Volume 2

Appendices to the Report: Dredging and Dredged Material Disposal in the Port of New York and New Jersey: A Case Study and An Assessment of Alternatives

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J. R. Schubel

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Introduction

The following appendicies provide detailed documentation for the material presented in Volume 1 of this report. Appendix A contains a summary of Federal laws and regulations affecting dredging and dredged material disposal. A brief history of the development of regulations is also presented. Appendix B includes charts and tables which describe the location, quantitites dredged, and levels of contamination for each of the 29 N.Y. Harbor dredging projects studied. Appendix C is a review of the literature dealing with the major disposal options for the New York area. Open water disposal, borrow pit disposal, contained upland and contained island disposal are discussed from both a general and site specific point of view. Appendix D presents an example of a ten-year dredging plan designed to permit capping of the most contaminated dredged material with cleaner dredged material. Scheduling of maintenance and new work dredging was found to be necessary to accomplish this goal.

Appendix A

Federal Legislation and Regulations Affecting Dredging and Dredged Material Disposal

R. M. Summers

Appendix A

Federal Legislation Affecting Dredging and Disposal

Rivers & Harbors Act of 1899 [33 U.S.C. Sec 401 et seq.]

Purpose: to ensure the continued maintenance of the navigable waters of the U.S. and to allow the free access of vessels

Effects: 1) prohibits construction of any bridge, dam, dike or other structure without the consent of Congress and the approval of the COE

2) prohibits any obstruction to the navigable capicity of U.S. waters, unless authorized by the COE

3) forbids deposition of material in any place on the banks of navigable waters, where such material is likely to wash into the water, excluding operations which improve the navigable capacity of the water and construction which is considered necessary and proper

National Historic Preservation Act of 1962 [16 U.S.C. 470 et seq.]

Purpose: to protect cultural features of national significance

Effect: National Register of historic places must be consulted for any project and adverse impacts must be avoided. Administered by the Advisory Council on Historic Preservation

National Environmental Policy Act [42 U.S.C. Sec 4341 (1969) amended by P.L. 94-52 & 94-83 (1975)]

Purpose: 1) to declare a national policy which will encourage a productive and enjoyable harmony between man and his environment

2) to promote efforts which will prevent or eliminate damage to the environment and stimulate the health and welfare of man

3) to enrich the understanding of the ecological systems and natural resources important to the nation

4) to establish a Council on Environmental Quality to advise the President and recommend national policies for the improvement of the environment

Effects: 1) All proposed Federal activities affecting land use and development must include a detailed statement of the environmental impact of the proposed action, identification of adverse environmental effects, alternatives to the action, as well as any irreversible and irretrievable resources involved in such activity, the statement is then reviewed by the Council on Environmental Quality for recommendation

2) the Act makes environmental protection a part of the mandate of every Federal agency

3) must incorporate comments and views of the appropriate State and local agencies

Fish and Wildlife Coordination Act [16 U.S.C. Sec 661-666 (1970)]

Purpose: to provide recognition of the vital contribution and significance of wildlife to the Nation

Effect: any activity which is proposed by any department or agency of the U.S. to impound, divert or deepen the water of any stream or other body of water requires consultation by the proposing agency and the U.S. Fish & Wildlife Service

Federal Water Pollution Control Act Amendment of 1972 [33 U.S.C. Sec 1251 et seq., P.L. 92-500 (1972)]

Purpose: to restore and maintain the chemical, physical and biological integrity of the Nation's waters

Effects: 1) the discharge of pollutants into navigable waters are to be eliminated by 1985

2) wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfiish, and wildlife, and provides for recreation in and on the water is to be achieved by July 1, 1982

3) the discharge of toxic pollutants in toxic amounts is prohibited

4) Federal financial assistance is to be provided to construct publicly owned waste treatment works

5) area-wide waste treatment management planning processes are to be developed and implemented to assure adequate control of pollutant sources in each state

6) a major research and development effort should be made to develop technology necessary to eliminate the discharge of pollutants into the navigable waters

7) since dredged material is considered to fall within the designation of a residual waste and the EPA in conjunction with the COE is required to establish waste treatment management for those areas with water quality control problems (sec 208) there should be coordination in the planning of long term solutions to dredged material disposal problems

8) Sec 404 establishes a permit program, administered by the COE, to regulate the discharge of dredged or fill material into the

waters of the U.S., criteria for the evaluation of permits are to be developed by the E.P.A. acting in cooperation with the CO.O.E.

9) the COE can issue a permit that violates thr huifrlinrd if the interests of navigation require it.

10) further authority is given to the EPA to restrict or prohibit discharge of dredged material if it may cause an unacceptable adverse effect on water supplies, shellfish beds, fishery areas, wildlife or recreational area

Marine Protection, Research and Sanctuaries Act of 1972 [PL 92-532]

Purpose: Title 1 - provides for the regulation of ocean dumping

Title 2 - provides for research into the causes and prevention of marine pollution

Title 3 - provides for the designation of marine sanctuaries

Effects: 1) Section 103 requires the COE to evaluate all proposed operations involving the transportation and dumping of dredged material into ocean waters to determine the potential environmental impact of such activities.

2) the EPA in conjunction with the COE is to develop regulatory criteria and guidelines for both inland and ocean waters

3) the COE is required to use ocean dumping sites that have been designated by the EPA

4) the COE must assess the need for the proposed dumping based on an evaluation of the potential effect on navigation, economic & industrial development and foreign and domestic commerce of the U.S. if the permit were denied

5) other proposed methods of disposal and appropriate locations for ocean dumping must be reviewed by the COE

6) the Secretary of the Army may seek a waiver of the criteria from the Administrator of the EPA after certifying that there is no economically feasible method or site available other than the proposed dump site

7) the Administrator must grant the waiver unless it is found that it will result in an unacceptable adverse impact on municipal water supplies, shellfish beds, wildlife, Fisheries, or recreational areas

<u>Coastal Zone Management Act of 1972</u> [PL 92-583]

Purpose: to assist individual states in preparing and implementing management programs to preserve, protect, develop and restore the coastal resources of the U.S.

Effects: 1) establishes a system of grants in aid for states to set up CZM programs

2) Federal agencies are encouraged to assist the states in developing programs and are required to cooperate and participate as much as is practicable with the states in carrying out the provisions of this act.

3) programs should include but are not limited to "... setting forth objectives, policies and standards to guide public and private uses of land and waters in the coastal zone"

4) grants only given to states in accordance with the prescribed Federal standards

5) must establish proceedures which provide for public notice and public hearings

6) any non-Federal applicant for a Federal license or permit to conduct an activity affecting land or water uses in a state's

coastal zone must be able to certify compliance with the CZM program

Safe Drinking Water Act of 1972

Purpose: to identify and protect potable water supplies from unnecessary degradation

Effects: leads to the identification of important water supplies which must be protected. Particularly relavant in the case of upland disposal in areas with important ground water resources.

Endangered Species Act of 1973 [PL 93-205]

Purpose: to provide means to conserve the ecosystems upon which endangered and threatened species depend

Effects: 1) requires identification of endangered and threatened species

2) implements conservation programs designed to protect those species

3) provides means for aquisition of lands, waters or interests deemed necessary for protection of those species

4) section 7 requires Federal actions to be conducted so that critical habitat will not be threatened

Resource Conservation and Recovery Act of 1976 [42 USC Sec 3251 et seq., P.L. 94-580]

Purpose: to provide technical and financial assistance for development of management plans and facilities for the recovery of energy and other resources from discarded materials and for the safe disposal of discarded materials and to regulate the management of hazardous waste.

Effects: 1) If dredged material was listed as a hazardous waste by the EPA the COE would be required to obtain a permit.

2) application for such permit must include a wide range of information on the concentration and quantity of the waste material, time and frequency of disposal and site environmental survey

<u>Wild and Scenic Rivers Act of 1976</u> [16 USC Sec 1274 et sec., P.L. 94-486]

Purpose: to preserve the free-flowing condition of selected valuable rivers in the nation and to protect their immediate environments.

Effects: 1) requires all administrative and management contracts and plans affecting lands within the boundaries of the river basin to be approved by the appropriate administrator

2) also protects rivers from degradation by upstream effects

<u>Clean Water Act of 1977</u> [P.L. 95-217]

Purpose: amendment to the Federal Water Pollution Control Act

Effects: allows the Governor of any state to administer its own permit system for discharge of dredged material into navigable waters

The above information was summarized from Cole and Brainard (1978), Long Island Sound EIS (1981) and Conner et al (1979).

Regulation of Dredging & Disposal

Prior to 1971 the regulation of dredging and disposal was provided by the River and Harbor Act of 1899. Section 10 of this act gives authority to the Secretary of the Army to control the construction of any structure in or over any navigable water of the U.S., the excavation from or depositing of material in such waters, of the accomplishment of any other work affecting the course, location, condition or capacity of such waters (Conner et al. 1979). During the late 60's as the public's environmental consciousness began to emerge the need for stricter controls on dredging and disposal became apparent initially in the Great Lakes region. As a result the so-called "Jensen Criteria" were developed and promulgated by the E.P.A. in 1971. The Corps of Engineers (Corps) followed by issuing Engineering Circular 1165-2-97 which stated that the dredged material disposal criteria formulated by the EPA should be applied to sediments dredged from all U.S. waters (Brannon 1978).

The Jensen Criteria are summarized on Table A-1. The principal part of the criteria is the seven chemical parameters which have specific numerical concentration standards that can not be exceeded without resulting in the sediment being classified as polluted. In 1972 the Corps of Engineers Waterways Experiment Station estimated that 31% of all material dredged in the U.S. was classified as polluted by the Jensen Criteria and as a result, if the guidelines were followed, dredging costs would increase dramatically. (Little 1973). Serious objections to the criteria were raised for several other reasons including; they did not address the potential availability of the contaminants to organisms, they did not consider natural levels in sediments and the fact that these vary geographically, and they did not consider the quality of the receiving waters in assessing the impact of disposal.

Table A-1 "Jensen Criteria"

Use of Criteria

These criteria were developed as guidelines for FWQA evaluation of proposals and applications to dredge sediments from fresh and saline waters.

Criteria

The decision whether to oppose plans for disposal of dredged spoil in United States waters must be made on a case-by-case basis after considering all appropriate factors; including the following:

(a) Volume of dredged material.
(b) Existing and potential quality and use of the water in the disposal area.
(c) Other conditions at the disposal site such as depth and currents.
(d) Time of year of disposal (in realtion of fish migration and spawning, etc.).
(e) Method of disposal and alternatives.
(f) Physical, chemical, and biological characteristics of the dredged material.
(g) Likely recurrence and total number of disposal requests in receiving water area.
(h) Predicted long and short term effects on receiving water quality. When concentrations, in sediments, of one or more of the following pollution parameters exceed the limits expressed below, the sediment will be considered polluted in all cases and, therefore, unacceptable for open water disposal.

Sediment in Fresh and Marine Waters	Conc. % (dry wt. basis)
Volatile Solids	6.0
Chemical Oxygen Demand (C.O.D.)	5.0
Total Kjeldahl Nitrogen	0.10
Oil-Grease	0.15
Mercury	0.001
Lead	0.005
Zinc	0.005

Dredged sediment having concentrations of constituents less than the limits stated above will not be automatically considered acceptable for disposal. A judgment must be made on a case-by-case basis after considering the factors listed in (a) through (h) above.

In addition to the analyses required to determine compliance with the stated numberical criteria, the following additional tests are recommended where appropriate and pertinent:

Total Phosphorus
Total Organic Carbon (T.O.C.)
Immediate Oxygen Demand (I.O.D.)
Settleability
Sulfides
Trace Metals (iron, cadmium, copper, chromium, arsenic, and nickel)
Pesticides
Bioassay

from Little (1973, Part II, Chap. II)

Regulations were revised beginning 1972 with the passage of the Federal Water Pollution Control Act (FWPCA) and the Marine Protection Research and Sanctuaries Act (MPRSA). These laws directed the EPA in conjunction with the COE to develop regulatory criteria and guidelines for both inland and ocean waters. Section 103 of MPRSA requires the Corps to evaluate all proposed operations involving the transportation and dumping of dredged material into ocean waters to determine the potential environmental impact of such activities. Section 404 of FWPCA establishes a permit program, administered by the COE, to regulate the discharge of dredged or fill material into the waters of the U.S. Criteria for the evaluation were to be developed by the E.P.A. acting in cooperation with the Corps (EPA/Corps 1977).

In response to this legislation, the first set of regulations for ocean disposal were published on 15 Oct 1973 in the Federal Register. In the new proceedure the bulk sediment analysis required by the Jensen Criteria were replaced by the Elutriate Test which measures the concentration of certain pollutants released from the sediment when it is mixed with water. Guidelines for disposal in inland waters were not published until 5 Sept 1975 in the Federal Register. These require the permit applicant to consider the physical effects, chemical-biological interactive effects and to conduct a thorough site selection review. For this analysis, the Elutriate Test is required to determine the chemical water column effects of disposal (Brannon 1978).

One requirement of MPRSA is that the criteria for ocean disposal be updated at least every three years. During the first three-year period, the Elutriate Test was studied extensively under the Corps' Dredged Material Research Program (DMRP) (Jones and Lee 1978). A major criticism of the test was that while it can give a reasonable estimate of the short-term contaminant releases from dredged material it does not provide a means to evaluate long-term releases or the significance of those releases to the biota. In answer to these criticisms, DMRP research was directed toward application of bioassay proceedures to the evaluation of dredged material (Rosenberger et al. 1978, Shuba et al. 1978). As a result, when the 1973 criteria were updated in 1977, bioassay proceedures were incorporated into the evaluation of dredged material designated for ocean disposal. The exact proceedures are described in a joint EPA/Corps publication (EPA/Corps 1977) and are at the present time (March 1982) still in effect.

Considering the evaluation of sediment contamination as discussed above, regulations require the complete evaluation of the dredging project as summarized from Conner et al. (1979):

1) The benefits of a given project must be balanced against its reasonably foreseeable detriments.
2) All relevant factors must be considered including; conservation, economics, aesthetics, general environmental concerns, historic values, fish and wildlife values, flood damage prevention, land use, navigation, recreation, water supply, water quality, energy needs, safety, food production and in general the needs and welfare of the people.
3) Within the above framework, several points must be considered:
   a) the relative extent of the public and private need for the proposed project
   b) the availability of appropriate alternatives
   c) the extent and permanence of the effects
   d) impact of the project in relation to the cumulative effects of existing or anticipated projects
4) For the purposes of FWPCA protecting the waters of the U.S., the following are considered:
   a) the discharge will not be located in the proximity of a public water supply intake

b) the discharge will not occur in areas of concentrated shellfish production

c) the discharge will not destroy threatened or endangered species or their critical habitat

d) the discharge will not disrupt the movement of those species indigenous to the water body

e) the discharge will consist of suitable material free from toxic pollutants in other than trace quantities

f) the fill created will be properly maintained to prevent erosion and other nonpoint sources of pollution

f) the discharge will not occur in a component of the National or state wild and scenic river system

5) For the purposes of MPRSA, protecting ocean waters, the district engineer of the Corps must:

a) issue a public notice identifying the location of the proposed disposal site, its status as an EPA approved site, a brief description of known discharges at the site, effects of other authorized disposals at the site, an estimate of the time required for disposal, characteristics and composition of the dredged material and a statement concerning the need for or availability of an environmental impact statement

b) evaluate the project to determine whether the proposed dumping will unreasonably degrade or endanger human health, welfare or amenities, or the marine environment, ecological systems or economic potentialities

c) determine the need for the ocean dumping and the availability of alternatives including land based disposal

    d) see that the dredged material meets the criteria for ocean disposal as specified in the Federal Register Vol 42, No 7, Tuesday, 11 January 1977.

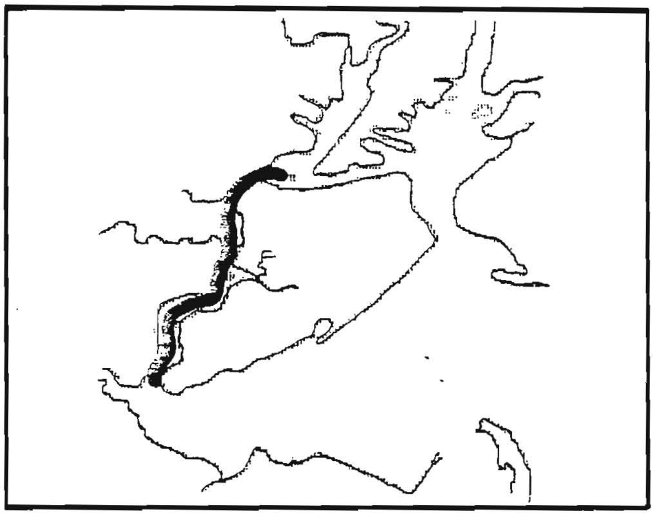
6) The project must comply with all state and local regulations and all necessary permits must be obtained.

There are provisions in both FWPCA covering inland waters and MPRSA covering ocean waters for bypassing the EPA criteria if there is no other alternative for disposal and the work is critical. After an evaluation of the effect on navigation, economic and industrial development, and foreign and domestic commerce of the United States the Secretary of the Army may seek a waiver of the criteria from the Administrator of the EPA who must grant the waiver unless he finds that the proposed disposal will result in an unacceptable adverse impact on municipal water supplies, shellfish beds, wildlife, fisheries or recreational areas.

