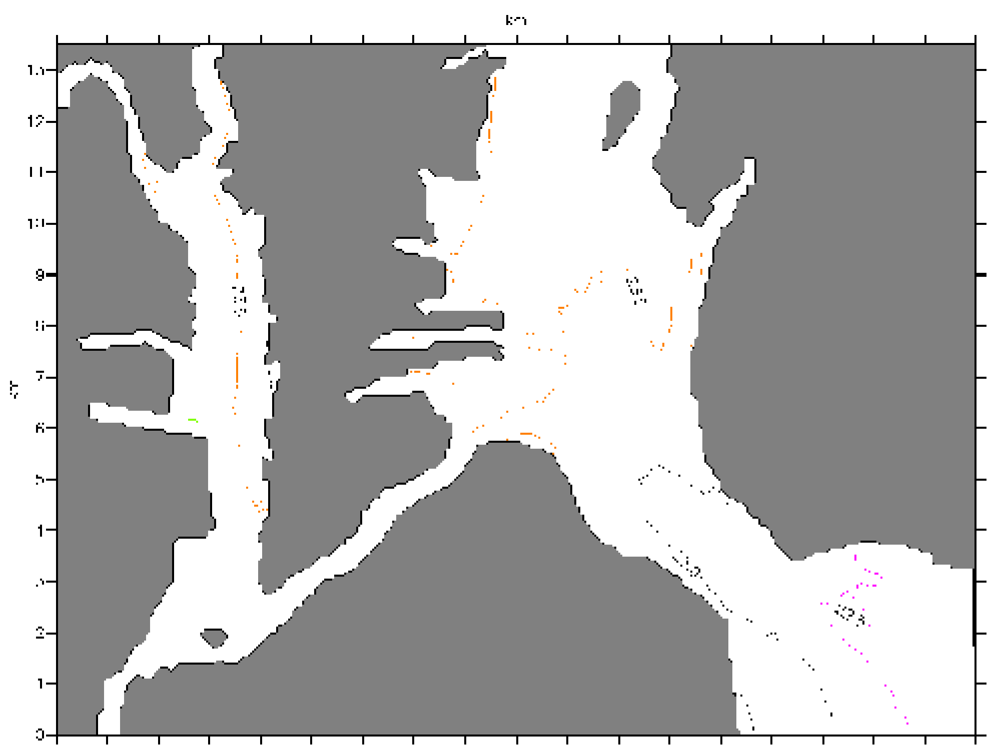

Figure B2-5 Bottom Temperature (°C): Interim Consolidated (solid) vs Completed Project (dashed)

CHANGES DISSOLVED OXYGEN

B2.18 Figures B2-6 and B2-7 show surface and bottom contours of Dissolved Oxygen (DO) concentration averaged over the 24-hour period with the lowest DO levels in Newark Bay during the simulations, 24 August to 25 August 2003. Each figure shows contours for the interim consolidated condition and for the completed New York and New Jersey Harbor Deepening Project condition. Table B2-4 presents the minimum 24-hr average modeled DO concentrations at the vertical consolidation areas.

Table B2-4: Changes Minimum Daily Average DO Concentrations

	Surface DO (mg/L)		Bottom DO (mg/L)	
	Interim Consolidated	Completed HDP 50 ft.	Interim Consolidated	Completed HDP 50 ft.
PJ Area 2b	4.46	4.47	4.66	4.56
KVK Area 4b/5	4.26	4.30	4.17	4.21

B2.19 **Surface Changes:** Figure B2-6 shows that generally surface DO concentrations are no lower under the interim consolidated condition than under the completed HDP 50 FT. project. In the vertically consolidated Port Jersey Area 2b, the DO concentrations under the interim consolidated condition are virtually the same as the no project condition. In KVK Area 4b/5, the modeled surface DO concentrations in the interim consolidated condition are 0.04 mg/L lower (0.9%) than under the completed New York and New Jersey Harbor Deepening Project condition.

B2.20 **Bottom Changes:** Figure B2-7 shows that generally bottom DO concentrations are no lower under the interim consolidated condition than under the completed HDP 50 FT.. In the vertically consolidated Port Jersey Area 2b, the DO concentrations under the interim consolidated condition are higher than under the completed New York and New Jersey Harbor Deepening Project condition. In KVK Area 4b/5, the modeled bottom DO concentrations in the interim consolidated condition are 0.04 mg/L lower (0.9%) than HDP 50 FT..

