APPENDIX A

ENGINEERING DESIGN AND COST ESTIMATES

NORFOLK HARBOR AND CHANNELS, VIRGINIA

LONG-TERM DISPOSAL (INNER HARBOR)

US Army Corps
Of Engineers

Norfolk District
June 1990

Draft Information Report

APPENDIX A

TABLE OF CONTENTS

Item	Page
INTRODUCTION	A-1
DREDGED DISPOSAL REQUIREMENT	A-1
SOURCES OF DREDGED MATERIAL	A-1
HISTORICAL REQUIREMENT	A-1
PROBABLE FUTURE SHOALING RATES	A-10
DISTRIBUTION OF SEDIMENTS BY TYPE	A-10
DEBRIS REQUIREMENT	A-12
DREDGING METHODS	A-14
HYDRAULIC DREDGES	A-14
MECHANICAL DREDGES	A-17
CRANEY ISLAND DISPOSAL AREA	A-18
DESCRIPTION OF PROJECT	A-18
REMAINING LIFE OF CIDA	A-24
OPERATION AND MAINTENANCE COST OF CIDA	A-24
CIDA EXPANSION PLANS CONSIDERED	A-24
WATERWAYS EXPERIMENT STATION	A-25
PHYSICAL DATA OF EXPANSION ALTERNATIVES	A-27
DREDGING SCENARIOS CONSIDERED	A-28
STORAGE CAPACITY EVALUATIONS	A-29
RESULTS OF LABORATORY ANALYSIS	A-30
DESIGN DATA	A-31

TABLE OF CONTENTS
(Cont'd)

Item	Page
UTILITY INVENTORY	A-32
DESCRIPTION OF EXPANSION ALTERNATIVES	A-33
CONSTRUCTION COST	A-36
COST OF OPERATION AND MAINTENANCE	A-44
DREDGING COSTS	A-44
COST DATA	A-45
METHOD OF ANALYSIS	A-45
REMOVAL OF MATERIAL FROM CRANEY ISLAND	A-46
CHESAPEAKE BAY PLANS	A-48
PHYSICAL DATA	A-48
DREDGING SCENARIO AND LIFE OF PLAN	A-49
DESIGN DATA	A-49
COST ESTIMATES	A-50

LIST OF TABLES

No.	Title	Page
A-1	SOURCES FOR DREDGED MATERIAL PLACED IN CRANEY ISLAND DISPOSAL AREA	A-2
A-2	CRANEY ISLAND DISPOSAL HISTORY	A-4
A-3	ESTIMATED AMOUNT OF FUTURE DREDGING	A-11
A-4	PRINCIPAL SOURCES OF FLOATABLE MATERIAL	A-13
A-5	RESULTS BY WES OF USEFUL LIFE STUDY	A-30

LIST OF TABLES
(Cont'd)

No.	Title	Page
A-6	RESULTS OF USEFUL LIFE STUDY AMOUNT OF DREDGED MATERIAL TO BE STORED	A-31
A-7	DESIGN DATA FOR CIDA EXPANSION PLANS	A-37
A-8	EXPANSION OF CRANEY ISLAND ESTIMATED FIRST COST, PLAN A	A-38
A-9	EXPANSION OF CRANEY ISLAND ESTIMATED FIRST COST, PLAN B	A-39
A-10	EXPANSION OF CRANEY ISLAND ESTIMATED FIRST COST, PLAN C	A-40
A-11	EXPANSION OF CRANEY ISLAND ESTIMATED FIRST COST, PLAN D	A-41
A-12	EXPANSION OF CRANEY ISLAND ESTIMATED FIRST COST, PLAN E	A-42
A-13	EXPANSION OF CRANEY ISLAND ESTIMATED FIRST COST, PLAN F	A-43
A-14	COST OF OPERATION AND MAINTENANCE	A-44
A-15	DIMENSIONS OF HORSESHOE AREA OFF BUCKROE BEACH, OCEAN VIEW AND CHESAPEAKE BAY BRIDGE TUNNEL	A-49
A-16	COST ESTIMATES FOR CHESAPEAKE BAY SITES	A-50
A-17	ESTIMATED COST OF CONSTRUCTION OCEAN VIEW	A-51
A-18	ESTIMATED COST OF CONSTRUCTION HORSESHOE AREA OFF BUCKROE BEACH	A-52
A-19	ESTIMATED COST OF CONSTRUCTION CHESAPEAKE BAY BRIDGE-TUNNEL	A-53