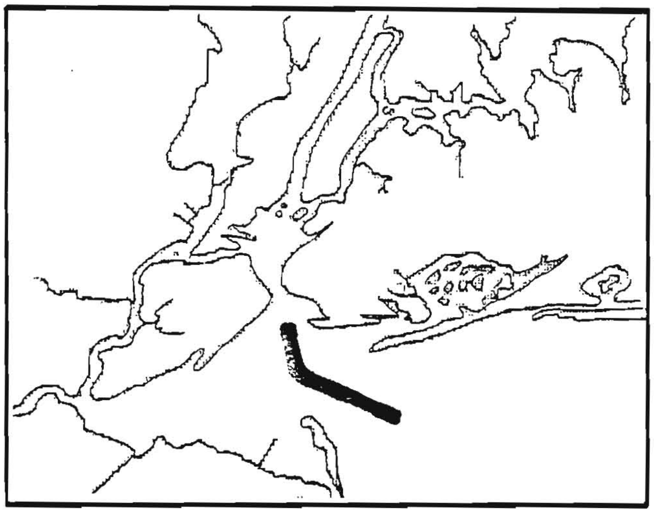
Appendix B

Project Locations, Quantity Dredged, and Contaminant Levels

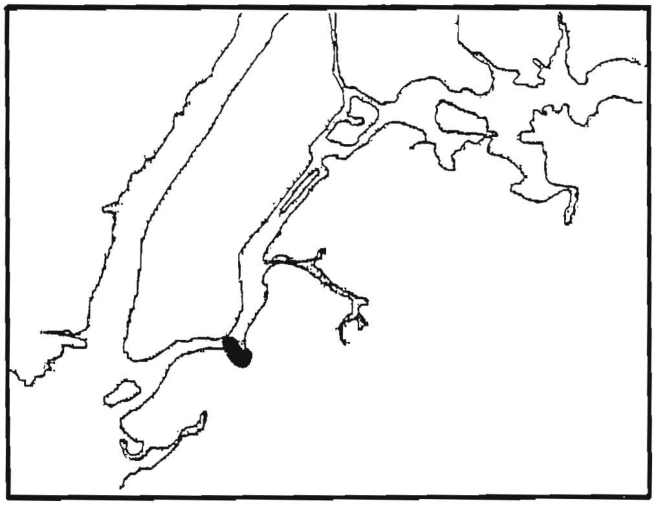
G. Feldman
R. M. Summers



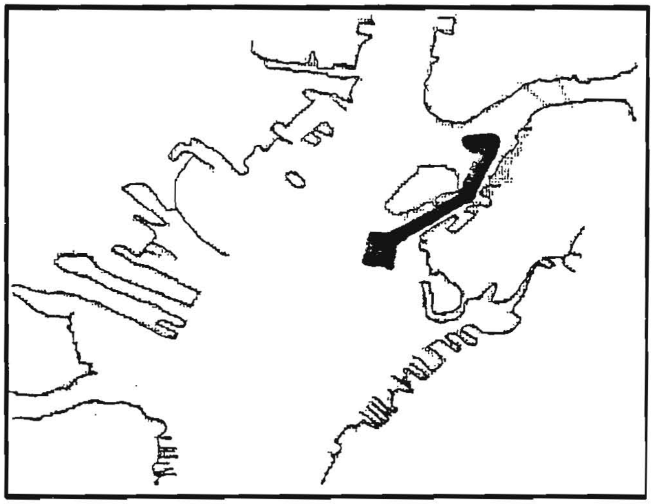
AK - Arthur Kill



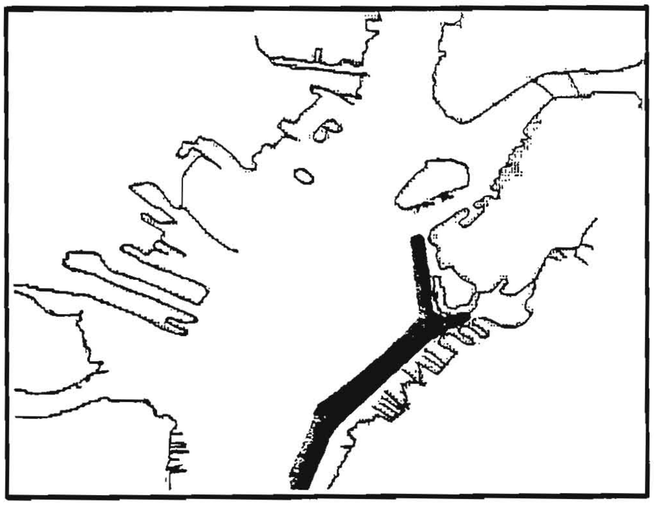
AMB - Ambrose Channel



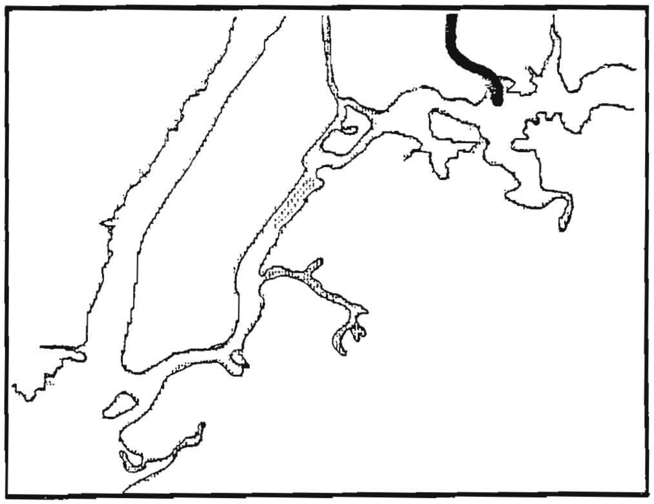
BKLNY -Brooklyn Navy Yard



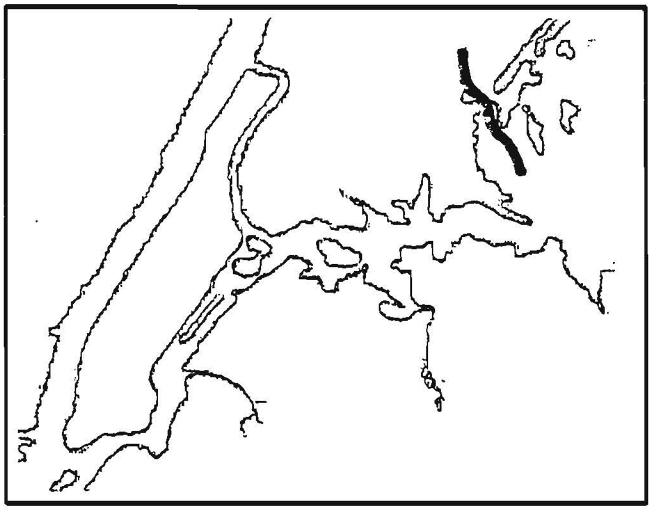
BMLK -Buttermilk Channel



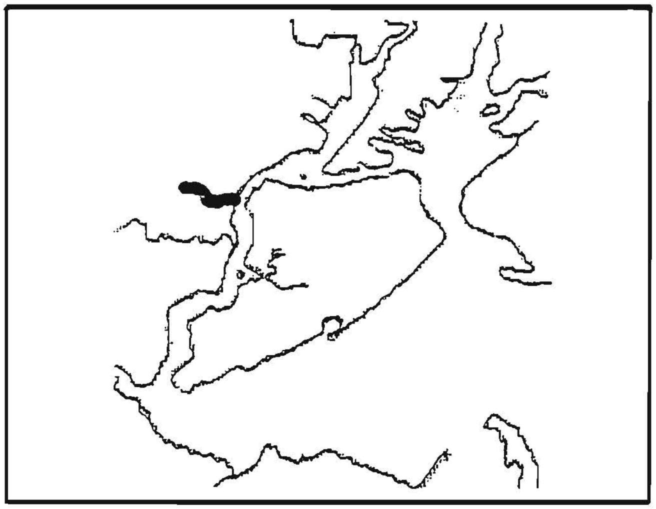
BRRH - Bay Ridge-Red Hook Channel



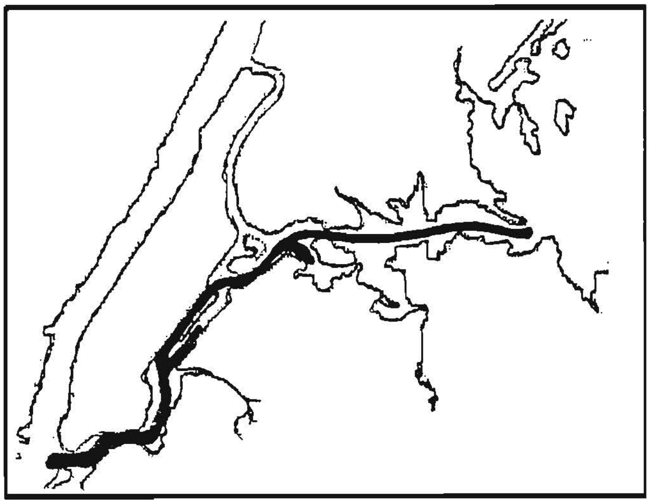
BRX -Bronx River



ECHST -Eastchester Creek

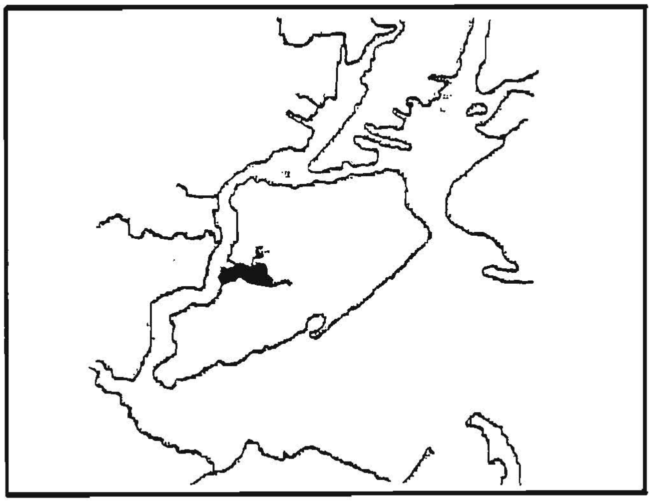


ELZR- Elizabeth River

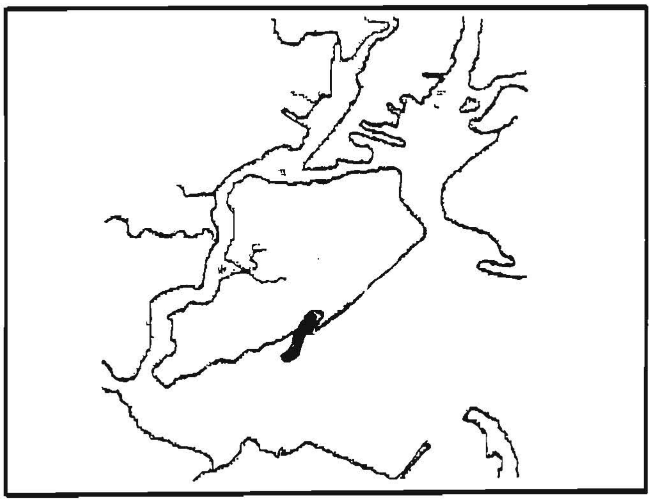


ER -East River

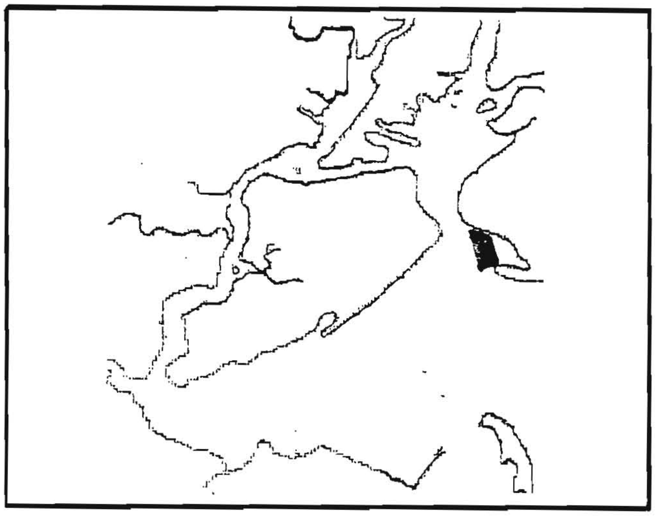
FLSH -Flushing Bay and Creek



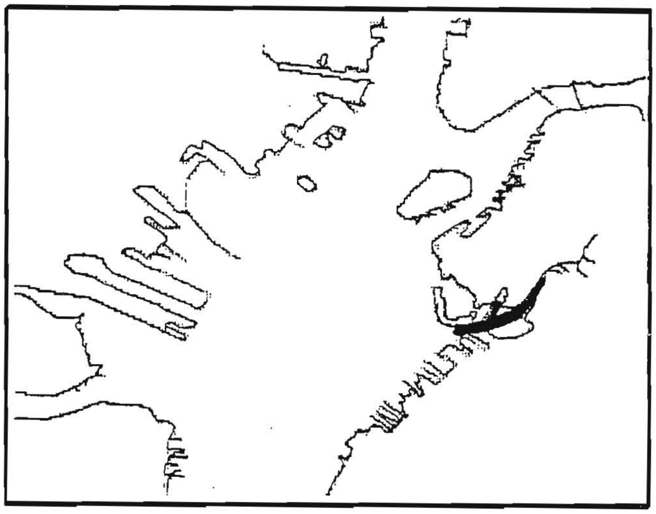
FRKL -Fresh Kills



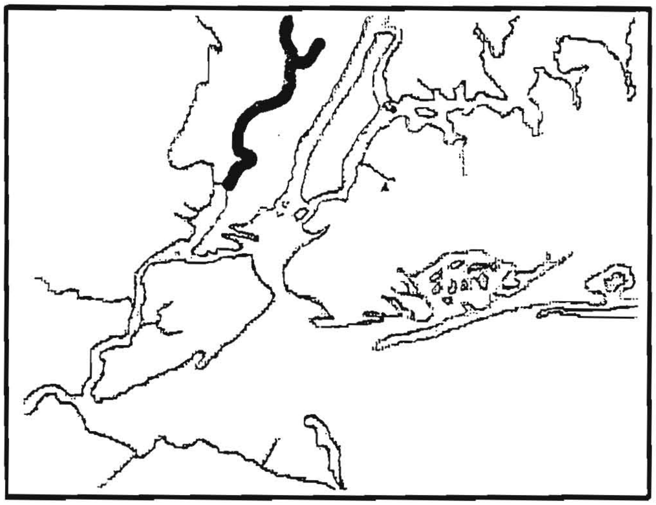
GRKL -Great Kills



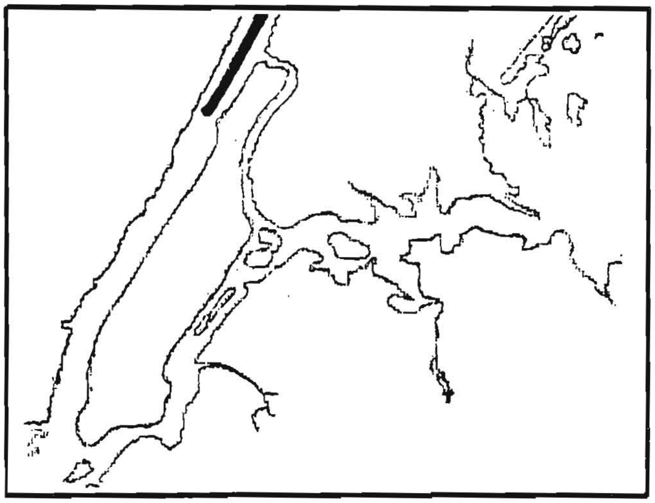
GRVS -Gravesend Bay



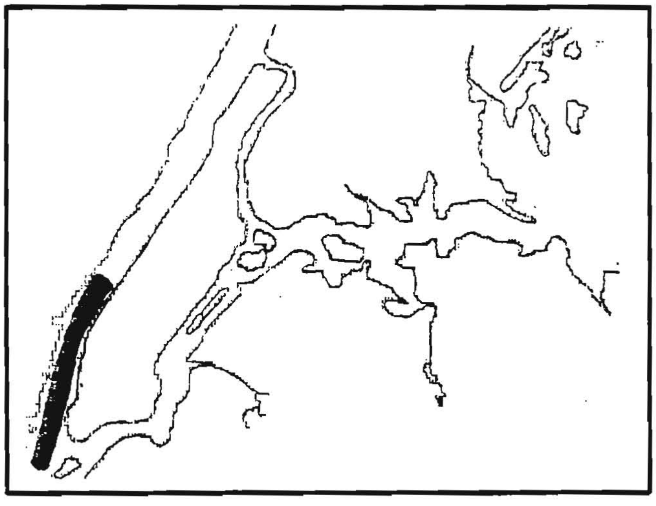
GWB -Gowanus Bay and Creek



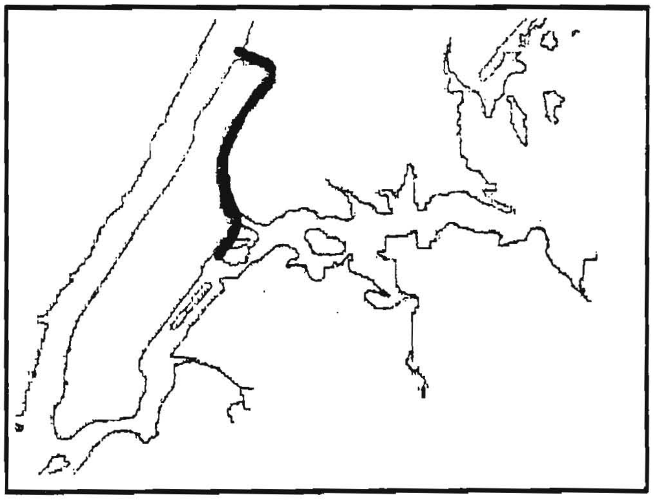
HCK -Hackensack River



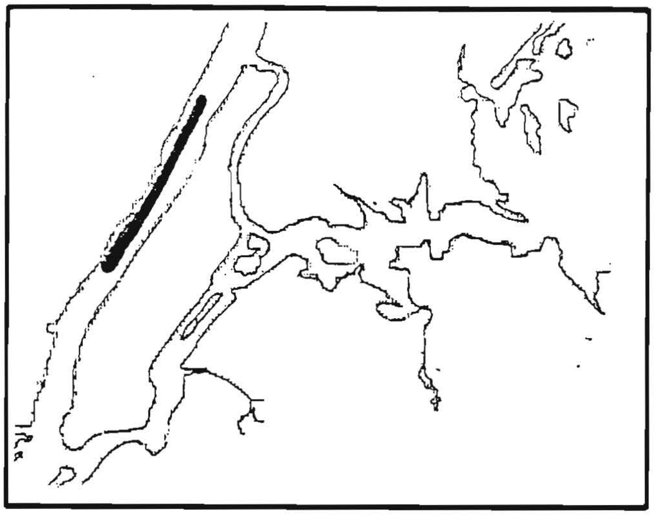
HRAE -Hudson River-Above Edgewater



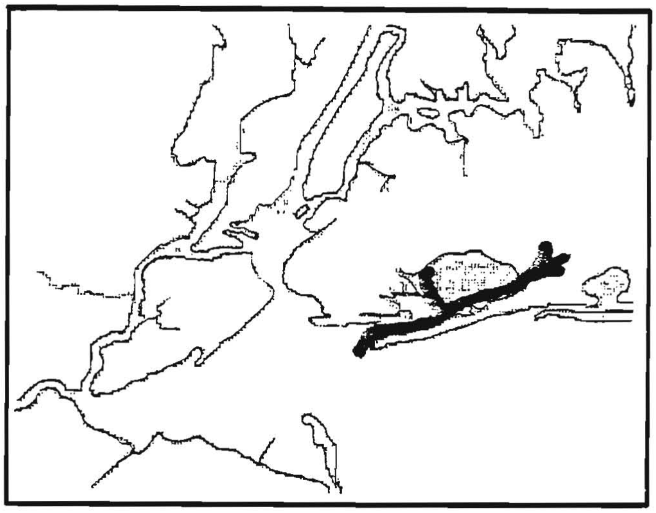
HRBW -Hudson River-Battery to Weehawken



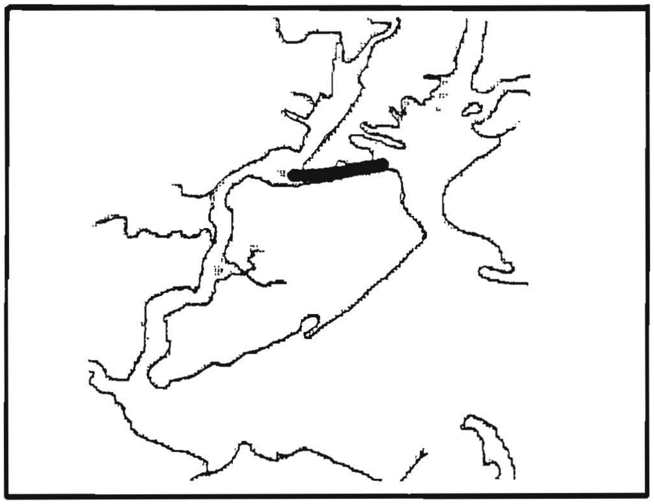
HRLM -Harlem River



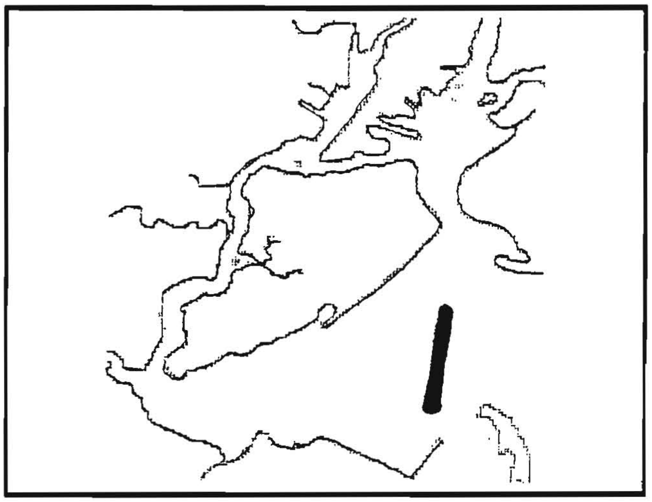
HRWE -Hudson River-Weehawken to Edgewater



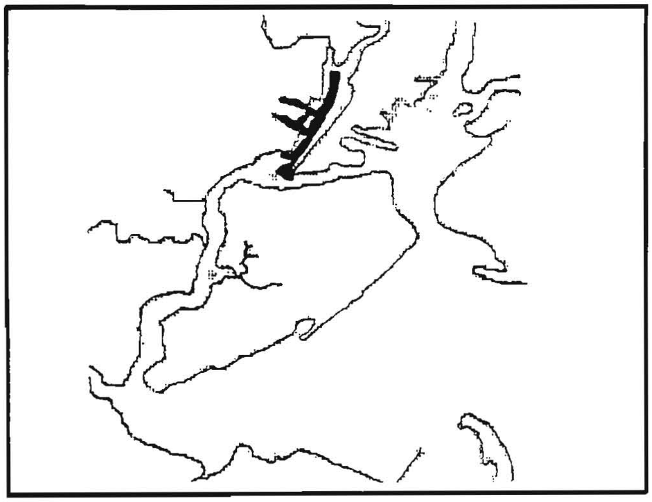
JAMB -Jamaica Bay



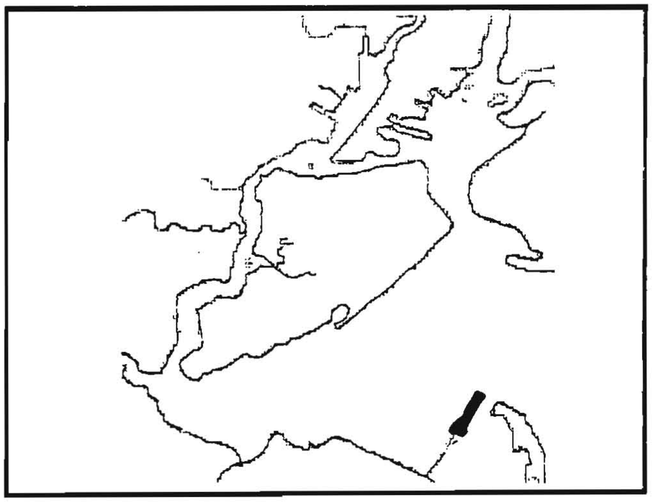
KK -Kill Van Kull



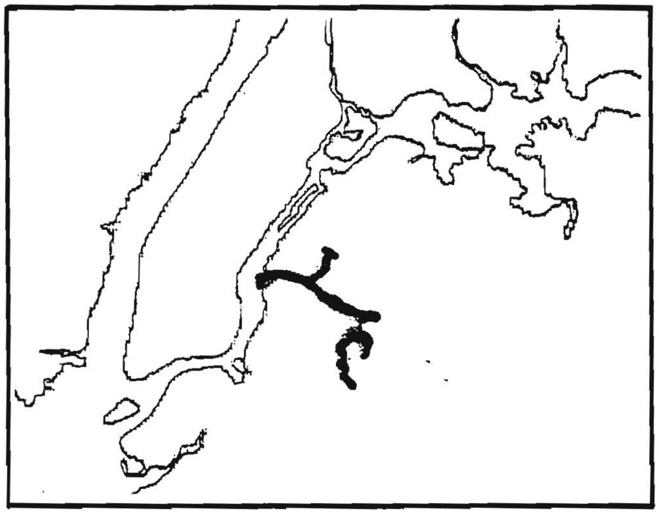
MSCH -Main Ship Channel



NB -Newark Bay

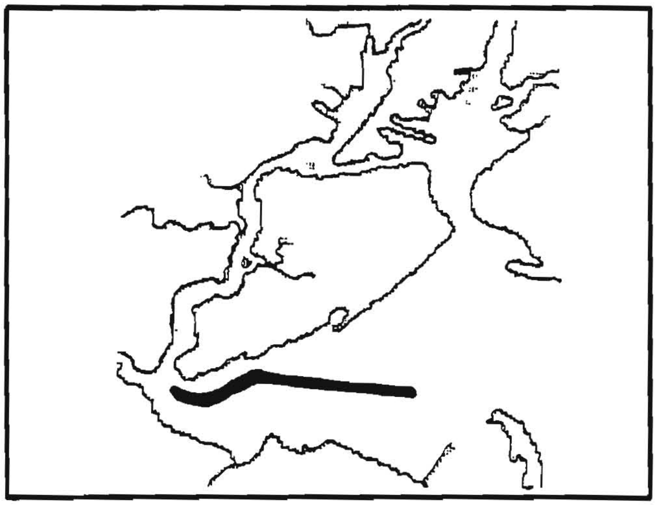


NTML -Navy Terminal Channel

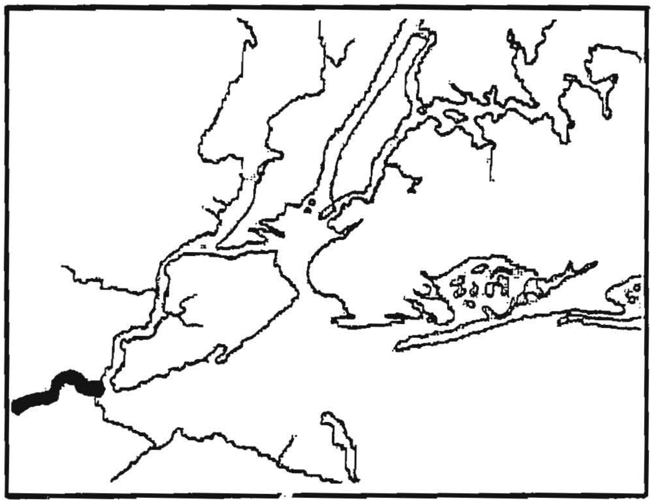


NTWN -Newton Creek

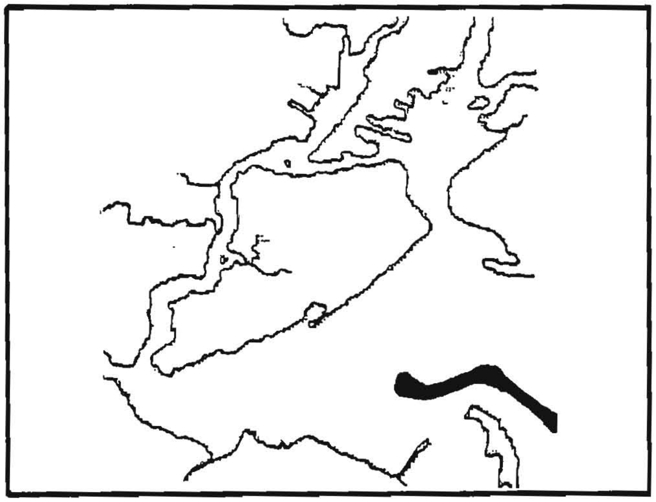
PAS -Passaic River



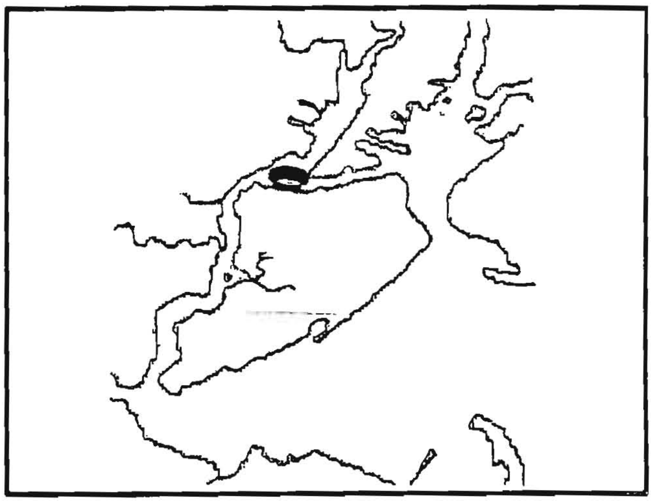
RBCH -Raritan Bay Channel



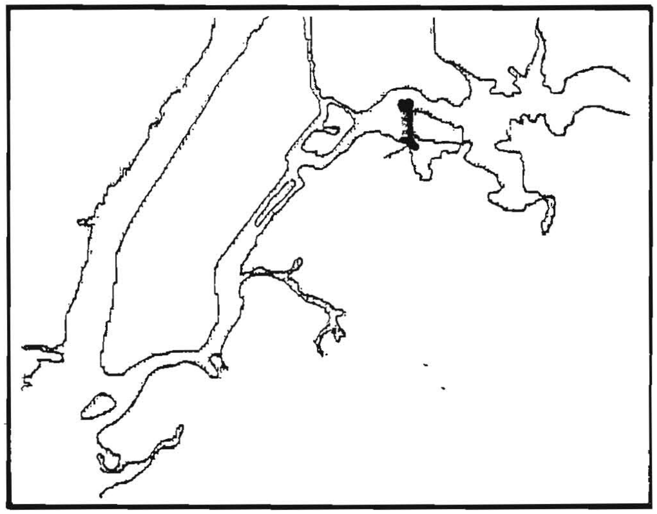
RR -Raritan River



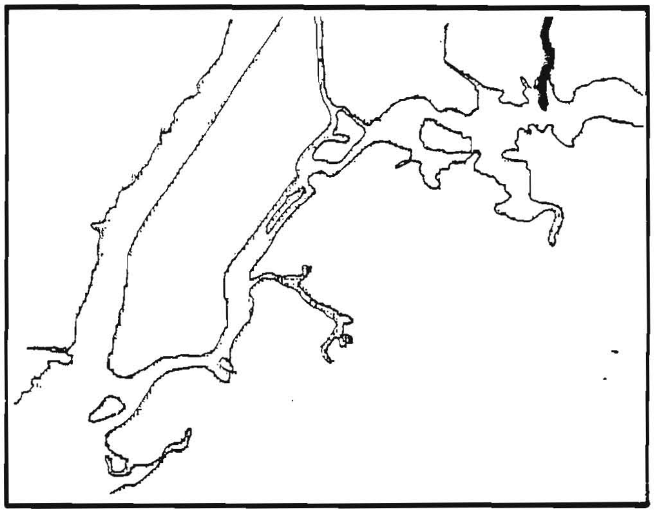
SHCH -Sandy Hook Channel



SHTR -Shooters Is. Channels



SPUR -East River Spur Channel



WCHST -Westchester Creek

Table B-1

Annual Federal Maintenance Dredging ($10^3 yd^3$)

Project	15-yr Avg Annual	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
RB	912	755	740	1728	615	1471	1223	1186	1539		819	2870	177	321	243	
AMB	834	522		247						1111	1501	1238	1844	2100	2319	1630
BRRH	704		382	385	1399		1678	25	404	350	1368	1879	594	650	1296	148
HRWE	594	468	900	713	729	1181	521	840	493	397	1451	860			357	
HRBW	423		910	791	1584		521						267	2273		
RR	318	185	1057	199		104	205	270	204		999	1541				
SHCH	256	64		654	503		469	434	243		188	188		626	471	
BMLK	217	400	650			271	1086				275	225			247	
NB	212			255	128		73	146	290	588				821	880	
UB	162						499		609		26	78			1224	
SHB	136	276	78				556	563	563							
MSCH	129	1158						777								
SHTR	111		335			550	60			726						
PAS	78						263	158				231	525			
AK	71							1066								
WCHST	62	274				85			135							441
JAMB	30							31				277			141	
BRX	26	84						94								219