CONCLUSIONS

B2.21 HPM3D model results indicate that salinity and temperature conditions for the consolidated project are no worse or very similar to conditions for the completed New York and New Jersey Harbor Deepening Project condition. Only DO concentrations in the vertically consolidated area of the KVK are slightly lower for the interim consolidated condition, though the difference is equivalent to only 0.9% of ambient DO concentration during the 30Q10 design event. This reduction is also limited to the immediate vicinity of the deepened channel bottom and no effects are observed elsewhere in the harbor. More importantly, the difference is short-term and when the surrounding channels are deepened to the authorized 50ft depth, the DO concentrations will increase to completed under the completed New York and New Jersey Harbor Deepening Project condition.

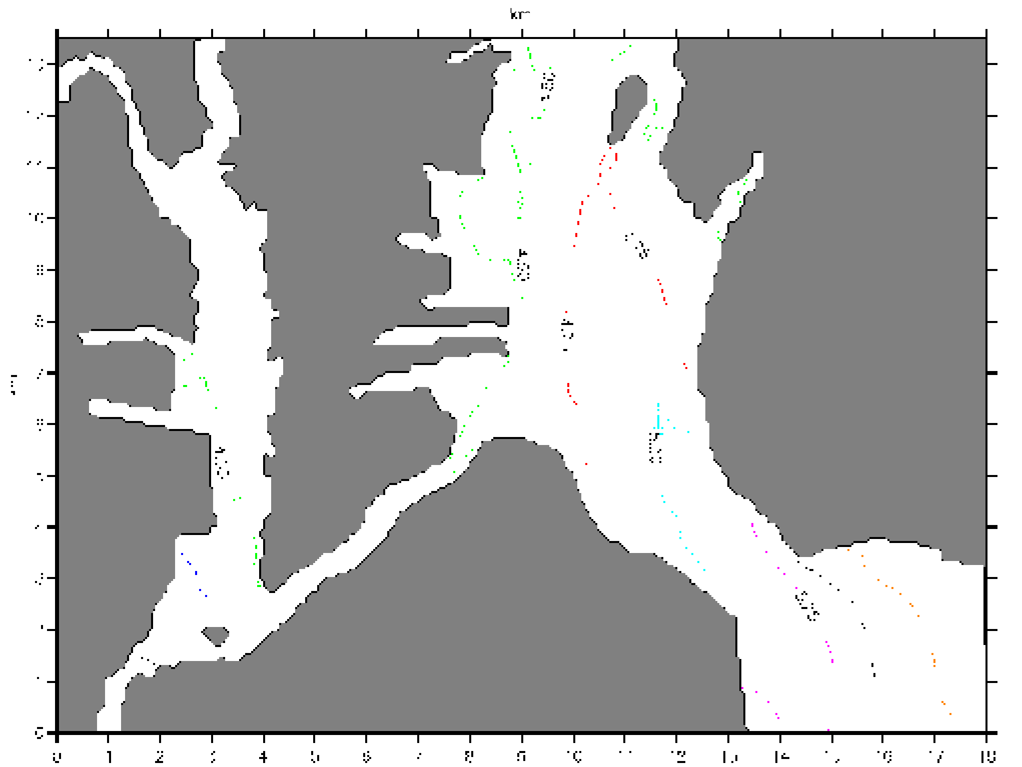

Figure B2-6 Surface DO (mg/L): Interim Consolidated (solid) vs Completed HDP 50 FT. (dashed)