LIST OF FIGURES

No.	Title	Page
A-1	HYDRAULIC DREDGES	A-16
A-2	MECHANICAL DREDGE	A-17
A-3	CRANEY ISLAND PROJECT LOCATION	A-19
A-4	GENERALIZED FOUNDATION CONDITIONS IN VICINITY OF CRANEY ISLAND	A-20
A-5	TYPICAL DIKE CROSS SECTION USED FOR SLOPE STABILITY STUDIES	A-22
A-6	PLAN VIEW OF INTERIOR LEVEES AND WEIR LOCATIONS	A-23
A-7	ALTERNATIVE CONFIGURATIONS FOR EXPANSION OF CRANEY ISLAND	A-26
A-8	CRANEY ISLAND EXISTING PLAN	A-54
A-9	CRANEY ISLAND EXPANSION PLAN A	A-55
A-10	CRANEY ISLAND EXPANSION PLAN B	A-56
A-11	CRANEY ISLAND EXPANSION PLAN C	A-57
A-12	CRANEY ISLAND EXPANSION PLAN D	A-58
A-13	CRANEY ISLAND EXPANSION PLAN E	A-59
A-14	CRANEY ISLAND EXPANSION PLAN F	A-60

LIST OF ATTACHMENTS

No.	Title
1	STORAGE CAPACITY EVALUATION FOR CRANEY ISLAND EXPANSION ALTERNATIVES TECHNICAL REPORT EL-89-6, APRIL 1989 BY WATERWAYS EXPERIMENT STATION

LIST OF ATTACHMENTS
(Cont'd)

No.	Title
2	GEOTECHNICAL FEASIBILITY STUDY - REPLACEMENT OR EXTENSION OF THE CRANEY ISLAND DISPOSAL AREA, NORFOLK, VIRGINIA. MISCELLANEOUS PAPER GL-87-9 JUNE 1987 BY WATERWAYS EXPERIMENT STATION AND DRAFT ADDENDUM TO MISCELLANEOUS PAPER GL-87-9 DATED JULY 1988
3	INVENTORY OF EXISTING UTILITIES AND ADJUSTMENT RECOMMENDATIONS RELATED TO REPLACEMENT OR EXTENSION OF THE CRANEY ISLAND DISPOSAL AREA, NORFOLK VIRGINIA, 15 JULY 1988, BY LANGLEY AND MCDONALD, P.C.
4	DREDGING IN HAMPTON ROADS, NORFOLK HARBOR, 24 OCTOBER 1988 BY RICH AND ASSOCIATES
5	EMPTYING CRANEY ISLAND, 9 FEBRUARY 1989 BY RICH AND ASSOCIATES

APPENDIX A

ENGINEERING DESIGN AND COST ESTIMATES

INTRODUCTION

1. This appendix discusses the sources, amount, and type of material dredged from the inner harbor of Hampton Roads and the operational details for the disposal thereof. It also discusses (a) the need for a disposal area, (b) the existing Craney Island Disposal Area (CIDA), (c) confined alternatives for replacement of CIDA including its expansion, (d) ocean disposal including the Dam Neck Ocean Disposal Area (DNODS) and the Norfolk Disposal Site (NDS), and (e) cost estimates for the future disposal of dredged material from the inner harbor of Hampton Roads.

DREDGED DISPOSAL REQUIREMENT

SOURCES OF DREDGED MATERIAL

2. Sources of the majority of dredged material are shown in the following table. The total amount from Federal, state/local entities, and private interests by river reaches are shown in a table in the main report. Areas of Federal responsibility are shown on plates 2 and 3 of the main report.