HCK	24											355				
FLSH	19								279							
ER	15	202										28				
HRLM	13			10					179							
SPUR	11											122				41
NTWN	9						104			36						
ECHST	3									49						

Table B-2

Annual Private Dredging ($10^3 yd^3$)

Project	5-yr Avg Annual	1976	1977	1978	1979	1980
HRBW	601	664	660	977	366	338
AK	195	140	278	38	286	234
NTML	150			752		
KK	114	30	72	80	79	307
GWB	78		43	78		253
NB	72			235		127
BKLNY	56			66	141	71
PAS	39	126	24		18	25
BMLK	35				175	
HCK	34	20	2	95		52
RB	18		66	24		
BRRH	15			31	45	
UB	9		45			
NTWN	4			.5	12	5
SPUR	3		17			
JAMB	3			1	12	
HRWE	2			11		
SHB	2		5	2		3
ER	.8		4			
HRLM	.5					2
ECHST	.1		.6			

Table B-3

Federal New Work Dredging

Location	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
NB					1374	625	2424	2009							
UB			204	1324	259	3297	3363								
GRVS							1734	1108		833	291				
KK	660	302	158								197				
RR		104													
SHTR														18	

Table B-4

Bulk PCB Levels

Project	Number of Samples	(ppm) Mean	Std. Dev.	95% Confidence
Hudson River-Battery to Weehawkin	1	4.80	0	0
Raritan Bay		- ND -		
Ambrose Channel		- ND -		
Bay Ridge-Red Hook	8	<0.1	ND	ND
Hudson River-Weehawkin to Edgewater	23	0.223	0.186	0.081
Raritan River	7	0.2	ND	ND
Newark Bay	3	<0.1	ND	ND
Arthur Kill	42	0.468	0.429	0.130
Sandy Hook Channel	4	<0.1	ND	ND
Buttermilk Channel		- ND -		
Upper Bay	6	<0.1	ND	ND
Navy Terminal	3	0.017	0.012	0.029
Sandy Hook Bay		- ND -		
Main Ship Channel	2	<0.1	ND	ND
Passaic River	9	0.2	ND	ND
Kill van Kull	1	<0.1	ND	ND
Shooter's Island	1	0.900	0	0
Gowanus Bay	6	0.052	0.038	0.040
Westchester Ck.	5	0.6	ND	ND
Hackensack R.	2	<0.1	ND	ND
Brooklyn Navy Yd.		- ND -		
Jamaica Bay		- ND -		
Bronx River		- ND -		
Flushing Bay		- ND -		
East River		- ND -		
Spur Channel		- ND -		
Harlem River		- ND -		
Newtown Ck.	12	0.7	ND	ND
Eastchester Ck.	7	0.186	0.121	0.112
Hudson R.-above Edgewater		- ND -		
Coney Is. Channel		- ND -		
Gravesend Bay		- ND -		
Little Neck		- ND -		

Table B-5

Bulk Mercury Levels

Project	Number of Samples	(ppm) Mean	Std. Dev.	95% Confidence
Hudson River-Batter to Weehawkin	10	2.3	ND	ND
Raritan Bay	24	1.8	ND	ND
Ambrose Channel		- ND -		
Bay Ridge-Red Hook	8	3.1	ND	ND
Hudson River-Weehawkin to Edgewater	23	0.700	0.259	0.112
Raritan River	7	2.2	ND	ND
Newark Bay	79	4.229	2.513	0.554
Arthur Kill	51	2.180	1.474	0.404
Sandy Hook Channel	4	0.03	ND	ND
Buttermilk Channel	2	2.2	ND	ND
Upper Bay	3	1.233	0.153	0.379
Navy Terminal	3	0.767	0.058	0.143
Sandy Hook Bay	2	0.3	ND	ND
Main Ship Channel	2	1.9	ND	ND
Passaic River	7	11.214	9.177	8.487
Kill van Kull	3	4.333	1.155	2.869
Shooter's Island	23	9.296	4.238	1.833
Gowanus Bay	7	1.143	0.341	0.315
Westchester Ck.	5	3.3	ND	ND
Hackensack R.	3	3.767	3.412	8.477
Brooklyn Navy Yd.		- ND -		
Jamaica Bay		- ND -		
Bronx River		- ND -		
Flushing Bay		- ND -		
East River		- ND -		
Spur Channel		- ND -		
Harlem River		- ND -		
Newtown Ck.	12	5.1	ND	ND
Eastchester Ck.	7	1.086	0.797	0.737
Hudson R.- above Edgewater		- ND -		
Coney Is. Channel		- ND -		
Gravesend Bay	3	0.933	0.473	1.174
Little Neck		- ND -		