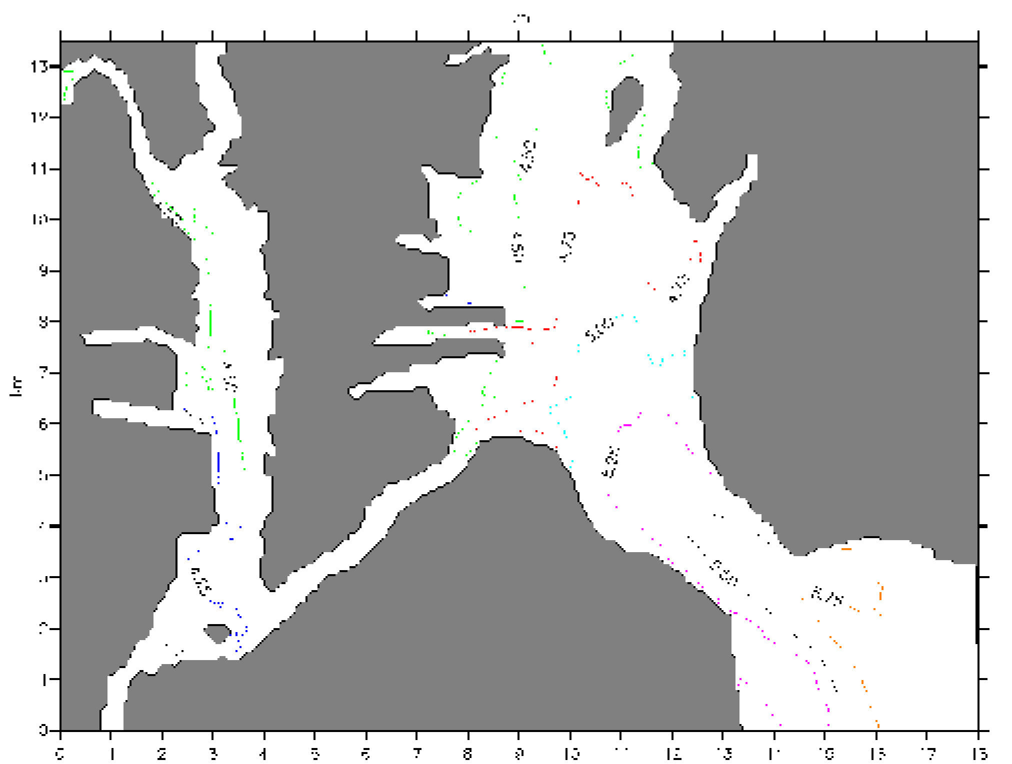

Figure B2-7 Bottom DO (mg/L): Interim Consolidated (solid) vs Completed HDP 50 FT. (dashed)

B3 SEDIMENT TRANSPORT EVALUATION – SHOALING

B3.1 The sedimentation impacts of unconsolidated implementation of the New York and New Jersey Harbor Deepening Project were documented in the *New York and New Jersey Harbor Navigation Study Feasibility Report, (December 1999*). Specifically, the Waterways Experiment Station (WES) developed a hydrodynamic and sediment transport model and used it to assess overall changes in sediment transport and channel shoaling conditions in the harbor under With and Without Project conditions.

B3.2 Consolidated implementation of New York and New Jersey Harbor Deepening Project (i.e., With Project condition) would change the timing of channel deepening, but not the final configuration of channels; therefore, no differences in sedimentation patterns leading to changes in channel shoaling rates and maintenance requirements are expected between Without (i.e., unconsolidated implementation of the New York and New Jersey Harbor Deepening Project) and With Project conditions. In the other words, long-term channel shoaling rates and maintenance requirements will not be affected by the consolidated implementation of the New York and New Jersey Harbor Deepening Project.

B3.3 Nonetheless, the short-term effects of the interim consolidated condition on shoaling rates in the harbor were investigated, particularly where vertical consolidation will lead to relatively small channel areas that are deeper than adjacent channels. These areas include Port Jersey (Area 2b) and the Kill Van Kull (Areas 4b and 5).

OVERVIEW OF EXISTING SEDIMENT TRANSPORT PROCESSES

B3.4 Fine Holocene sediments are typically responsible for most of the shoaling an attendant channel maintenance requirements in the harbor. These sediments consist of recent shore and marsh deposits, fine-grained wind-blown sand, silt, and artificial fill. The recent shore and marsh deposits that also blanket many areas of Harbor bottom consist of fine-grained sand and organic clay. Areas of artificial fill exist in areas around the Harbor (e.g., the western shoreline in Elizabeth).

B3.5 Bottom sediment characteristics and attendant erosion and sedimentation patterns vary throughout the harbor. The near surface stratigraphy in the study can be generally grouped into three major units: Bedrock, Pleistocene Sediments and Holocene (i.e., recent) Sediments (USACE, 1999). The aerial extent and thickness of these units are significant factors to be considered in the assessment of sediment transport processes. Bottom channel areas where Pleistocene and Holocene sand/gravel are exposed at the surface, and particularly areas where Bedrock is exposed, are indicative of relatively high-energy environments that are not conducive to sedimentation, thus the lack recent accumulation of fine silts and clays. These areas include the eastern and western ends of the KVK channel (bedrock), the middle of the KVK channel (Pleistocene sand), the South Reach in Newark Bay (mostly Pleistocene sand and gravel), the northern end of the Elizabethport Reach in the Arthur Kill (Pleistocene sand and gravel) and the Gulfport Reach, also in the Arthur Kill (Pleistocene sand and gravel).