HISTORICAL REQUIREMENT

3. During the late 1930s and early 1940s, it became increasingly evident to the Engineer District, Norfolk, that a need existed for providing an adequate and convenient dredged material disposal area for material removed from the channels, anchorages, docks and berthing areas in Norfolk Harbor and adjacent waters. This necessity resulted from the progressive reduction of available shoreline disposal areas for hydraulic dredges and deep water areas used by hopper and bucket dredges.

Table A-1. SOURCES OF DREDGED MATERIAL PLACED IN CRANEY ISLAND DISPOSAL AREA (a)

Source	Description
Corps of Engineers:	
Norfolk Harbor	Includes material dredged from both the 40-, 45-, and 50-foot channels generally extending from Sewells Point anchorage upstream (south) to N&W railway bridge (Mile 15).
Sewells Point	Includes material dredged from Sewells Point Anchorages.
Newport News	Includes material dredged from Newport News Anchorage and Newport News Channel extending to Sewells Point Anchorage.
Rehandling Basin	Includes material dredged from Craney Island Rehandling Basin.
Southern Branch	Includes a portion of material dredged from 35-foot channel upstream (south) of the N&W railway bridge.
Miscellaneous	Includes material dredged from the Federal channels under small contracts i.e. Newport News Creek, Hampton Creek, Western and Eastern Branches.
Other:	
Navy Department	Includes material dredged from areas east of Norfolk Harbor 45-foot channel and slips located along the Naval Yard on Southern Branch. Also, includes material from the U.S. Naval Facilities in the York River.
Private Permit (state and private interests)	Includes material dredged from slips located south of Craney Island along eastern side of the channel and slips north of Newport News Anchorage as well as other areas in Norfolk Harbor.

(a) See plate 3 of main report.

4. A study was accomplished by the Norfolk District that considered past practices and future requirements for dredging and disposal in the Hampton Roads area. The Craney Island Disposal Area (CIDA) was the culmination of that study and was authorized by Congress in the Rivers and Harbors Act of 24 July 1946. The project was authorized on a self-liquidating basis by the collection of a unit toll for all material deposited therein. A comprehensive history of the deposits is shown in the following table and is the basis for projecting the future requirements for disposal of material from Hampton Roads and surrounding waters since most, if not all, dredged material from the area has been deposited in Craney Island.