Table B-6

Bulk Cadmium Levels

Project	Number of Samples	(ppm) Mean	Std. Dev.	95% Confidence
Hudson River-Battery to Weehawkin	10	5.4	ND	ND
Raritan Bay	54	3.494	1.614	0.430
Ambrose Channel	11	2.200	1.362	0.915
Bay Ridge-Red Hook	8	4.8	ND	ND
Hudson River-Weehawkin to Edgewater	23	1.174	0.384	0.166
Raritan River	7	2.6	ND	ND
Newark Bay	79	8.558	5.851	1.290
Arthur Kill	55	4.176	3.206	0.847
Sandy Hook Channel	4	0.18	ND	ND
Buttermilk Channel	2	6.1	ND	ND
Upper Bay	3	1.633	0.929	2.308
Navy Terminal	5	1.900	1.699	2.109
Sandy Hook Bay	12	3.942	1.917	1.218
Main Ship Channel	8	3.275	3.265	2.730
Passaic River	7	11.841	5.238	4.844
Kill van Kull	3	8.333	1.155	2.869
Shooter's Island	23	18.765	8.448	3.654
Gowanus Bay	7	3.586	1.087	1.005
Westchester Ck.	5	7.8	ND	ND
Hackensack R.	3	6.600	3.857	9.583
Brooklyn Navy Yd.		- ND -		
Jamaica Bay	1	1.000	0	0
Bronx River		- ND -		
Flushing Bay		- ND -		
East River		- ND -		
Spur Channel		- ND -		
Harlem River		- ND -		
Newtown Ck.	12	94.4	ND	ND
Eastchester Ck.	7	2.714	1.505	1.392
Hudson R.-above Edgewater		- ND -		
Coney Is. Channel		- ND -		
Gravesend Bay	3	2.100	1.389	3.451
Little Neck		- ND -		

Table B-7

Bulk Arsenic Levels

Project	Number of Samples	(ppm) Mean	Std. Dev.	95% Confidence
Hudson River-Battery to Weehawkin	10	1.0	ND	ND
Raritan Bay	24	9.9	ND	ND
Ambrose Channel		- ND =		
Bay Ridge-Red Hook	8	6.8	ND	ND
Hudson River-Weehawkin to Edgewater	11	4.1	ND	ND
Raritan River	7	31.1	ND	ND
Newark Bay	81	5.566	ND	ND
Arthur Kill	7	19.6	ND	ND
Sandy Hook Channel	4	2.2	ND	ND
Buttermilk Channel	2	1.9	ND	ND
Upper Bay	6	10.383	ND	ND
Navy Terminal		- ND -		
Sandy Hook Bay	2	11.4	ND	ND
Main Ship Channel	2	6.3	ND	ND
Passaic River	9	7.8	ND	ND
Kill van Kull	1	30.8	ND	ND
Shooter's Island	18	10.189	11.293	5.617
Gowanus Bay	1	0.2	0.0	0.0
Westchester Ck.	5	9.8	ND	ND
Hackensack R.	2	20.4	ND	ND
Brooklyn Navy Yd.		- ND -		
Jamaica Bay		- ND -		
Bronx River		- ND -		
Flushing Bay		- ND -		
East River		- ND -		
Spur Channel		- ND -		
Harlem River		- ND -		
Newtown Ck.	12	42.1	ND	ND
Eastchester Ck.	7	7.243	4.424	4.092
Hudson R. - above Edgewater		- ND -		
Coney Is. Channel		- ND -		
Gravesand Bay	4	7.2	ND	ND
Little Neck		- ND -		

Table B-8

Bulk Lead Levels

Project	Number of Samples	(ppm) Mean	Std. Dev.	95% Confidence
Hudson River-Battery to Weehawkin	10	230.4	ND	ND
Raritan Bay	76	148.5	ND	ND
Ambrose Channel	11	25.3	16.4	11.0
Bay Ridge-Red Hook	8	234.2	ND	ND
Hudson River-Weehawkin to Edgewater	23	63.1	23.8	10.3
Raritan River	7	160.6	ND	ND
Newark Bay	94	267.7	ND	ND
Arthur Kill	55	192.8	429.3	113.4
Sandy Hook Channel	4	4.4	ND	ND
Buttermilk Channel	2	238.5	ND	ND
Upper Bay	6	76.5	ND	ND
Navy Terminal	5	92.7	68.2	84.7
Sandy Hook Bay	12	132.5	70.2	44.6
Main Ship Channel	8	43.0	22.0	18.4
Passaic River	9	477.8	ND	ND
Kill van Kull	3	367.6	140.8	350.0
Shooter's Island	23	400.4	129.4	55.9
Gowanus Bay	7	108.6	34.2	31.7
Westchester Ck.	5	623.7	ND	ND
Hackensack R.	3	238.0	71.0	176.4
Brooklyn Navy Yd.		- ND -		
Jamaica Bay	1	6.0	0.0	0.0
Bronx River		- ND -		
Flushing Bay		- ND -		
East River		- ND -		
Spur Channel		- ND -		
Harlem River		- ND -		
Newtown Ck.	12	865.9	ND	ND
Eastchester Ck.	7	263.2	140.5	129.9
Hudson R.-above Edgewater		- ND -		
Coney Is. Channel		- ND -		
Gravesend Bay	4	111.6	ND	ND
Little Neck		- ND -		

Table B-9

Average Percent Fines for Dredged Material

Project	Number of Samples	(%) Mean	Std. Dev.	95% Confidence
Hudson River - Battery to Weehawkin	12	81.1	16.7	10.6
Raritan Bay	10	45.3	22.4	16.0
Ambrose Channel		- ND -		
Bay Ridge - Red Hook	11	57.9	26.2	17.6
Hudson River - Weehawkin to Edgewater	19	86.9	7.4	3.6
Raritan River	4	66.8	25.7	40.9
Newark Bay	4	91.5	9.6	15.4
Arthur Kill	18	52.7	30.8	15.3
Sandy Hook Channel		- ND -		
Buttermilk Channel	11	38.6	21.9	14.7
Upper Bay	6	33.2	29.4	30.9
Navy Terminal	1	46.0	0	0
Sandy Hook Bay	2	80.5	14.8	133.4
Main Ship Channel		- ND -		
Passaic River	10	83.9	11.5	8.3
Kill van Kull	23	56.6	29.0	12.5
Shooter's Island	9	52.6	34.0	26.1
Gowanus Bay	5	47.2	33.7	41.8
Westchester Ck.	5	90.8	9.5	11.8
Hackensack R.	2	76.5	12.0	108.0
Brooklyn Navy Yd.	3	91.3	3.5	8.7
Jamaica Bay		- ND -		
Bronx River	6	79.5	10.6	11.2
Flushing Bay	2	85.5	10.6	95.3
East River	2	87.0	8.5	76.2
Spur Channel	6	81.6	16.5	17.3
Harlem River	1	13.0	0	0
Newtown Ck.	12	49.2	22.0	14.0
Eastchester Ck.	7	30.4	24.3	22.4
Hudson R. - above Edgewater	6	77.0	28.4	29.8
Coney Is. Channel		- ND -		
Gravesend Bay	4	20.3	7.0	11.2
Little Neck		- ND -		

Table B-10

Mercury Levels for the Elutriate Test

Project	Number of Tests	(ppb) Mean	Std. Dev.	95% Confidence
Hudson River - Battery to Weehawkin	2	0.350	0.212	1.906
Raritan Bay	2	0.200	0	0
Ambrose Channel	1	0.200	0	0
Bay Ridge - Red Hook	3	0.173	0.142	0.353
Hudson River - Weehawkin to Edgewater	4	0.225	0.050	0.080
Raritan River	2	0.200	0	0
Newark Bay	3	0.200	0	0
Arthur Kill	10	0.212	0.089	0.063
Sandy Hook Channel			- ND -	
Buttermilk Channel	2	0.365	0.233	2.096
Upper Bay	2	0.365	0.233	2.096
Navy Terminal			- ND -	
Sandy Hook Bay	2	0.200	0	0
Main Ship Channel			- ND -	
Passaic River	3	0.233	0.058	0.143
Kill van Kull	9	0.189	0.076	0.058
Shooter's Island	1	0.300	0	0
Gowanus Bay	2	0.315	0.163	1.461
Westchester Ck.	1	0.200	0	0
Hackensack R.			- ND -	
Brooklyn Navy Yd.	2	0.250	0.071	0.635
Jamaica Bay			- ND -	
Bronx River	1	0.200	0	0
Flushing Bay	2	0.200	0	0
East River	1	0.370	0	0
Spur Channel	1	0.800	0	0
Harlem River	1	0.200	0	0
Newtown Ck.	4	0.275	0.150	0.239
Eastchester Ck.			- ND -	
Hudson R. - above Edgewater	3	0.367	0.208	0.517
Coney Is. Channel			- ND -	
Gravesend Bay	1	0.200	0	0
Little Neck			- ND -	

Table B-11

Cadmium Levels for the Elutriate Test

Project	Number of Tests	(ppb) Mean	Std. Dev.	95% Confidence
Hudson River - Battery to Weehawkin	2	0.200	0.141	1.271
Raritan Bay	2	0.240	0.198	1.779
Ambrose Channel	1	0.270	0	0
Bay Ridge - Red Hook	3	0.190	0.115	0.287
Hudson River-Weehawkin to Edgewater	4	0.242	0.165	0.263
Raritan River	2	0.235	0.021	0.191
Newark Bay	3	0.177	0.133	0.330
Arthur Kill	10	0.332	0.364	0.261
Sandy Hook Channel			- ND -	
Buttermilk Channel	2	<0.100	0	0
Upper Bay	2	0.450	0.495	4.447
Navy Terminal			- ND -	
Sandy Hook Bay	2	0.325	0.064	0.572
Main Ship Channel			- ND -	
Passaic River	3	0.233	0.231	0.574
Kill van Kull	9	0.737	1.518	1.167
Shooter's Island	2	0.330	0	0
Gowanus Bay	2	<0.100	0	0
Westchester Ck.			- ND -	
Hackensack R.			- ND -	
Brooklyn Navy Yd.	2	2.950	0.311	2.795
Jamaica Bay			- ND -	
Bronx River	1	0.540	0	0
Flushing Bay	2	0.100	0	0
East River	1	0.300	0	0
Spur Channel	1	1.500	0	0
Harlem River	1	0.400	0	0
Newtown Ck.	4	0.617	0.405	0.644
Eastchester Ck.			- ND -	
Hudson R. - above Edgewater	3	1.080	0.570	1.417
Coney Is. Channel			- ND -	
Gravesend Bay	1	0.260	0	0
Little Neck			- ND -	

Table B-12

PCB Levels for the Elutriate Test

Project	Number of Samples	(ppb) Mean	Std. Dev.	95% Confidence
Hudson River - Battery to Weehawkin	2	<0.1	0	0
Raritan Bay	2	0.055	0.064	0.572
Ambrose Channel	1	<0.1	0	0
Bay Ridge - Red Hook	3	0.103	0.095	0.236
Hudson River - Weehawkin to Edgewater	4	0.08	0.091	0.144
Raritan River	2	<0.1	0	0
Newark Bay	3	0.04	0.052	0.129
Arthur Kill	10	0.06	0.045	0.032
Sandy Hook Channel			- ND -	
Buttermilk Channel	2	0.055	0.064	0.572
Upper Bay	2	0.170	0.226	2.033
Navy Terminal			- ND -	
Sandy Hook Bay	2	<0.1	0	0
Main Ship Channel			- ND -	
Passaic River	3	0.09	0.075	0.188
Kill van Kull	9	0.124	0.034	0.026
Shooter's Island	1	0.270	0	0
Gowanus Bay	2	0.150	0.071	0.635
Westchester Ck.	1	<0.1	0	0
Hackensack R.			- ND -	
Brooklyn Navy Yd.	2	0.165	0.021	0.191
Jamaica Bay			- ND -	
Bronx River	1	<0.1	0	0
Flushing Bay	2	<0.1	0	0
East River	2	<0.1	0	0
Spur Channel	1	0.46	0	0
Harlem River	1	<0.1	0	0
Newtown Ck.	4	<0.1	0	0
Eastchester Ck.			- ND -	
Hudson R. - above Edgewater	3	0.153	0.092	0.229
Coney Is. Channel			- ND -	
Gravesend Bay	1	<0.1	0	0
Little Neck			- ND -	

Sources of Dredging Data (Tables B1 to B3)

1) U.S. Army Corps of Engineers, New York District, Unpublished data
2) Conner et al., 1979
3) U.S. Army Corps of Engineers 1976 through 1979

Sources of Bulk Contaminant Levels (Tables B4 to B8)

1) U.S. Army Corps of Engineers, New York District, Water Quality Section, Unpublished data
2) Conner et al., 1979
3) Meyerson et al., 1981
4) Koons and Thomas, 1979
5) Olsen et al., 1978
6) Williams et al, 1978
7) Suszkowski, 1978
8) Greig and McGrath, 1977
9) Bopp, 1979

Sources of Particle Size and Elutriate Levels (Tables B9 to B12)

1) U.S. Army Corps of Engineers, New York District Water Quality Section, Unpublished data

Appendix C

Comparison of Disposal Options

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APPENDIX C Comparison of Disposal Options

Part 1 Environmental Impacts of Open Water Disposal and the Effectiveness of Capping

Open water disposal is the most widely practiced form of dredged material disposal in the United States (Boyd et al., 1972). Many variations of open water disposal have been used, ranging from sidecasting operations which place material alongside the dredged channel to hopper dredging operations which are capable of transporting material hundreds of miles to deep ocean disposal sites. Each of these variations entails differing circumstances of transportation, dumping and deposition which influence the impacts caused by disposal. For the purposes of this discussion, these impacts have been divided into three broad categories: 1) physical impacts, 2) chemical impacts, and 3) biological impacts. Each of these is discussed in general and with respect to specific types of open water disposal in the following sections.

Physical Impacts of Open Water Disposal

Physical impacts of open water disposal are primarily associated with the suspension and dispersion of sediment particles throughout the water column and the deposition of large amounts of new material over short time scales on limited areas of the sea floor. Many variables affect the extent and magnitude of these impacts including the type of sediment dredged (particle size, water content, density etc.), the type of dredging equipment used (hydraulic or clam-shell type dredge), currents, depth of the water and its exposure to storms. Impacts can occur over three phases of the operation: during dredging, during dumping and subsequent to dumping. Because of the much shorter time scales involved, the dredging and dumping phases are generally of less consequence than the period of time subsequent to dredging.

Turbidity During Dredging and Disposal

The amount of turbidity generated in the dredging and dumping operations is dependent on the type of material being dredged and the type of equipment utilized. Weschler and Cogley (1977) measured settling and flocculation rates for various types of sediments. They identified the important factors to be sediment composition (particle-size distribution, clay mineralogy, organic content), water composition (salinity, hardness, pH) and physical effects such as turbulence. In their examination of particle agglomeration, they found salinity to be an important factor in reducing turbidity, as was high organic composition of the sediment to be dredged. Their prediction of rapid settling of turbidity during dredging is in good agreement with field observations. For example, when transported and dumped from barges, cohesive blocks of material such as result from clam-shell type dredging or sediment-water slurries resulting from hydraulic dredging, reach the bottom within 20 to 35 seconds at shallow water disposal sites (Bokuniewicz et al., 1978). Individual particles may take 10 to 15 minutes to settle. Thus turbidity reaches ambient levels very quickly after the disruptive event.

Schubel and co-workers (1978) investigated the turbidity generated by open-water pipeline operations. They found that 97 to 99 percent of the total mass of sediment discharged settled rapidly to the bottom within a few tens of meters of the point of discharge. The other 1 to 3 percent was dispersed as a turbidity plume. Pipeline operations consist of hydraulically transported sediment slurries, and probably represent a worst case condition for dispersal of particulates. Thus clam-shell dredge and barge operations may be expected to result in lesser turbid losses.

This is not the case for deep ocean disposal. Pequegnat (1978) describes material dumped in deep water as falling through the photic zone as a hydraulic jet. At about the depth of the pycnocline, the jet will have entrained enough water to suffer hydraulic collapse. Thereafter, the particles continue to fall with velocities as might be characterized by Stokes' Law for individual particles or agglomerates (.02 to 2 cm/sec). Agglomeration can be attributed to physicochemical flocculation and biological processes. Thus particles of differing sizes and densities would fall at different rates, resulting in large-scale dispersion of the dredged material.

A secondary mechanism contributing to the dispersal of material during the disposal operation is the creation of a bottom surge. The impact of the material with the bottom generates a surge which spreads radially outward (Bokuniewitz et al. 1978) in the case of point dumping, the deposit will take the form of a circular ring whose diameter depends on the water depth and bottom morphology and composition. Typical values are on the order of hundreds of meters.

Erosion of Dredged Material following Open Water Disposal

Once emplaced, there are a number of factors affecting the physical stability of the dredged material deposit. The surface of the dredged material may be resuspended by benthic organisms, tidal currents or storm events. The relative importance of these processes depends on the composition of the materials, the depth of the overlying water, and the physical regime.

Several groups have investigated the resuspensory mechanisms at work in the vicinity of the New York Bight dredged material disposal site. Allen and Cochrane (1976) used radioisotope disequilibria and X-ray data to characterize biological reworking of sediments in the Bight apex. From their radioisotopic data and from the laminations in the radiographs, they inferred that the area is characterized by episodes of rapid sediment accumulation separated by periods of relative sediment stability.

The tidal influence in resuspending sediments was investigated by Young et al. (1981). They found the time scales of suspensory processes to correspond to the periods of surface waves (seconds) and storms (days), and concluded that tidal motions appear to have only a weak influence on near-bottom suspended load. Storms then appear to be the major factor in resuspending dredged material at shallow ocean sites. Bokuniewicz and co-workers (1977) concluded that storms were capable of suspending up to the top two feet of a dredged material mound in Long Island Sound. The work of Stubblefield et al. (1977) and Freeland et al. (1979) suggests that the mud deposits observed in the vicinity of the Mud Dump Site and Christiaensen Basin imigrate on a seasonal basis, with the dredged material mound serving as a source of fine material to the surrounding area.