B3.6 KVK Areas 4b and 5 consist mostly of Bedrock and Pleistocene Sand and Gravel. Recent Holocene silt and clay sediments are only present along the southern edge of the channel in Area 4b. Port Jersey Areas 1 and 2 also consist of recent Holocene silt and clay sediments. All of Newark Bay channel reaches, with the noted exception of the South Reach, consist of fine Pleistocene and Holocene silts and clays, which is indicative of relatively low-energy velocities and high shoaling rates.

B3.7 The Feasibility Report (USACE, 1999) prepared a comprehensive evaluation of shoaling rates in the Harbor accounting for recent channel improvements. These results are summarized in Table B3-1. In addition Table B3-2 presents a results from a previous detailed shoaling study in the KVK, Arthur Kill, and Newark Bay also performed by USACE (1986). The shoaling estimates from this earlier study are somewhat out of date, inasmuch as some of these channels have been deepened and a major shoal area between the Port Elizabeth Pierhead Channel and Newark Bay Middle and South Reach Channels has been removed since the analysis was prepared. Nevertheless, these numbers provide additional insight into sedimentation patterns within specific channel sub-reaches an are also useful for reference.

Table B3-1: Historic Shoaling Rates (USACE, 1999)

Channel	Last Improv.	Last Maint'd.	Average Mainten. Interval (Years)	Average Mainten. Rate (Existing) (cy/yr)	Previous Published Rate (Adj to Existing) (cy/yr)	Adopted Rates (cy/yr
Ambrose	1951	1984	1.7	400,000		400,000
Anchorage	1953	1973	6.7	0		0 (1)
KVK Con Hook	1994	1997	3.0	1300	20,800	28,000
KVK Bergen Pt	1994	(1)			4,000	4000
Newark Bay Main	1990	(1)			211,000	211,000
NB Port Elizabeth	1990	1998	7.5	78,000	121,700	121,700
NB Port Newark	1990	(1)			226,200	226,200
AK N. Shooters Is.	1962	1999	5.7	82,000	154,000	115000 (3)
AK Eliz. & Gulf	1964	1999	14	5,000	0	7000 (3)
Bay Ridge (+ RH)	1940	1992	1.2	520,000		520,000
Port Jersey	1998	1984	10(4)		58,000	58,000
Claremont			12.5(4)		25,000	25,000
NJ Pierhead	1961	1973	6.0	40,000		40,000
Red Hook Anch.	1975	1992	2.1	145,000		145,000
Gravesend Anch.	1984	1998	4.7	28,000		28,000
Stapleton Anch.	_	_	_	0		0

(1) No Maintenance Since Last Improvement
(2) Not Maintained In Past 25 Years
(3) Existing Rate Adjusted To Base Conditions
(4) From Previously Published Reports

Table B3-2: Shoaling Rates in Selected Federal Channels (USACE, 1986)

Reach No.	Reach Name	Length (ft)	Shoaling Rate (cy/yr)	Shoaling Rate (in/yr)
	Kill Van Kull			
1	Kill Van Kull Entrance	5250	14,800	0.39
2	Constable Hook	6000	(a)	(a)
3	Bergen Point East	6000	2900	0.09
4	Bergen Point West	6600	(b)	(b)
	Arthur Kill			
5	North of Shooters Island	5100	110,000	11.65
6	South of Shooters Island	5600	37,200	5.38
7	Elizabeth Port	6600	0	0
8	Gulfport	7100	0	0
	Newark bay			
9	Newark Bay South Below Bridge	4100	10,000	0.79
10	Newark Bay South Above Bridge	4000	11,200	0.91
11	Newark Bay Middle	8400	84,300	4.65
12	Newark Bay North	4250	52,400	6.93
13	Port Elizabeth South	2500	3,900	1.67
14	Port Elizabeth Pierhead	6500	18,400	1.46
15	Port Elizabeth Inshore	5250	39,900	4.93
16	Port Elizabeth Branch	2750	18,900	4.45
17	Port Newark Pierhead	4100	47,600	18.81
18	Port Newark Inshore	6100	35,200	4.67
19	Port Newark Branch	2700	68,000	10.20
(a) Kill Van Kull Entrance and Constable Hook evaluated together.				
(b) Bergen Point East and West evaluated together.				