A comparison of bathymetric records from 1936 and 1973 (Freeland and Merrill, 1976) shows that 87% of the dredged material barged to the Mud Dump during that period can presently be accounted for. Efforts have been made to determine whether the material at the site is as deposited, or whether transport and possible subsequent deposition has occurred. Several cores taken by Dayal and co-workers (1981) suggest that there has been some loss of fines from the pile and some migration of neighboring sands onto the shoulders. However, the location and depth of the cores taken render these observations inconclusive.

Little can be said of the resuspension of materials deposited in the deep ocean. In general, conditions are much more quiescent than shallower waters. However, the ability to mound deposits in the deep ocean has not been established for reasons mentioned above; the question of subsequent resuspension is largely academic.

Effectiveness of Capping

Although the losses from the dredged material mound do not appear to be major, there does exist some sediment material whose contaminant nature makes it desirable to avoid any degree of resuspension. In such a case, capping is viewed as a suitable precaution. Once capping has taken place, it would be the clean cap material which would be subject to physical suspension rather than the contaminated material below. Preliminary results in a cap stability study being performed at the New York Mud Dump (Young, 1981) indicate that there is no disturbance of the cap in response to tidal oscillations. Efforts have been made to establish chemical signatures to distinguish between cap and sediment material in order to establish the stability of the cap over longer time periods.

The capping of open-water deposits has been studied by the New England Division of the U.S. Army Corps of Engineers (Morton, 1980). They compared two similar dumpsites, one capped with fine-grained material, the other with sand. Neither showed erosion of the cap material until the occurrence of a hurricane, when some losses were noted from the fine-grained cap. In view of the generally greater erodability of sands over cohesive fine-grained material, the investigators concluded that the fine-grained cap had probably retained surface irregularities after deposition, thus subjecting it to greater erosion.

Contaminant Impacts of Open Water Disposal

The second concern with respect to the disposal of dredged material in open water is the potential release of contaminants that may accompany the physical disturbance of the sediments or may occur subsequent to its deposition at the disposal site. As was discussed in the main body of this report in the section on chemical mechanisms, there are three major classes of contaminants with distinctive chemical properties: nutrients--which are highly soluble, chlorinated hydrocarbons--which have a low solubility, and trace metals which vary in their solubility. The concentration of metals in solution in a given environment is not directly a function of their solubility but rather is governed by a number of mechanisms by which they become associated with fine particles, and especially with their organic component. Among the metals, there are those like Fe and Mn that are soluble in reducing conditions, and tend to be present in large concentrations in the interstitial waters of reduced sediments. The other trace metals are largely insoluble under such conditions. Although such metals might be subject to oxidation and dissolution during mixing, their association with particulate material makes these reactions less than straight forward.

Early work involving suspensions of sediments indicated a potential release of trace metals and nutrients to the water column. Chen et al. (1976) measured elevated levels of Co, Cu, Pb, Fe, Mn, Zn, N, and P in such suspensions, although longer-term field studies showed only Fe, Mn and N remaining elevated. Such work indicated that a laboratory simulation test could reproduce dumping conditions and led to the development of the elutriate test, as outlined by Jones and Lee (1978).

To date, however, there have been no significant releases of trace metals observed during disposal (Wright, 1978), although this may change as analytical techniques are improved. Field investigations at Eaton's Neck, Long Island (MSRC, 1977) and Elliott Bay, Washington (Baumgartner et al., 1978) have demonstrated temporary elevations in nutrient concentrations accompanying disposal. However, the return to pre-disposal ambient levels occurred within minutes. PCB levels at the Elliott Bay Site (Pavlou et al., 1978) rose substantially for a few minutes, remained at intermediate levels for approximately one week and returned to pre-disposal levels within one month. This suggests that repeated dumping could have an impact on water-column concentrations of PCBs.

Post-disposal monitoring of the Elliott Bay site showed no significant elevations of trace metals in the overlying waters, although manganese, phosphate and ammonia were present in high concentrations in the interstitial waters (Sugai et al., 1978). Investigations at the New York dumpsite by Dayal et al. (1981) suggest that there may be some losses of metals from the sediment. They postulate that transport of fines from the site or dilution of sediment concentrations by encroaching sands may explain their observations. A report by Mukherji et al. (1981) does indicate that metals are elevated in particulate matter in the layer of water immediately above the dredged material. The similarity of the Fe, V, Mn, Cu, Cd and Pb to Al ratios with crustal composition suggests resuspension of sediment particles. The elevated concentrations of Si and PO_4 that occurred in the bottom waters in the days following the dump are indicative of the escape of pore waters during compaction.

It has been suggested that capping of material disposed of in shallow ocean environments might serve to effectively isolate contaminants from the overlying waters. A cap would prevent resuspension of sediment particles by physical and biological mechanisms and would also provide a buffer zone within which those metals soluble under reducing conditions, namely iron and manganese, could precipitate.

In deep ocean disposal, because of the much longer transit times and greater dispersion of particles, the processes associated with dumping play a much greater role than they do at shallow water sites. In the course of dispersion, almost all of the surface area of the particles will be exposed to the water, and hence to an oxidizing environment. Nearly all of the nutrients will be dispersed through solution, but the dilution effect is expected to obscure any rise in concentration (Pequegnat, 1978). PCBs and other chlorinated hydrocarbons are likely to reach a partition equilibrium between the sediment particles and the water, although this equilibrium is apt to shift as the particles are biologically reworked during their descent. Likewise, metals are apt to undergo alterations subsequent to the initial oxidation reactions as a result of biological processes. Regardless of the specific reactions that may occur during the course of deep ocean disposal, the net result will be maximum dispersion and dissolution of contaminants.

Biological Impacts of Open Water Disposal

Although many possible impacts of dredging and dredged material disposal have been identified, it is not presently possible to accurately evaluate the extent and magnitude of these impacts on the ecosystem. Attempts to do so are thwarted by the complexity of ecological systems. Without an adequate understanding of how the natural system functions, scientists can not be expected to know the effects of anthropogenic perturbations to the environment. In addition, many anthropogenic influences are acting in combination and their effects cannot be readily separated. This results in lack of a clear evaluation of impacts and their causes. Many impacts have been observed and possible explanations have been suggested, but very little can be stated with certainty.

For the purposes of discussion, biological impacts can be separated into three categories: 1) effects of the addition of suspended material and nutrients to the water column, 2) effects of the disruption of benthic habitats, and 3) the effects of increased contaminant load. Material suspended in the water column can have both physical and chemical effects on the biota and it is often difficult to distinguish between the two. Temperature, dissolved oxygen, salinity, water column stability, available light, nutrient and contaminant loads may all be affected by the introduction of dredged material to the water column (Stern and Stickle, 1978). While water column impacts tend to be fairly rapidly dispersed, benthic impacts tend to be localized and persistent. Benthic organisms may be destroyed by burial or by dissolved oxygen depletion immediately after dumping. In the absence of a significant change in sediment type, populations can quickly recover. On the other hand, addition of contaminants or changes in substrate can have long-term detrimental impacts on the benthos and those parts of the system dependent upon them.

Water Column Impacts

Suspended Particulates

High levels of suspended matter in the water column have been shown to affect all levels of the ecosystem. Turbidity can restrict the light available for photosynthesis and primary production while suspended materials can contain large quantities of nutrient that stimulate growth. Little is known about how the time necessary for algal stimulation relates to the duration of dredging related turbid events, but most investigators consider that reduced water transparency is of too short duration to have significant effects on primary production (Stern and Stickle 1978).

Peddicord (1980) and McFarland and Peddicord (1980) measured lethality associated with suspended sediment concentrations on several marine and estuarine organisms, including bivalves and fishes. They observed mortalities at concentrations ranging from 2 to 20 grams per liter (2,000 - 20,000 ppm) over 21 day exposures. Field measurements of the turbidity associated with dredging have typically been less than one gram per liter (1,000 ppm) (Wright, 1978). Thus it would seem that such a turbidity level would not adversely affect most estuarine or coastal organisms, except in the case of such sensitive systems as coral reefs (Roy and Smith 1971).

Oxygen Demand

Reduction in the dissolved oxygen content of receiving waters has been associated with high levels of suspended particulate matter. Berner (1951) observed low oxygen levels in the lower Missouri River and attributed this to the high turbidity levels. Brown and Clark (1968) investigated continuous dredging in highly contaminated tidal bays in Staten Island and New Jersey, and found that the dissolved oxygen levels at these sites were 16 to 83 percent lower than during non-dredging periods. However, in situations where dredging and disposal are intermittent occurrences, such severe effects have not been noted.

No single factor acts independently of all others, and the oxygen demand of dredged material should be considered as it might superimpose on pre-existing conditions. Lee et al. (1975) calculated that the introduction of dredged material with an oxygen demand of from 1.6 to 2.5 mg O_2/m^3 sediment to water which already had an oxygen level of 2 mg/l or less could lead to a depletion of oxygen, if the proportion of water to sediment were less than 100 to 1. Such low ambient concentrations of oxygen are not unusual for the New York Bight during the summer, and the disposal of dredged material may have been a contributory although almost certainly not a major factor in the major anoxic event of 1975 (Segar and Berberian, 1976).

Nutrient Release

Biological production in coastal waters is generally limited by the nutrient concentrations, especially by available nitrogen. Thus a large increase of nutrients within the euphotic zone could cause a large increase in photosynthesis and exacerbate oxygen demand. Segar and Berberian (1976) calculated the inputs of organic carbon and total nitrogen to the New York Bight from several sources: sewage sludge, dredge spoil, river and atmospheric inputs. They showed that the organic carbon introduced by dredge spoil dumping is considerably less than primary production in the area and about half of the total riverine input. Nitrogen is also supplied by dredged material. Segar and Berberian (1976) calculated that the total nitrogen input to the New York Bight from dredged material dumping exceeds that supplied by sewage sludge, although the quantity is only roughly half of that supplied by rivers. However, dredged material nitrogen is rapidly transported to the bottom, undergoing very little mixing within the euphotic zone. Thus it is difficult to estimate what fraction of the nitrogen is available, but in all likelihood the quantity is small compared to the river input and is not likely to be a major factor in generating the excessive primary production which leads to low oxygen concentrations in the region.

Two other effects that dumping may have on the nitrogen cycle are the generation of possibly toxic concentrations of ammonia and physical disruption of the water column structure which might cause transport of nitrogen through the thermocline and mixing into surface waters.

Ammonia may stimulate productivity or exert toxic effects depending on concentration. Lee et al. (1975) and Chen et al. (1976) noted large-scale ammonia releases with the resuspension of bottom sediments, but field studies report that the observation of elevated levels are of short duration (Baumgartner et al., 1978).

Nutrient loading may have more severe effects in deep waters than in the coastal ocean (Peguegnat, 1978). First, because of the greater dispersion of the dumped material, a greater percentage of the nutrients may be put into solution. Second, the normal paucity of nutrients in the deep ocean may have led to less flexibility in the responses of the biological systems to variations in nutrient concentrations (Pequenat, 1978). Even though adverse effects from increased productivity in the deep ocean are difficult to envision, the fact remains that as organisms die and sink, oxygen uptake results. Thus if surface productivity is increased significantly where there is poor renewal of deeper waters, significant oxygen depletion could occur.

Trace Metal and Organic Contaminant Effects

Other compounds which may be released to the water column as a result of the disposal of dredged material are metals and organics such as pesticides and other chlorinated hydrocarbons (CHCs). These compounds are of interest because of the possible toxic effects they may have on the biota.

Calabrese et al. (1981) investigated the effects of uptake of toxic heavy metals on some marine animals of the New York Bight. They found that the degree of toxicity varied with salinity, salt form of the metal, life stage of the organism and species. Early life stages showed a greater sensitivity to mercury and silver than to cadmium, whereas the order of toxicity was different for adult organisms, cadmium producing the most severe effects. Differences in bioavailability were observed for different salts of the same metal. Anadramous fish species showed a greater resistance to toxic effects than did purely marine species. The authors concluded that early life stages show acute sensitivity to low levels of toxic metals, and that in adults the sublethal stresses induced by exposure to toxic metals places an abnormal demand on the animal's energy reserves, rendering it more susceptible to environmental stresses. Such work has implications not only for the timing of dredged material disposal, given the seasonal nature of biological susceptibility, but also reflects some of the problems inherent in bioassay testing, that is, appropriate choice of species, life stage and test conditions.

Trace metal levels in phytoplankton and zooplankton of the New York Bight have been determined by Grieg et al. (1977). They concluded that plankton are the most important living elemental reservoirs, in terms of turnover, physical transport and redistribution processes. However, an important aspect of this and similar work that remains unresolved is the distinction between uptake of dissolved and particulate trace metal species. This area must be further investigated before the effects of dredged material disposal can be fully assessed.

A number of organic contaminants were identified as being of concern in the New York Bight (O'Connor and Stanford, 1979). The three major classes of compounds, chlorinated pesticides, polychlorinated biphenyls and polynuclear aromatic hydrocarbons, have been identified in the water, suspended sediments, deposited sediments and biota of the Hudson/Raritan Estuary and the New York Bight. While the major source of organic contaminants to the estuary is the Hudson River flow, sewage sludge and dredged material represent the major input to the Bight (O'Connor et al., 1981). O'Connor et al. found ubiquitous contamination of biota with these compounds, although at relatively low levels. The only instance of organic contamination of a food species to exceed Food and Drug Administration limits occurred with the striped bass in the Hudson River. This is not to say that there are no ecological effects of organic contamination.

Rapid uptake rates and large bioaccumulation factors for organic contaminants have been demonstrated for phyto- and zooplankton (Peters and O'Connor, 1981), in some cases exceeding that predicted on the basis of partition coefficients. Feeding experiments by these authors (Peters and O'Connor 1981) indicated that PCBs are not biomagnified in the food chain; elimination of PCBs by striped bass whose body burdens were obtained from food sources was more rapid than by fish that accumulated PCBs directly from the water. Thus, although a large body of literature exists describing both the distribution and toxicity of organic contaminants, their impacts on existing ecosystems are not fully understood and merit ongoing research.

Benthic Impacts

The impact of dredged material on benthos has been historically more well documented than have water column effects, having garnered more attention both because of the obviousness of the effects and the availability of tools to measure them.

Change in Substrate

A number of investigators have demonstrated significant decreases in species diversity and population density at dredged material dumpsites. Pearce et al. (1976, 1977, 1981) surveyed the New York Bight seasonally and observed that stations having sediments with high pollutant indices and elevated organic matter were generally populated by benthic assemblages of low species diversity. They noted the predominance of opportunist and pollution tolerant species such as Nucula proxima and Pherusa affinis and the absence of highly sensitive amphipod crustaceans in highly stressed areas such as the sewage sludge and dredged material dumpsites (Steimle et al., 1981).

Boesch (1981) examined the implications of community structure and benthic processes in the New York Bight, and concluded that the ability of the Bight to sustain harvestable living resources has been impaired as a result of man's impact. Boesch studied a gradient from the Christiaensen Basin down the Hudson River Valley along which sediment properties remained relatively constant, but contaminant levels declined away from their source. Near the sewage sludge and dredged material dumpsites, he found few macrobenthic species and high densities of the polycheate Capitella capitata. He suggests that this high standing crop might be attributable to organic enrichment or to predator exclusion by hypoxia or toxicants. He also noted the absence of sensitive amphipod species at the contaminated end of the gradient.

It is often quite difficult to distinguish between the effects of physically and chemically disruptive events on benthic communities. The changes in sediment type that result from disposal and the stress of continual burial can drastically alter the composition of benthic communities at a dumpsite. Maurer et al. (1978) tested in the laboratory under worst-case conditions the ability of several important species to migrate vertically after burial. They found that burrowing activity depended on sediment type, amount of sediment load, duration of burial and temperature. In general, benthic animals showed high mobility in material resembling their native sediments. Differing materials, whether higher or lower in sand than the native sediment tended to inhibit burrowing. In some cases, burrowing was inhibited by the toxic effects of sediment sulfides or ammonia. Juvenile bivalves showed an acute sensitivity to ammonia while hydrogen sulfide was highly toxic to several species of amphipod.

Contaminant Effects

The effects of contaminant uptake from sediments are difficult to appraise unless they result in mortality. There is evidence that individuals of a given species can develop a tolerance for certain contaminants in a stressed environment. Litchfield et al. (1981) isolated strains of cadmium resistant bacteria from sediments of the New York Bight. Whether the increases in contaminant load within a given species are amplified in the food chain, and whether increased body burdens have ecological repercussions are questions receiving continuing attention.

Several authors have attempted to compare the body burdens of contaminants from organisms living within the dumpsite area to those from less contaminated areas. Surveys by Pearce et al. (1977), Grieg et al. (1977), Wenzloff et al. (1979) have demonstrated an accumulation of trace metals in benthic organisms at dumpsites within the Northeast. Koons and Thomas (1979) measured whole body concentrations of $C_{15}+$ hydrocarbons to be 2 to 3 orders of magnitude greater at the Mud Dump Site and sewage sludge sites than in the Hudson estuary or in the mid-shelf region. A recent bioaccumulation study using mussels (Mytilus edulis) demonstrated accumulation for mercury and cadmium greater than at other stations; PCB levels were not significantly different and DDT concentrations were below detection limits (Koepp et al., 1982).

Studies using more mobile species have rarely detected significant differences in organisms from within and outside the dumpsite. Trace metals in finfish have been found to be higher in the inner Bight than for other points on the Atlantic Coast (Grieg and Wenzloff, 1977; Hall et al., 1978) although no specific correlation exists for the dumpsite.

In order to address the question of potential ecological impact of these higher contaminant levels, it is important to understand the mechanisms that control the levels of accumulation in organisms. The work of Neff et al. (1978) indicated that metals in organisms did not correlate with sediment metal concentrations, suggesting a variable partition coefficient. More recent work (O'Connor and Raichlin, 1978) suggests that organisms are able to regulate metals uptake; the regulatory mechanisms seem more refined for metabolically utilized metals such as copper or iron, than for non-essential metals such as cadmium and lead, rendering the latter more potentially toxic. Still to be answered is the question of whether bioconcentration occurs primarily from sediment or from food. Understanding the bioregulatory mechanisms will be essential in predicting the impact of increasing contaminant inputs to New York Bight.