APPROACH

B3.8 Sediment transport and shoaling changes follow directly from changes in hydrodynamics. Deepening the channels in some specific isolated areas first as part of the consolidated implementation alternative may lead to short-term reductions in current velocities in those areas, which may result in temporary shoaling increases. Therefore, this sediment transport evaluation relied on the HPM3D model to provide hydrodynamic conditions under With and Without Project alternatives.

B3.9 Shoaling rates at the specific bcations throughout the harbor where developed based on HPM3D results and analytical estimates of sedimentation processes. As explained above, fine Holocene sediments (silts and clays) are responsible for most of the shoaling an attendant channel maintenance requirements in the harbor. These sediments are commonly referred to as "mud". Mud contains a large portion of very small particles which have a large specific area such that the effect of the surface physico-chemical forces becomes as important as the effect of gravity forces, resulting in flocculation of particles. "Stickiness" is also a defining characteristic of muds, which are technically classed as cohesive sediments (Whitehouse et al., 2000). The process of deposition, consolidation, and erosion of cohesive sediment are controlled by complex array physical, biological and chemical factors, which are only partly understood. Nonetheless, researchers and engineers have developed relatively simple analytical expressions founded on empirical data that describe the these processes.

B3.10 **Deposition** involves the settling through the water column and on to the bed of flocculated sediment. Deposition may be computed using the following expression, which is generally found in most numerical sediment transport models.

$$D = w \cdot C \cdot \left(1 - \frac{t}{t_d}\right), \text{ for } t \leq t_d$$

$$D = 0 \text{ for } t > t_d$$

where:

D	Deposition rate (kg/sec)
t	Bottom shear stress (Pa)
t_d	Critical bottom shear stress for deposition (Pa)
w	Settling velocity of the sediment flocs (m/s)
C	Suspended sediment concentration (kg/m^3)

B3.11 Bottom shear stress is computed based on ambient current velocity as follows.

$$t = r.g\left(\frac{V}{C}\right)^2$$

where :

V	- Speed in (m/s)
r	- Water density (kg/m^3)
C	- Chezy coefficient (m$^{0.5}$/s)

B3.12 Values of suspended sediment concentration in the water column were determined based on data published by Suszkowski (1978) and more recently by USACE (2002), which suggest average ambient concentrations in the main Harbor channels are on the order of 15 mg/L.

B3.13 **Consolidation** is the gradual expulsion of interstitial water by the self weight for the sediment accompanied by an increase in both the density of the bed and its strength in time. Generally, site specific information regarding this process is not available, and typical surface layer density and shear strength values are commonly used as a basis for sediment transport models. A typical dry density value of 225 kg/m^3 was used in this study.

B3.14 **Erosion** is the removal of sediment from the surface of the bed due to the stress of the moving water above it. Deposition may be computed using the following expression, also found in most numerical sediment transport models.

$$E = e \cdot \left(1 - \frac{t}{t_{ce}}\right), \text{ for } t \leq t_e$$

where:

t Bottom shear stress (Pa)

t_e Critical bottom shear stress for erosion (Pa)

e Erosion rate (kg/m^2/s)

B3.15 Values of the settling velocity, critical shear stress for deposition, and critical shear stress for erosion were also obtained from the available literature (USACE, 1999). All input parameters to the sedimentation analysis are summarized in Table B3-3.

Table B3-3: Input Sediment Transport Parameters

Parameter	**Value**
Water density (kg/ m^3)	1014
Settling velocity of the suspended sediments (mm/s)	0.40
Critical Shear Stress for Deposition (Pa) *	0.07
Critical Shear Stress for Erosion (Pa)	0.65
Erosion rate constant (g/ m^2/sec)	0.005
Ambient Concentration of Suspended Sediments (mg/l)	15
(*) Channel areas with bedrock and or sand/gravel at the surface have significantly higher values of the critical shear stress for erosion	

RESULTS AND CONCLUSIONS

B3.16 Hourly time series of current velocities extracted from HPM3D and the sediment transport expressions described above were combined in a spreadsheet model to provide estimates of changes in shoaling patterns in the areas of vertical consolidation during the interim condition those areas will be deeper (50ft) than adjacent channels. Velocity changes are summarized in Table B3-4. The best indication of the impacts of the different alternatives are the "shoaling indexes", which are the ratios of the computed alternative condition to the computed existing condition (i.e., representative of the conditions leading to the recent shoaling records presented in Table B3-1). These ratios are then applied to the historical maintenance dredging estimates presented in tables B3-1 and B3-2 to produce estimates of the changes in shoaling rates. The results are summarized in table B3-5 & B3-6.