Effectiveness of Capping

While it is not clear whether water column effects or sediment effects have a greater influence on the biota over equivalent time spans, it is fairly clear from the preceding discussion that the exposure to contaminants in sediments is of far greater duration than that in the water column. Although it has not yet been determined just how serious these effects might be, there is available a tool which has been demonstrated to mitigate the consequences of the disposal of contaminated material, that is, capping. The physical and chemical effectiveness of capping highly contaminated material with cleaner material have been discussed previously. Recently, bioaccumulation studies have demonstrated success in isolating sediment-borne contaminants from organisms (Koepp et al. 1982). While the criteria for determining which material is most highly contaminated is constantly under debate, capping is receiving widespread approval as a means of mitigating long-term effects of the disposal of contaminated dredged material.

Open Water Disposal in New York

Since 1914, the major portion of the material dredged from New York Harbor has been disposed of at the Mud Dump Site. The Mud Dump Site is an area one mile by two miles and is located approximately 5.5 nautical miles offshore New Jersey and 9.6 nautical miles offshore Long Island, in an average depth of 24 meters. As a result of the Marine Protection, Research and Sanctuaries Act of 1972 as amended in 1977 and the Environmental

Protection Agency's Ocean Dumping Regulations and Criteria, interim disposal sites were designated and environmental studies initiated with the intent of eventual final designation of disposal sites. The Mud Dump, Christiaensen Basin and the Outer Apex Site (Figure C1) were selected from among many potential locations for study preliminary to final designation (IEC, 1981). Other sites considered and rejected as alternative disposal sites included current cellar dirt, acid wastes, sewage sludge and industrial wastes disposal sites, as well as deep ocean sites, the 106-mile site.

The Mud Dump, Christiaensen Basin and the Outer Apex Site were evaluated with respect to geographic, physical, biological and economic considerations. The Outer Apex Site was deemed least acceptable. Although it is outside navigational traffic lanes and recreational fishing areas, it would require closing additional areas to shellfishing, thus interfering with the growing ocean quahog fishing. Moreover, round-trip transit time would be increased by 4 hours over that to the current site, resulting in transportation costs 3.3 times higher than present (IEC, 1981). It was felt that this added expense was not justified by any clearly foreseeable environmental benefit.

The Christiaensen Basin Site has the advantage of being the deepest of the three considered, giving it the greatest long-term capacity. Although it has not been used as a waste disposal site, this natural reservoir has been significantly impacted by material from the sewage sludge site; its present-day sediments are high-organic, unconsolidated fine sediments (Freeland et al., 1979). Perhaps as a result of contaminant migration from the Mud Dump and sewage sludge sites, biomass and species diversity at the Christiaensen Basin are low and pollution tolerant deposit and suspension feeders predominate (Pearce et al., 1976). The Basin is within the shellfish closure area and supports little recreational fishing; hence the likelihood

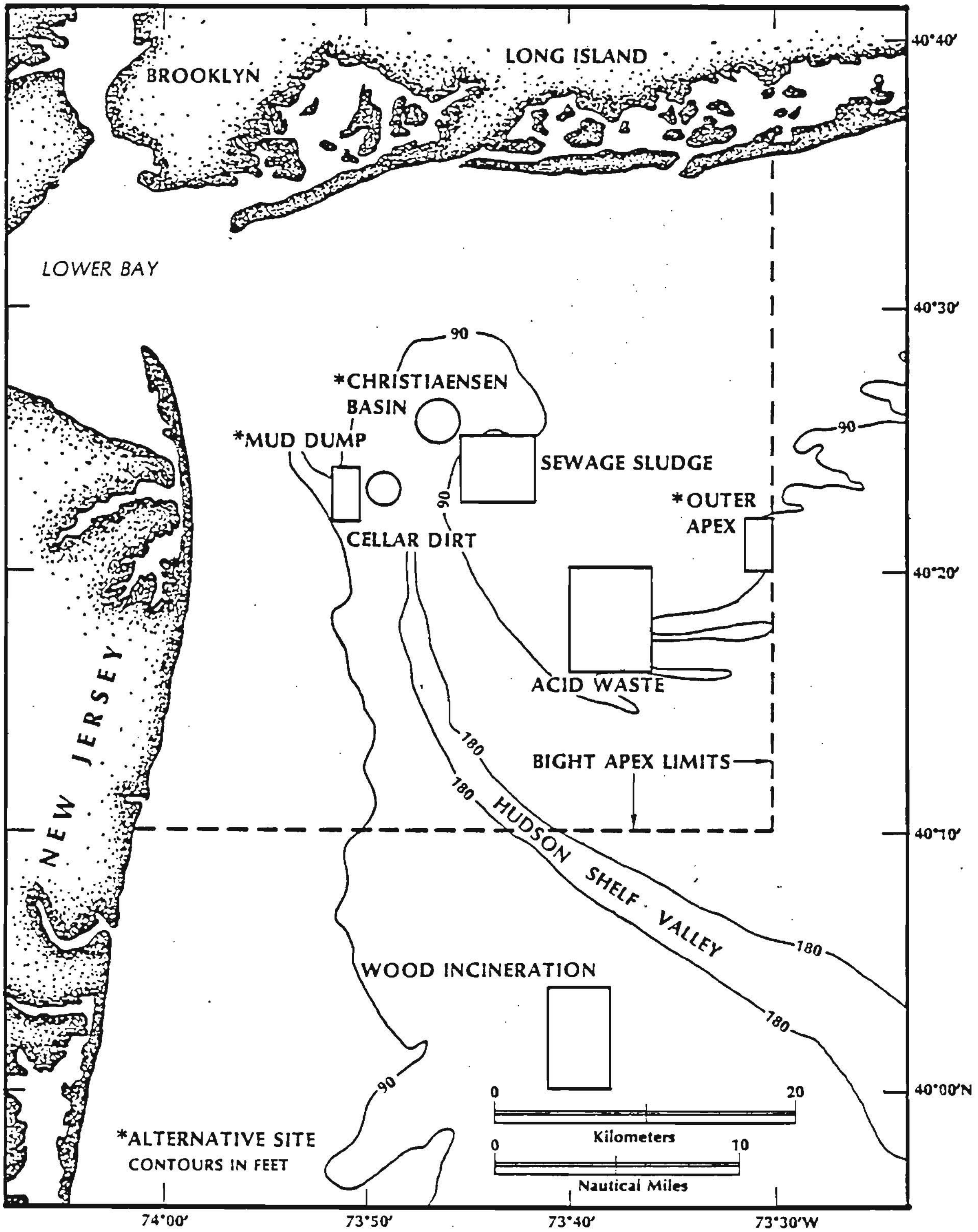

Figure C-1. The Mud Dump and alternative dredged material disposal sites in the New York Bight (I.E.C. 1981) of transference of toxic substances or pathogens to human populations is very low. Dumping at the location would not be expected to pose navigational hazards to harbor use and the costs of utilizing this site would be only marginally higher than for the Mud Dump, given the slightly greater transport distance.

Overall, the Christiaensen Basin was judged to be the most favorable site, its advantage over the Mud Dump being primarily its depositional environment and greater depth. However, it was decided to recommend that the Mud Dump be awarded final designation due to its prior listing of use, all other factors being nearly equal.

The Mud Dump has a demonstrated capacity to retain dredged sediments (Freeland and Merrill, 1976) and a biota impoverished as a result of frequent dumpings. It is closest to the source of the sediment making transportation costs lowest of the sites considered; average costs in 1976 were \$1.32 per cubic yard (Conner et al., 1979). In 1981, costs were \$2.99/yd^3 (U.S. Army COE, 1982). Thus it was concluded that the Mud Dump is a suitable disposal site, and even though the Christiaensen Basin might be marginally better, the advantages it might offer are not sufficient to warrant relocating the dumpsite.

Historically, the northwest corner of the present Mud Dump, being the closest to the port, has been preferentially utilized and it is currently at capacity. Another quadrant is being reserved for the capping of contaminant materials and related studies. Present estimates for capacity of the site are 98 million cubic yards (U.S. COE, 1982). It is obvious then that the final designation of this site is not a long-term solution to the dredging situation. In time, either open-water dump facilities will need to be expanded, or other disposal/dredging management options must be implemented, or both.

Part 2 Borrow Pit Disposal of Dredged Material

As early as 1973, it was suggested (Carpenter, 1973) that sand and gravel mining pits might well serve as disposal sites for contaminated material. In a report to the Dredged Material Research Program, Johannes et al. (1976) examined the technical feasibility of containing dredged material in such pits. In light of the large demand for sand and gravel construction materials in the New York Metropolitan area (13 million cubic yards annually is projected for the upcoming decade) such an operation would, in effect, kill two birds with one stone. In recognition of the attractiveness of this option, and in spite of the fact that, to date, it has been less intensively studies than the other two options considered in this section, the MITRE Report (Conner et al., 1979) judged capped disposal in borrow pits feasible for large volumes of material dredged from the port of New York and New Jersey.

The sites under consideration for pit disposal are in the Lower Bay, where most of the bottom is sand (Jones et al., 1979). The Bay west of Ambrose Channel is coarser in composition, and it is predominantly from this area that construction materials are commercially extracted. Current engineering limitations make excavation from below 100 feet infeasible.

The pits that are presently in existence are on the order of 40 feet deep (Swartz and Brinkhuis, 1978). If capped disposal of material were to become routine, excavations would have to be deeper, as the material at the bottom of the pit would become irretrievable through burial. These pits have been shown to trap fine-grained sediments, with which most contaminants are associated. Sedimentation rates for two of the pits have been calculated as 5 cm/yr and 9 cm/yr (Swartz and Brinkhuis, 1978). Studies by Swartz and Brinkhuis (1978) have indicated that anoxic conditions prevail in the pits as a result of this trapping of fine-grained, high organic material and the relatively quiescent conditions within.

There has been concern that material to be placed in the pits might be lost during disposal. Measurements have been made of the amount of material remaining in suspension during disposal, showing that as more than 5% of the sediment is dispersed through suspension (Schubel et al., 1978). In Long Island Sound, Gordon (1974) observed less than 1% of material to remain in suspension long enough to be dispersed.

Another mechanism for loss of dredged sediment is a bottom surge. Almost all of the material spreads out in a dense, thin surge, as it is deposited on the bottom. The thickness of the surge and the distance it travels depend on the amount of sediment, its water content, and the rate at which it is released. Experimental dumps (Bokuniewicz, 1981) have measured surges between 2 and 14 meters thick, whose distance of travel ranged from 70 to 185 meters. Bokuniewicz and others (1978) have calculated the amount of energy available in such a surge and have concluded that the surge may be capable of escaping pit walls of 4 to 5 meters. In order to prevent the escape of material from the pit, dumps must be positioned no closer than 100 meters from the rim and pits should not be filled more than 4 to 5 meters from the top.

Once the material is emplaced in the pit, one must consider whether it will remain there until the point at which it is capped. As has been mentioned, the pits are very efficient sediment traps, in fact pits of as little as two meters in depth have been found to accumulate sediment (Swartz and Brinkhuis, 1978). Since, due to surge considerations, the pit can only be filled to within 4 meters of ambient sea floor, it is expected that they, too, will be efficient traps. A comparison of the thickness of mud deposited, sediment trap data, and particle fluxes (Bokuniewicz, 1981) all give similar sedimentation rates.

The depth of tidal resuspension for the Inner Harbor has been found to be on the order of 1 to 3 mm (Olsen, 1979). However, tidally induced salinity changes within a pit have been observed to be considerably less than those at its rim (Bokuniewicz, 1981), suggesting that tidal influences and hence tidal resuspension, are less. Bokuniewicz (1981) measured the changes in the vertically integrated suspended sediments over the pits during a tidal cycle. He found that if all the observed changes were attributed to resuspension, then a layer of .14 mm had been suspended. Some of the excess turbidity may have been advected into the area, however, and the actual resuspension may be even less. Storms may contribute to the suspension of the top few millimeters of sediment, as evidenced by the greater trapping rate of sediment traps during the months of February and March (Bokuniewicz, 1981).

Once the cap is emplaced, these same mechanisms act on uncontaminated sands rather than the dredged material itself. As discussed above, the mud cannot be higher than within 4 or 5 meters of the rim, thus requiring a cap of several meters in thickness. None of the processes discussed is capable of penetrating a cap of this thickness, as tidal resuspension is on the order of millimeters and storms on the order of centimeters. (Sanders and Komar, 1975).

It is also highly unlikely that benthic organisms would be able to penetrate the cap and disturb the sediments below. Studies report that 50 - 85% of the benthic macrofauna is found in the upper 10-15 cm of sediment, with some species such as bivalves able to burrow to depths of 30-60 cm (Myers 1977; Pratt and O'Connor 1973). Gandarillas (1981) conducted a survey of the species of the Lower Bay and found polychaetes Glycera and Nereis to be the most abundant. These species are known to burrow to 30 cm. Lobster (Homarus americanus) burrows extend up to 20 cm into mud sediments and 10-15 cm in sand (Cobb, 1976). No other deep-burrowing crustaceans have been reported in the area of the pits (Brinkhuis, 1980).

Having established that there is little likelihood of loss of material from the pit before capping, the release of contaminants during consolidation merits some attention. Before the sand cap can be placed, the dredged mud must consolidate under its own weight, expelling pore waters. If a clam-shell dredge is used to remove the sediments, then the volume of pore water expelled would be no more than 5% of the volume of the deposit (Bokuniewicz, 1981). Consolidation is anticipated to require three months.

The dewatering phase is expected to be the largest release of dissolved contaminants. Once the material is capped diffusive fluxes will be exceedingly small, and fresh groundwater is not expected to seep across the sea floor at the location of the pits. Most of the metals are bound to the sediments as reduced compounds. Once the sediment is emplaced, bacteria quickly oxidize the organic matter and create an oxygen-free microenvironment. In this state, the trace metals, such as Cu, Zn, Cd, Pb, Hg are insoluble and highly immobile. Iron and manganese form soluble sulfur compounds and migrate to the surface where they are oxidized and precipitate. In the course of their precipitation, they co-precipitate any dissolved metals that may be present there (Khalid et al., 1978) thus preventing their release into the water column. The mobilization of toxic organics, then, is more potentially problematic, and it is this area that merits more research.

The expulsion of pore waters will also cause a release of excess nutrients into the overlying waters. Nitrogen compounds are of the greatest concern. Bokuniewicz (1981) has calculated the expected release of ammonia for a sample pit. If a 200 m wide pit contains 2 m of mud covered by 1 m of sand and settles 10% in 100 days, then 2.5×10^7 liters of pore water will have been expelled. If the waters contain 6000 μm/liter NH_4^+ (very high) then the total release of ammonia will be 1.5×10^{11} μm. The contribution of NH_4^+ from the Hudson River is 5×10^9 μm/hr (O'Connors and Duedall, 1975). Thus the total release of ammonia from this pit over 100 days is approximately the output of the Hudson for one day.

Although the release of dissolved chemical species seems small, the potential effects on benthic organisms should not be overlooked. The initial colonizing organisms will be polychaetes and isopods/amphipods. The burrowing of these organisms might change equilibrium concentrations of chemical contaminants at the surface. These organisms might concentrate the contaminants, and subsequently serve as food for other organisms. Two studies conducted at the mud dumpsite (Pequegnat et al., 1980; Tifft et al., 1979), where similar conditions exist, concluded that the concentrations of toxic metals and chlorinated hydrocarbons in organisms were not localized at the disposal site. The concentrations they observed were roughly equivalent to contaminated areas in the harbor.

Thus it appears that capping dredged material within borrow pits is an effective means of isolating contaminants from the environment. The question that presents itself, then, is how long-term is this containment, or, what is the stability of the cap? A sand cap is a denser layer than the mud upon which it lies. Yet is known that such configurations can persist for very long periods of time, as they are preserved in the geologic record. For an instability to manifest itself, the shear stresses along the interface must be greater than the shear strength of the layered deposit. Bokuniewicz

(1980) calculated that, for the sand/mud layers in the pits, the deposit would be unstable if the irregularities in the interface exceeded .2 m. It is unlikely that a deposit could be constructed with irregularities less than this value, but the rate of deformation can be minimized by, for example, insuring that the mean level of the sand surface be well above the tops of the irregularities in the sand/mud interface.

It has been postulated that the inherent instability might be aggravated by the generation of gas bubbles within the anoxic muds. It is, however, the opinion of low-temperature geochemists that, at the rate of methane released observed in such muds, the bubbles will dissolve in the under-saturated pore waters of the cap before reaching the sand-water interface (Bokuniewicz, 1981).

In order to address these currently unresolved questions, there is in progress a pilot dump in the CAC (Construction Aggregates Corporation) pit on the West Bank of the lower bay. A berm was constructed of Ambrose Channel sand in order to create a smaller compartment within the pit. The construction of this berm was also a valuable exercise to test the ability to accurately place material within the pit.

This pilot project is currently at a standstill while awaiting the legal approval for material to be confined within the pit. The ideal material to be disposed should bear enough contaminants to serve as markers, so that the material can be identified in case of failure or escape, yet be clean enough for open water disposal, as that is the situation that would exist should a failure occur (Bokuniewicz, pers. comm.).

Judged on theoretical considerations, capped borrow pit disposal bears much promise for the disposal of contaminated material in the New York Bight.

The questions that need yet to be answered can be addressed only by a field pilot project.

The currently existing suitable pits have a finite capacity of about 30 million cubic yards (Bokuniewicz, 1981). It is clear that not all of the material dredged from New York harbor could be disposed of in this manner. Even if they were utilized for only a fraction of the material (e.g. the most contaminated), they would have a finite lifetime. However, a successful demonstration in the field, along with an increase in sand and gravel demand, could provide an impetus for the creation of new pits. Such a combination of mining and disposal practices may someday be environmentally and economically beneficial.

Part 3 Contained Disposal of Dredged Material

Contained disposal of dredged material is widely used in the United States in areas where open water disposal is undesirable because of water quality impacts, long transport distances or in situations where shoaling of channels would be significantly increased if dredged material were unconfined. Containment areas can be located in many environments including upland, wetlands, shallow protected water and even deeper unprotected water. Impacts and benefits of contained disposal also vary widely and are dependent on a number of site specific factors. However, many aspects of this class of disposal options are common regardless of the site chosen. In this section the factors common to all contained disposal are discussed first, followed by specific problems and research efforts in the New York area.

The majority of the research to date on contained disposal has been as a result of the U.S. Army Corps of Engineers Dredged Material Research Program (DMRP). Four phases of the disposal process are covered in synthesis reports of DMRP results. Palermo et al. (1978) describe the design, operation and management of containment basins. Chen et al. (1978) describe the effluent and leachate problems associated with existing disposal sites and report on laboratory studies of leaching from different types of dredged material. Suggestions for techniques to control effluent and leachate are also made. Haliburton (1978) discusses results of research into dewatering and densification of dredged material and Walsh and Malkasian (1978) report on investigations into productive uses for containment sites.

In the following disucssion of contained disposal, five phases of the dredging and disposal process are discussed:

1) selection of suitable sites
2) dredging, transport and filling of the basin
3) sediment control
4) contaminant control

Selection of suitable sites will be dealt with last since most of the selection criteria are based on the intended basin design and nature of the dredged material.

Dredging, Transport and Filling of the Basin

There are two basic types of dredging equipment currently in use in the United States (Little 1973). Hydraulic type dredges, including hopper, cutterhead, and dustpan dredges, operate by entraining water and sediment together to form a fluid slurry that can be pumped into a barge, holding tank or disposal area. A great deal of water is incorporated in the dredged material and must be eliminated for efficient disposal. The second type of dredge, the clam-shell, operates by physically scooping sediment from the bottom. Dredged material is then placed directly into a barge or disposal site with minimum entrainment of excess water. Dredging by clam-shell techniques is typically somewhat slower than hydraulic dredging although this is offset somewhat by the fact that much less water must be moved.

Containment basins are frequently filled directly using hydraulic techniques unless the basin is not located close enough to the dredging site. In these cases, material must be barged to a rehandling site where it is dumped, dredged a second time, and pumped into the basin. It is possible to use clamshell type dredges to fill a containment basin although some sort of spreading device is then necessary to distribute the dredged material evenly throughout the basin.

Location of containment basins in inland areas requires additional transport facilities. Hydraulic techniques can be used to fill basins up to several miles away but booster pumps are required at frequent intervals depending on the nature of the dredged material and the dredging equipment. Right of ways and pumping equipment can add greatly to disposal costs. Overland transport of dredged material in trucks or by rail requires substantial dewatering for most fine-grained dredged material. Dewatering facilities can be quite costly depending on land requirements and effluent treatment methods.

The need for dredged material rehandling or transport can add to costs and environmental impacts significantly. Rehandling areas require turbidity control to prevent the escape of sediment and associated contaminants. Dewatering facilities may require large land areas for drying of dredged material and expensive treatment facilities for contaminated effluents.

Sediment Control

A dredged material containment basin generally must serve two functions. It must be a sedimentation basin for the removal of suspended sediment and it must contain sufficient volume to serve as a storage facility for consolidated dredged material. Proper basin design must take several factors into account including: the dredging method, rate of filling, sediment properties, water properties and the amount of land available. To prevent unacceptable suspended sediment releases in the effluent, the basin must provide adequate surface area for sedimentation. Adequate volume must be provided to store dredged material during dredging and still leave room for ponding required for efficient sedimentation. Basin designs must therefore take dredged material settling and consolidation behavior into account as well as dredge production rates and the time necessary to complete the project. These factors can be very difficult to predict accurately and will vary considerably during the course of a given disposal operation (Summers and Brush, 1981; Montgomery, 1978). As a result, containment basins must be conservatively designed to avoid effluent quality problems. Unfortunately, this requires increased basin size and associated cost increases.

Chen et al. (1978) summarize field measurements of suspended solids release made at nine operating containment basins. Four fresh water sites and five brackish water sites were studied and average suspended solids removal efficiencies of 99% and 95% respectively were reported. Even so, effluents from fresh water sites averaged 97 times the suspended solids concentrations of the receiving waters while brackish water sites averaged 52 times higher. Should improved removal efficiencies be needed, basin operators must resort to further treatment of effluents. The use of chemical flocculants for this purpose has been investigated by Jones et al. (1978). Another attractive option is the use of natural vegetated areas for final effluent treatment. Lee et al. (1976) have investigated this option and found vegetated areas to be very effective at removing both suspended solids and dissolved nutrients.

Release of Contaminants

Contaminants may be released from containment basins by two routes, in surface effluents during the filling and consolidation of the dredged material, and in leachates from pore water and percolation of rainwater through the dredged material (Hoeppel et al., 1978; Yu et al., 1978). The dangers to surface waters and groundwater aquifers must be considered fully in the containment basin siting and design process.

Dredged material placed in containment areas is subject to frequent and rapid changes in its environmental conditions. Oxidation, pH, salinity and temperature are all important parameters that are significantly altered by removal and transfer of the material. Trace and heavy metals, halogenated hydrocarbons and nutrients are usually the contaminants of concern in the disposal of dredged materials (Canter et al., 1977). The hydrocarbons and the metals are primarily bound to the sediment particles, especially fine clays. Humic acids and other organics have been implicated as ligands in this binding action, as have metal hydroxides. This sorption is highly pH-dependent. The affinity of the cation for the particle is dependent on the degree of ion hydration and charge, with divalent and trivalent cations competing successfully for sites. Anions, except for phosphate under some conditions, do not sorb onto sediment surfaces. Hence the concentrations of nutrients in the sediments are not so dependent on this mechanism (Yu et al., 1978; Stumm and Morgan, 1970).

Two other mechanisms which help control the concentration of metals in sediments and sediment-water systems are formation of iron oxides and hydroxides, and the formation of sulfide precipitates. Iron hydroxides form under anaerobic conditions and during their formation may co-precipitate many trace metals. Thus, trace metals may be bound in the form of colloidal precipitates in the water column or in the hydroxide coatings of sediment particles. The rate of this process depends on diffusion or mixing rates, the initial concentration of the metal ion and competing reactions in the environment (Boyle et al., 1977; Gotoh and Patrick, 1974; Oakley et al., 1980).

Under anoxic conditions, many trace metals are insoluble, forming sulfide compounds. The formation of sulfides is accomplished by microbial oxidation of organic material, thereby releasing hydrogen sulfide gas. Thus, the composition of the organic material present as well as the Eh and pH are important in determining the rate of production (Davis and Leckie, 1978). The heavy metals that have a strong affinity for sulfides and form insoluble sulfide complexes are, in order of decreasing solubility: mercury, copper, lead, cadmium, zinc, nickel, iron and arsenic (Khalid et al., 1977). Since the least soluble compounds are the ones to precipitate first, and since iron is so abundant in sediments, iron sulfide tends to be the dominant sediment sulfide. However, there is generally enough sulfide present to precipitate the trace metals completely (Stumm and Morgan, 1970; Gotoh and Patrick, 1974).

The form and mobility of contaminant species depend upon a number of competing chemical mechanisms, and tend to stabilize within a given set of conditions. The parameters that determine the state of the contaminants are: sediment texture (grain size), oxidation-reduction status, pH, sulfide and organic matter concentrations and solids to water ratio (Hoeppel et al., 1978).

When sediments are dredged and disposed of, these conditions are drastically altered. Whereas most sediments exist in quiescent, anoxic regimes of nearly neutral pH, hydraulic dredging and disposal can cause mixing, exposure to oxygen and changes in salinity and pH.

The changes that are undergone by the contaminants, then, are physical and chemical. Physical mixing and dilution during the dredging process increase dramatically the amount of solids in suspension. Hydraulic dredging may entail delivery to the disposal site of slurries containing 75 to 95 per cent bottom and interstitial water. When this material is confined to a disposal site, approximately 95% of the total solids will have settled out by the time the effluent is released (Hoeppel et al., 1978).

Contaminants enter the disposal area in one of three forms: adsorbed to sediments, in insoluble or colloidal complexes, or soluble compounds trapped within reducing sediment pore waters by an overlaying oxidizing interface. In order to assess the changes in the level of each contaminant, it is necessary to identify the form in which it enters and in which it leaves. Obviously, it has little validity to compare contaminant per volume of influent and effluent if the compound enters as species adsorbed to sediment particles and leaves in a soluble form. In such a case, it may appear that the confinement area has a trapping efficiency of, say 90%, whereas, in fact, 10% of the previously insoluble material is leaving in a dissolved and mobile form. Thus, material that was originally soluble may be examined on a per volume basis, but adsorbed materials must be assessed as being enriched or depleted with respect to the suspended solids. Yet more information may be derived by employing chemical techniques which permit the identification of the specific forms of the contaminants in influent and effluent materials.

Effluent Losses

When Hoeppel et al. (1978) looked at influent and effluents from disposal sites from around the country, they not only did bulk analyses and filtered samples, but also did geochemical phase separation and standard elutriate testing. They found that suspended solids were reduced by 95% to 99%, and that the presence of vegetation in the confinement area promoted rapid settling.

Within reduced sediments, iron and manganese, organic carbon, ammonia and phosphate tended to be in soluble form. Of these, iron and ortho-phosphate were removed during the confinement by precipitation of iron hydroxides and iron phosphate. In fact, this precipitation was highly visible in the transformation of dark waters to light orange. Yet removal was far from complete; 77% removal was observed for each. It is debatable whether a longer settling time would yield a higher figure, as the compounds formed are of colloidal size. Organic nitrogen and soluble phosphorus showed lesser removals of 63% and 62%; manganese and ammonia-nitrogen poorer yet at 38% and 35%. Nitrate and nitrite nitrogen increased a dramatic 94%, showing the effects of oxidation on organic and ammonia-nitrogen (Hoeppel et al., 1978).

Some of the metals that were expected to decrease via coprecipitation from solution (Cd, V, Ni, Ti, Pb, Mg, Zn, Cr, Cu, K) in fact showed very poor removal, the last four even increased on the order of 10%. This may be due to the slow rate of oxidation of the iron hydroxides, with which they would co-precipitate, or to their remaining in solution as colloidal solids (Hoeppel et al., 1978).

The geochemical phase partitioning performed on influent and effluent solids by Hoeppel et al. (1978) showed that some metals exhibited noticeable phase changes during migration through the containment areas, whereas others did not. On a functional level, metals can be designated as being dissolved, in an exchangeable affinity with solids, in organic/sulfide, carbonate, easily reducible and crystalline phases. Of these not only dissolved, but exchangeable and carbonate phases can be considered to be available to organisms, as they are easily removed by mild chemical treatment. Thus, a metal may appear to be removed from solution or maintained in a solid phase, when, in fact, a significant amount may have been made available to organisms.

Measurable increases in exchangeable Ca, Na, Cu and As were noted in effluent solids, and exchangeable Mn, Mg, and Ca was high in both influent and effluent solids. Zn, Cd, Mn, Pb, Cu, and Na all showed major increases in the carbonate phase. Arsenic showed a large increase in the exchangeable phase in some samples. All of these metals showed a significant decrease in the crystalline phase (Hoeppel et al., 1978). Thus, a reporting of approximately 90% removal for all of these metals is somewhat deceptive. To all appearances, this figure seems very much in keeping with the 95% to 99% removal of suspended solids, but closer examination reveals that of the solids in the effluents, a perhaps significant amount of metals is being made available to biological activity.

When these results were compared to the standard elutriate test, the test showed a fairly good prediction of percent removal when the settling time was adjusted to duplicate land disposal conditions. But as pointed out above, these results may be misleading about the biological activity of the materials. If the activities are increased greatly, it may be detected by bioassay of soluble and solid fractions from the elutriate test. However, the bioassay as it exists is not sensitive to possible sublethal or chronic effects.

Most of the chlorinated hydrocarbons seemed to be effectively removed with proper solids retention, as might be expected from their very low solubilities (Lu et al., 1978). However, there is some evidence that land disposal impedes the breakdown of DDT. DDT has two degradation pathways; in aerobic conditions its intermediate is DDE, whereas in anaerobic condition the degradation intermediate is DDD. The anaerobic DDD pathway leads to a much faster breakdown. However, disposal on land creates oxidizing conditions, leading to DDE formation. Moreover, DDE has a high affinity for very fine-grained particles, thus making it difficult to remove. In fact, significant amounts of DDE are sometimes detected in effluents (Lu et al., 1978).

PCBs are significantly decreased in containment areas, with over 90% being removed. This may still leave, however, concentrations of up to ten times background levels. The use of flocculants has been suggested as aiding in their removal.

Leachate Losses

The other type of contamination that may result from confined land disposal of dredged material is the leaching of contaminants into groundwater. The disposed dredged material is almost always higher in any given contaminant than is the soil upon which it is deposited, creating a potential for leaching. The extent to which the leaching occurs will be a function of the physico-chemical properties of the dredged material, the type of underlying soil, the hydrogeological properties of the site and the environmental conditions of the area (Mang et al., 1978).

Properties of the dredged material that may affect the extent of leaching are the texture and the amount of organic matter. Generally, the material deposited in the containment area is somewhat coarser than the bottom sediment as it was dredged due to the loss of fine particles in the effluent. The extent of the loss will depend on the residence time of the ponding water, which, in turn, depends on the size of the containment area.

The organic matter of the disposed material is primarily humus, a product of the degradation of a number of complex biological molecules. Humic acids are known to bind strongly to clays. They have very high cation exchange capacities and form strong covalent or ionic bonds with metals. Thus organic matter may strongly influence the migration of cationic contaminants within a soil. As discussed earlier, other factors influencing migration are (Mang et al., 1978):

a) pH
b) oxidation-reduction
c) dilution
d) ion-exchange
e) adsorption
f) solubility/complexation
g) diffusion
h) biological activity

In field studies conducted by SCS Engineers (Mang et al., 1978) at a number of upland disposal sites, interstitial water was collected from within the dredged material (on-site), beneath the material (under-site), and downstream in the groundwater (off-site), as well as background samples from non-disposal areas. They found that for all sites, total dissolved solids corresponded to the salinity of the area from which the dredged material was taken and that concentrations on-site were greater than concentrations off-site, which were, in turn, greater than background levels, suggesting leaching of salinity.

Looking at individual ions, they found that chloride concentrations were highest undersite, with concentrations decreasing off-site with distance, suggesting dilution as the attenuating mechanism. Similar behavior was observed for sodium and potassium, which is in keeping with the very high solubilities of these ions. Although they are very abundant in the minerals present, there is apt to be very little dissolution or precipitation of these ions. Their high mobility and concentration are likely to have negative effects; they make drinking water unpalatable, the area unsuitable for agriculture and cause degradation of the structure of aerable soils.

Calcium and magnesium, at some sites, are higher undersite than in the monitoring wells, whereas, at other sites, the reverse is true, suggesting a possible dissolution of calcium carbonate (for calcium) or hydromagnesite (for magnesium). Calcium and magnesium may also undergo cation exchange reactions, either replacing sodium or potassium in clay lattices or filling in lattices of weathered minerals. Thus, these ions are also highly mobile, although they may be adsorbed somewhat more by highly weathered soils. The fact that the alkalinity is greater in the disposal and surrounding area than it is in the background also substantiates the probable dissolution of calcium carbonate, although in some circumstances it could be attributed to weathering or biological activity.

All of the trace metals except iron and manganese were observed in the ppb or sub-ppb range. At such low concentrations precipitation/dissolution, complexation and adsorption are apt to be the dominant mechanism in transport. These metals (excluding iron and manganese) were present in the dredged material in concentrations higher than the surrounding areas, creating the potential for leaching. Yet in no case was leaching observed, suggesting that the metals were adsorbed in the soil. Iron, on the other hand, was sometimes observed to greatly exceed the EPA drinking water standard of .3 ppm in groundwater samples. In fact, at one site, a concentration of 2500 ppm was observed. These very high concentrations were always ephemeral and concentrations returned to sub-EPA levels very quickly. This was probably due to oxidation of FeS as reduced sediments were exposed to oxidizing conditions. Thus, iron could be a potential problem, and timing of disposal events, especially with respect to precipitation, could be critical. Manganese, too, is a very soluble metal under oxidizing conditions. Almost all of the samples taken were found to exceed the EPA limits for manganese in drinking water.

No chlorinated hydrocarbons were found in the under-site or off-site interstitial waters. It would appear that their solubilities and high affinities for clay particles prevent them from being mobilized. Thus, the migration of a number of the potentially most toxic compounds seems to be impeded, predominantly by adsorptive mechanisms. The dredged material constituents that seem most likely to have adverse effects on groundwater quality are chlorine, potassium, sodium, organic carbon, alkalinity, iron and manganese.

Mang and his co-workers (1978) performed laboratory studies that, for the most part, corroborate the field studies. They constructed leaching columns, filled them with dredged sediment and disposal site soil and eluted them with influents of various qualities including rainwater, groundwater and landfill leachate. Their results were expressed in terms of the following indices:

1) Mobility Index - the ratio of the soluble concentration of various constituents in leachate to that in the interstitial water prior to passage through the column.
2) Evaluatory Index - the ratio of a soluble concentration of a constituent in the leachate to the EPA drinking water standard for that constituent.
3) Impact Index - the product of the Mobility Index and the Evaluatory Index of a particular constituent.

Manganese, nitrate, total phosphorus and iron were the most highly mobile constituents. Calcium, ortho-phosphate, zinc, chloride, total Kjeldahl nitrogen, potassium, mercury, and magnesium showed moderate mobility, and copper, sodium, ammonia-nitrogen, lead and cadmium were adsorbed by the soil.

When the Impact Index was calculated for these constituents, manganese, total organic carbon, iron and total phosphorus had the highest impacts with TKN, nitrate, chloride, calcium and sodium being possibly of concern. These findings are in surprisingly good agreement with field studies, suggesting that laboratory evaluations may help determine the suitability of a given site for dredged material of a given composition. Such a consideration, in addition to those enumerated in the first part of this paper, could help prevent possible negative impacts of upland disposal of dredged material.

Measures to Control Contaminant Release

In their synthesis of DMRP results, Chen et al. (1978) suggest that the majority of effluent water contaminants studied were associated with suspended solids. However, even with 95 to 99% removal of suspended material the authors state ".....ammonia nitrogen, total phosphorus, chlorinated hydrocarbons, and most of the trace metals in unfiltered effluent water samples fail to meet most water quality criteria" (p 76). To improve the suspended solids removal efficiencies, along with removal of most contaminants and soluable nutrients, Chen et al. (1978) recommend the use of actively growing vegetated areas for treatment of effluents. The major expense involved is for the provision of adequate land area. Other treatment possibilities include standard wastewater treatment processes such as flocculation sedimentation, chemical treatment for the removal of nutrients, activated charcoal filtration, etc.