Table B3-4: Changes in Velocity

	Interim Consolidated Condition		Completed HDP 50 ft. Condition	
	Avg. (*) (m/s)	Max. (m/s)	Avg. (*) (m/s)	Max. (m/s)
PJ Area 1	0.09	0.16	0.10	0.18
PJ Area 2	0.13	0.24	0.14	0.25
KVK Areas 4b/5	0.27	0.53	0.29	0.58
(*) Avg. represents the average of the absolute value of ebb and flood velocities				

Table B3-5: Changes in Shoaling Rates (in/yr)

		Interim Consolidated Condition		Completed HDP 50 ft. Condition	
	Historic Rate (in/yr) (*)	Shoal Index	Shoaling Rate (in/yr)	Shoal Index	Shoaling Rate (in/yr)
PJ Area 1	3.00	0.73	2.20	0.68	2.05
PJ Area 2	1.56	1.25	1.96	0.98	1.53
KVK Areas 4b/5	0.44	1.20	0.53	1.18	0.52
(*) Estimated from Tables B3-1 and B3-2					

Table B3-6: Changes in Shoaling Rates (cy/yr)

		Interim Consolidated Condition		Completed HDP 50 ft. Condition	
	Historic Rate (cy/yr) (*)	Shoal Index	Shoaling Rate (cy/yr)	Shoal Index	Shoaling Rate (cy/yr)
PJ Area 1	46,000	0.73	33,700	0.68	31,500
PJ Area 2	12,000	1.25	15,000	0.98	12,000
KVK Areas 4b/5	13,000	1.20	15,600	1.18	15,400
(*) Estimated from Tables B3-1 and B3-2					

B3.17 Modeled flow velocities and shoaling estimates summarized in the previous tables suggest that changes to sedimentation processes due to consolidated implementation of the HDP 50 FT. project would be minimal. Moreover, historic shoaling rates in these areas are relatively small, therefore the increases in shoaling due to small decrease in flow velocities over the vertically consolidated areas only result in increases of a few hundreds (KVK Areas 4b/5) to a few thousand cubic yards per year (PJ Area 2).

B4 COASTAL EROSION

B4.1 Changes in bottom topography in Lower New York Bay (Ambrose Channel) associated with the Recommended Plan may affect the direction and magnitude of wave propagation and potentially increase coastal erosion. In addition, vessel generated waves (wake) within the Upper New York Bay navigation channels may be sufficient to contribute to erosion of channel banks. The potential for increased coastal erosion under the Recommended Plan was documented in the *New York and New Jersey Harbor Navigation Study Feasibility Report, (December 1999*).

B4.2 The Feasibility Report concluded that deepening the Ambrose Channel will increase wave heights in the immediate vicinity of the channel, but that waves on adjacent shorelines will be unchanged in virtually all areas, with no attendant contribution to coastal erosion. In addition, the Feasibility Report concluded, based on the results of the analytical ship wake model, that wakes generated by a design vessel will remain unchanged under Recommended Plan conditions, because increases in vessel size will be offset by deeper channels.

B4.3 More importantly, recent field studies (Moffatt & Nichol Engineers, 2003) indicate that tugs typically generate the type of short waves that may break and impact adjacent channel shorelines. On the other hand large vessels generate long waves (drawdown and return current) that do not typically break at the shoreline, and their impact on the shoreline is relative small. The relative importance of tug waves is also magnified by the fact that they represent a much larger percentage of total vessel traffic in the Harbor. The Moffatt & Nichol Engineers study also concluded that tug wake would be slightly reduced under deepened channel conditions. Therefore, a reduction in overall vessel traffic (a deeper channel will allow for larger vessels, less ship calls and a concomitant reduction in tug traffic) and wake energy will reduce the total energy absorbed at the shoreline with an attendant reduction in the potential for bank erosion.

B4.4 Consolidated implementation of the Recommended Plan would change the timing of channel deepening, but not the final configuration of channels; therefore, no differences in vessel generated wake leading to changes in the potential for coastal erosion are expected between Without (i.e., unconsolidated implementation of the Recommended Plan) and With Project (i.e., consolidated implementation of the Recommended Plan) conditions.

B5 REFERENCES

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