Leachate control may involve the selection of sites with impermeable substrata. Under drainage systems for the collection of leachate and/or impermeable liners may be necessary in other situations. The effectiveness of so-called impermeable liners is frequently questioned and provisions must generally be made for monitoring wells to ensure that valuable aquifers are not contaminated. In such cases leachate control can add substantially to disposal costs.

Dewatering and Basin Reuse

Subsequent productive uses or the need for additional storage capacity can require the dewatering of dredged material. Haliburton (1978) reports that the most cost effective means of dewatering dredged material is the use of progressive surface trenching techniques. By forming drainage trenches, basin operators can take advantage of natural dessication to dewater dredged material. In situations where time is a constraining factor, gravity or vacuum assisted underdrainage systems can speed up the process, although expenses can be high.

Other basin design and management practices may also aid in dewatering. Large basins may be subdivided to allow repeated placement of thin layers of dredged material in different sub-basins. Thin layers are typically much more quickly consolidated and dried (Haliburton, 1978). Movement of the dredged material inflow point can aid in optimizing the use of the coarse fraction of the dredged material which can be distributed to improve the drainage characteristics of the basin. If it is possible to increase the time span over which dredging is completed, more time can be provided for consolidation and drying of the dredged material at the bottom of the basin.

Productive uses for dredged material may extend the capacity if suitable material is removed for other purposes. Clean material for erosion control, fill material, construction aggregate and sanitary landfill cover can all be recovered from dredged material containment basins to provide more room for undesirable material.

Dredged material containment sites can be extremely valuable once they are filled and dried. Much of New York, Boston and Baltimore lies on fill material. The geotechnical properties of much dredged material makes it unsuitable for such constructive uses, however. In these cases, recreational areas or wildlife habitat may be reasonable productive uses for containment areas (Smith, 1978).

Site Selection

Many factors must be considered in the containment area selection process. Important characteristics of a suitable dredged material containment site to be considered in the selection process include: the amount of land available, its current use, the accessibility to transportation, the soil characteristics, subsurface hydrology, geologic condition, surface features and meteorological conditions (SCS Engineers, 1977).

Of these, the latter five are of paramount importance in determining the stability of the site and the potential loss of material, including the leaching or runoff of contaminants into the groundwater. Fine soils, clays and silts, impede leaching far more than coarser soils, and are the preferred material for site construction. They are also better adsorbers of contaminants leached from the dredged material. Thus soil permeability and texture need to be considered in locating a site, although unsuitable soils may be compensated for by the installation of liners, which may be clay or silty dredged materials, imported soil or artificial materials.

Likewise, the hydrology of the area is critical to site location. The depth to groundwater and the frequency and magnitude of groundwater fluctuations must be considered. This factor frequently works in opposition to the soil character as discussed above, as the water table is more often near the surface when the soils present are more impermeable. The direction of groundwater flow must be known both to assess the risk of groundwater contamination and to position wells for post-disposal sites over brackish or unusable groundwaters to avoid all possible risk of contaminating potable water supplies.

The surface features of the land affect both the relation of the disposal to groundwater and the stability of the site. Higher land is preferred to floodplain areas because it is dryer but slopes of greater than 2:1 should be avoided as there exists the potential for landslides and slumps.

Meterological conditions can also affect the stability of a disposal site. Prevailing winds may transport dust or odor and periods of extreme dryness may aggravate the production of dust. The leaching of contaminants may also be increased in areas of high rainfall.

Obviously, land that meets the above requirements for upland disposal is limited. Locating sites that are accessible to transportation is becoming increasingly difficult and costly. In heavily populated urban centers, typical of most major ports, many uses compete for available land. Many of the siting problems encountered for dredged material disposal areas are shared by power plants, sanitary landfills, hazardous waste landfills, prisons, waste treatment plants, etc. New York provides an excellent example of the problems encountered.

Contained Upland Disposal in New York

As a first step in the evaluation of upland disposal sites, the MITRE Corporation (Leslie et al., 1980) identified over 600 possible sites within 100 miles of New York City. Of these, 295 were barren areas, 282 were wetlands and over one million acres were being utilized as cropland and pasture. From these sites, they selected fifteen (eleven barren, two agricultural, and two wetlands) for closer evaluation. Seven of these sites were in New York, the other eight in New Jersey.

The evaluations were made on the basis of social acceptability, public health and safety, engineering and economic considerations, environmental risk and legal acceptability. Not all of the sites were immediately available; for example, one was a quarry where excavations were planned until the year 1990. Another serves as a training area for the West Point Military Academy. None of the sites was residentially occupied, although a part of one was zoned for such development. One of the New Jersey sites serves as a railroad freight transfer facility. While such prior uses do not preclude to possible use of a site, they do augment the cost of aquisition. This competition of uses for open area so near a major urban center is not surprising, and, if anything, is expected to get worse. Current assessments project a need to develop 200,000 more acres in the New York metropolitan area by the year 2000. This factor, however, may weigh in favor of disposal in those sites where the deposition of material restores a barren area to constructive use, as in the filling of old mines.

The differences in site costs primarily reflect the location and current uses of the land. Operation and maintenance costs for all of the sites were virtually the same; the major differences were the costs of land acquisition, site development and transportation. Aquisition costs vary from $2,000 per acre for barren and agricultural land in upstate New York (Ulster, Dutchess and Orange Counties) to $40,000 per acre for vacant and wetlands in New Jersey to a top figure of $80,000 for the Fresh Kills Site on Staten Island. For most of the sites, a barge transfer facility constitutes the largest of the transportation related expenditures. The exceptions were those sites requiring pipelines over a mile long. If booster stations were required in such cases, the costs nearly doubled. The cost of site closure and restoration ranged from 4% to 200% of the original aquisition costs.

Legal impediments to development of disposal sites were encountered primarily in the case of wetlands sites. Wetlands protection acts prohibited the development of several sites and portions of others. In other cases, land would need to be re-zoned for use as disposal sites, but this was not thought to be particularly obstructive.

Environmental hazards were judged to be the compelling arguments against site development in almost all cases. Most of the sites investigated were already in a highly disturbed state. Hence, except for the wetlands sites, habitat protection was not a major issue. Rather, the possible contamination of surface and groundwaters was a major factor. Of the fifteen sites investigated, only Fresh Kills on Staten Island had no interaction of site drainage with groundwater due to the impermeable nature of the material with which the site has been capped. The groundwater beneath the Secaucus, New Jersey site is not suitable for drinking water. The other thirteen sites are either aquifer recharge zones or experience interactions with such aquifers under special conditions, as, for example, periods of low rainfall. Although there are engineering solutions to this problem, such measures would add greatly to the expense.

It is expected that there would be strong public resistance to the deposition of contaminated material at these sites. The strength of public opposition to the development of a particular site is presumed to be in proportion to the number of residences in its proximity. More than one-half of the investigated sites have moderate to high-density residential areas nearby. It is expected that resident's opposition could be minimized by removing the site from view by landscaping and by stressing the constructive and rehabilitative aspects of filling in the sites.

Partly on the basis of this preliminary evaluation by the MITRE Corporation, the Army Corps of Engineers has concluded that, as a class, those sites on barren lands were worthy of further investigation. They are currently funding an investigation of all 295 barren areas within 100 miles of New York City that were identified by MITRE. They are to be classified with respect to the following criteria:

a) Map code
b) County and state
c) Town or township
d) Whether site is flooding
e) Location of sites with respect to access routes
f) Site topography
g) Visible rock outcrops
h) On-site vegetation community
i) On-site land use
j) Distance of nearest dwelling
k) Proximity to high density residential areas
l) Existence of on-site water bodies
m) Proximity to marine, estuarine, fresh water bodies or wetlands
n) Estimate of grain-size distribution

It is anticipated that a cataloging of sites in this manner will result in a clearer idea of the utility of upland disposal in the management of dredged materials for New York Harbor.

Aquatic Containment Areas in New York

Although not currently utilized as a major repository of dredged material, containment areas in the aquatic environment have been investigated for possible use in New York Harbor. Proposals which have been entertained include the creation of deepwater and nearshore islands, marsh creation, and the infilling of waterways and pier areas.

At one point, a proposed deep water island (Nigel Chatley Associates, 1977) received widespread publicity and some political support. The proposal outlined the construction of an eight square mile island approximately 12 to 15 miles south of Kennedy Airport. The volume of material required would be 475 million cubic yards, the bulk of which would be generated by a project to deepen the Erie Canal. The overall island project would then create deep water port facilities for New York, provide an economical means of delivering coal to the city (barge), and furnish an offshore site for the location of noisome industries and public facilities such as energy plants, refineries and airports. Such a plan would face environmental opposition and a maze of jurisdictional complexities, lying as it does outside of both state and national waters. (Connor et al., 1979). Hence, the idea has not been further developed although it continues to be mentioned in conjunction with the development of deep water facilities in the harbor.

A containment island was also proposed for the Lower Bay at the site of the Hoffman and Swinburne artificial islands. Some opposition has been raised to this project on the basis of the destruction of benthic habitat, interference with fisheries and the re-direction of wave energies impinging on the shoreline of Staten Island (Conner et al., 1979).

Recently the U.S. Fish and Wildlife Service (1982) performed a preliminary survey to identify from the wildlife perspective sites within the harbor that might serve as locations for aquatic containment areas. They considered the construction of large and small islands and the infilling of shoreline structures such as waterways and interpier areas. They concluded that the Hudson and East Rivers cannot accommodate large islands and that interpier areas on these waterways are important habitats for migrating striped bass, eels and bluefish, although highly polluted areas such as Newtown Creek have potential for disposal of large amounts of dredged material. The Upper Bay likewise cannot accommodate an island although interpier areas along Staten Island and Brooklyn offer possibilities. The use of interpier areas in Newark Bay was opposed in deference to the recovering blue crab fishery there. Similarly, Jamaica Bay harbors a large array of bird species within a Federally maintained national wildlife refuge. The lower Bay by virtue of its size offers the most likely location for the construction of containment islands such as the proposed Hoffman-Swinburne island, although it faces the objections raised above. Such preliminary investigations must be supported by further study of the environmental, engineering, economic, and navigational consequences of containment structure construction in the New York Harbor before such structures can be compared side by side with other disposal alternatives.

Appendix D

Ten Year Projection of Dredging Requirements for the Port of New York and New Jersey

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Appendix D

Ten Year Projection of Dredging Requirements for the Port of N.Y. and N.J.

The purpose of this projection of dredging requirements is to illustrate the procedure to be used and to identify the additional information needed to complete a realistic projection of dredging requirements. Because of the uncertainties involved in making such projections it must be realized that frequent revisions will be necessary as new information becomes available or unforseen circumstances arise. A given 10 year plan may never be executed as originally proposed because of revisions. It is hoped that with sufficient advance planning significant delays in dredging can be avoided while at the same time environmental values can be more conservatively treated than in the past.

The reason for projecting dredging requirements is to permit control of the sequence in which projects are dredged so that "highly contaminated" class I dredged material can be capped using "less contaminated" class III and IV material. Not only is the sequence of dredging important but quantities should be estimated and dredging scheduled on an annual basis to ensure an adequate supply of suitable capping material each year.

Figure D-1 is an example of a 10 year projection for federal maintenance and private dredging in the Port of N.Y. and N.J. Projections were based on average annual maintenance dredging and the frequency of dredging for each project as determined by the historical dredging record (tables B-1 and B-2). The projection shown on figure D-1 is designed to meet several objectives. First, projects were scheduled to restrict annual fluctuations in the quantity of each class dredged. For capping to be economical it is necessary to use

Table D-1

10 Year Maintenance Dredging Projection
($1000\ yd^3$)

Project	Avg	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
HRWE (f)	594	594	594	194	194	1188	594	594	594	594	594
HRBW (f)	423		423	846	1269		846		846	423	423
SHB (f)	136	1088						816			408
SHB (p)	2	2									18
AK (f)	71		710						426		
WCHST (f)	62	62				248				248	
HCK (f)	24			168				96			
HCK (p)	34			102				408			
BRX (f)	26	26								208	
ECHST (f)	3	21								24	
CLASS III TOTAL		1846	1820	1649	1832	1764	1976	1604	1820	1764	1832

Project	Avg	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
AMB (f)	834	834	834	834	834	834	834	834	834	834	834
SHCH (f)	256	512	256	256	256	256	256	256	256	256	256
MSCH (f)	129	258	258	129	258	258	258	129	258	258	258
JAMB (f)	30		90		60		60		60		60
JAMB (p)	3		9		6		6		6		6
CLASS IV TOTAL		1604	1447	1219	1414	1348	1414	1219	1414	1348	1414

MAINTENANCE DREDGING PROJECTION SUMMARY

CLASS I TOTAL	1846	1820	1649	1832	1764	1976	1604	1820	1764	1832
CALSS II TOTAL	2245	2653	2526	2508	2120	2027	2508	2286	2496	2027
CLASS III TOTAL	1793	1727	1710	1863	1436	1440	1914	1866	1497	1443
CLASS IV TOTAL	1604	1447	1219	1414	1348	1414	1219	1414	1348	1414
ANNUAL TOTAL	7488	7647	7104	7617	6668	6857	7245	7386	7105	6716

Table D-1 (continued)

10 Year Maintenance Dredging Projection - Federal and Private

(1000 yd^3)

Project	Avg	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
HRBW (p)*	601		1202		1202		1202		1202		1202
RR (f)	318	1590				1272				1272	
RR (p)	16	32				64				64	
NB (f)	212			848				848			
NB (p)	72			216				288			
AK (p)	195		390		390		390		390		390
KK (p)	114		228		228		228		228		228
GWB (p)	78	78				312				312	
PAS (f)	78			468				312			
PAS (p)	39			117				156			
ER (f)	15	75				60				60	
ER (p)	1	4				4				4	
NTWN (f)	9	63				36				36	
NTWN (p)	4	4				16				16	
HRWE (p)	2				12						12
CLASS I TOTAL		1846	1820	1649	1832	1764	1976	1604	1820	1764	1832
RB (f)	912	1824		1824		1824		1824		1824	
RB (p)	18	54				72				72	
BRRH (f)	704		1408		1408		1408		1408		1408
BRRH (p)	15		45				45				45
BMLK (f)	217		651		434		434		434		434
BMLK (p)	35		105				140				140
UB (f)	162			648				648			
UB (p)	9			54				36			
SHTR (f)	111		444		666				444		
BKLNY (p)	56	56				224				224	
FLSH (f)	19	152								152	
HRLM (f)	13	91								104	
HRLM (p)	1	1								8	
SPUR (f)	11	55								88	
SPUR (p)	3	12								24	
CLASS II TOTAL		2245	2653	2526	2508	2120	2027	2508	2286	2496	2027

* (p) = private dredging (f) = federal dredging

as much dredged material as possible. Proper scheduling of projects can ensure the most efficient use of available capping material. Second, projects dredged each year were grouped by geographical location whenever possible to minimize distances traveled by the dredge. Third, private dredging in a given area was scheduled to coincide with federal dredging to improve the efficiency of dredging equipment utilization.

Prediction of maintenance dredging requirements is complicated by the fact that the historical dredging record is not only dependent on relatively consistent natural sedimentation rates. Economic and environmental restrictions also play a major role in forming the dredging record. Availability of funds and suitable dredging equipment must be considered in the performance of dredging work and environmental restrictions may be responsible for the postponement of needed dredging. These are factors that are highly variable in their effect and complicate the projection of maintenance requirements. What is needed to minimize the impact of these factors is longer term dredging records. Unfortunately high quality dredging records are not available prior to 1966.

Major new dredging work has not been done in New York since 1976. However, new dredging can, and undoubtably will, have a significant effect on dredging requirements in the future. Fortunately for the purposes of projecting dredging requirements, substantial planning and lead time is required before new work can be accomplished. This permits new dredging projects to be scheduled enough in advance that maintenance projections can be adjusted and new material can be used to the best advantage as capping material or in other suitable ways.

According to sources at the New York district of the Corps no new dredging projects have been approved since 1976. Two projects, improvements to the Kill van Kull - Newark Bay Channel and the Gowanus Creek Channel, estimated at 32 million yd^3 and 400,000 yd^3 respectively, have been submitted to Congress for approval. Due to the state of the Federal Government at the present time it is impossible to predict when and if these projects will gain approval. Once approval is granted more detailed, updated plans must be made before dredging can progress. At best the projects will not start for one to two years. The larger Kill van Kull - Newark Bay project will take roughly 6 years to complete, provided funds are available. The Gowanus Creek project is expected to proceed quickly because of its small size.

Preliminary surveys of the characteristics of the material to be dredged from each project indicate that the Kill van Kull - Newark Bay project ranges from mud to rock. The Gowanus Creek project consists of mostly mud. Once approval is granted more detailed surveys will provide the information needed to include these projects in the dredging plan. Rock and gravel could best be used for construction purposes, sand for cap material or beach replenishment, and mud should be disposed of according to its contaminant classification. Existance of a pre-arranged dredging and dredged material disposal plan as described here will simplify the task of assignment of dredged material to the most suitable options.

Long range plans for new work also include two projects. A project at Arthur Kill - Howland Hook and a project for a large coal terminal at Greenville-Bayonne are under consideration. The former, consisting of 16 million yds^3 of rock and hard pan, has good potential for providing construction aggregate. The latter project may be deepened to either 45 or 60 feet and consists of 30-100 million yds^3 of varied material depending on the project depth selected. Both of these projects are at least a year from being submitted for approval. It is difficult to predict when work can start because of the requirement for Congressional approval. Uncertainties in the Federal budget and the status of various innovative cost sharing proposals also complicate projections.

To complete a fully acceptable management plan other information must be incorporated. First, the availability of funds necessary to perform the required work must be determined. Second, the availability and production rate of the dredging equipment must be sufficient to complete the projected dredging. Third, seasonal restrictions on dredging and disposal must be considered. Some portions of the harbor are restricted due to spawning or migration of fish. Other portions of the harbor, for example the passenger ship terminal, have seasonal peak traffic loads which must be taken into account. Finally, new dredging work may alter the hydraulic regime of the harbor so that sedimentation rates are affected and maintenance dredging requirements change. These changes are very difficult to forecast given our present understanding of sediment transport and coastal hydrodynamics.

For the reasons discussed above a successful dredging and dredged material management plan will be difficult to formulate. It must be flexible and have the capacity to be quickly and easily updated. This will require constant attention from the responsible agencies. However, the economic and environmental benefits of such a plan have the potential to far out-weigh the costs of implementing it.