D

Table A-2. CRANEY ISLAND DISPOSAL HISTORY

LOCATION & TYPE	DATES BEGIN	END	USAED	OTHER FED	COMMERICAL	YEARLY TOTAL	TOTAL DEPOSITS
PERMIT	Oct-56 -	Dec-56			982,566		
RE BASIN,NW	Jan-57 -	Aug-57	2,414,467				
RE BASIN,maint	Feb-57 -	May-57	302,243				
			2,716,710	0	982,566	3,699,276	3,699,276
NH,maint,HD	Oct-57 -	Nov-57	1,468,894				
NH,nw widen	Jul-58 -	Dec-58	4,708,210				
RE BASIN,maint	Jul-58 -	Sep-58	371,090				
			6,548,194	0	0	6,548,194	10,247,470
NH,SB,maint&nw	Jan-59 -	Apr-59	5,159,218				
NOB APPROACH	Jun-59 -	Aug-59		1,964,503			
RE BASIN,maint	Aug-59 -	Sep-59	940,351				
			6,099,569	1,964,503	0	8,064,072	18,311,542
NH,maint&nw	27-Oct-59 -	01-Jan-60	2,099,627				
CI RNCH,nw	25-Nov-59 -	22-May-60	4,643,020				
N&W PIERS A&B	10-Dec-59 -	27-Dec-59			127,630		
NAVY,DEGAUS	11-May-60 -	20-May-60		41,368			
			6,742,647	41,368	127,630	6,911,645	25,223,187
NH,SB,maint,HD	04-Oct-60 -	10-Nov-60	674,431				
RE BASIN,maint	20-May-61 -	20-Aug-61	1,042,693				
N&W PIERS,nw	02-May-61 -	30-Sep-61			687,634		
D&S PIERS,maint	01-Aug-61 -	17-Nov-61		817,673			
			1,717,124	817,673	687,634	3,222,431	28,445,618
N&W PIERS,nw	01-Oct-61 -	02-Mar-62			825,161		
S of N&W	24-Mar-62 -	02-Apr-62			119,740		
NH,maint, HD	03-Apr-62 -	25-Apr-62	1,258,530				
ESCI,barge reha	31-Aug-62 -	05-Sep-62			55,939		
CNN,maint,HD	05-Sep-62 -	22-Sep-62	766,893				
N&W PIERS,maint	14-Sep-62 -	10-Oct-62			156,545		
			2,025,423	0	1,157,485	3,182,908	31,628,526
NH,maint,HD	22-Sep-62 -	21-Oct-62	1,910,338				
NNSY	15-Oct-62 -	21-Oct-62		26,376			
RE BASIN,maint	05-Jan-63 -	01-Apr-63	795,559				
N&W PIERS	11-Feb-63 -	24-Feb-63			67,924		
NNSB	24-Feb-63 -	02-Mar-63			26,500		
NOB & D&S PIERS	02-Mar-63 -	13-Jun-63		521,419			
			2,705,897	547,795	94,424	3,348,116	34,976,642
NOB,maint	14-Jan-64	12-Mar-64		357,575			
NH,maint,HD	07-May-64	29-Jun-64	1,579,115				
RE BASIN,maint	02-Jun-64	30-Sep-64	503,878				
THIMBLE SHOALS,HD	23-Jun-64	02-Jul-64	60,920				
NOB,maint	27-Jul-64	12-Sep-64		371,275			
N&W,maint	10-Sep-64	02-Oct-64			146,853		
			2,246,913	728,850	148,853	3,124,616	38,101,258

Table A-2. CRANEY ISLAND DISPOSAL HISTORY

RE BASIN.maint	01-Oct-64	05-Jan-65	603,878				
NH 40.maint.HD	03-Mar-65	02-Jun-65	2,618,550				
NNSY.maint,HD	14-May-65	22-May-65		107,900			
ESCI.BR	12-Jul-65	24-Jul-65			64,755		
NOS.maint	26-Jul-65	07-Oct-65		602,060			
HRSD.TP	03-Aug-65	31-Aug-65			1,096		
N&W.maint	11-Sep-65	12-Sep-65			4,770		
			3,222,428	709,960	70,621	4,003,009	42,104,267
N&W PIERS.maint	08-Oct-65	12-Oct-65			28,613		
NOB.D&S PIERS	10-Oct-65	07-Dec-65		466,515			
NH45maint.HD	03-Sep-65	01-Dec-65	2,333.940				
NH45.nw	23-Mar-66	30-Sep-66	2,931,330				
CI FUEL DEPOT	20-Aug-66	19-Nov-66		360,815			
			5,265,270	827,330	28,613	6,121,213	48,225,480
NH45.nw	01-Oct-66	16-Jan-67	1.465.600				
RE BASIN.maint	24-Sep-66	21-Apr-67	1,032,198				
NH45.nw	26-Oct-66	22-Dec-66	176,575				
NH40.maint.HD	29-Oct-66	19-Dec-66	1,197,650				
N&W.nw	20-Nov-66	11-Jan-67			281,960		
PMT.VPR.nw	17-Jan-67	17-Apr-67			1,004,959		
CNN45.nw	25-Mar-67	30-Sep-67	3,258,490				
NH45.nw	22-Apr-67	22-Aug-67	3,588,859				
C&O.NN.nw	27-Aug-67	22-Oct-67			420,710		
			10,719,372	0	1,707,629	12,427,001	60,652.481
CNN45.nw	01-Oct-67	11-Jan-68	1,629,245				
ATLAS CEMENT	15-Jan-68	20-Jan-68			46,590		
NP&IR	12-Jan-68	13-Feb-68			811,471		
NOB.maint	20-Feb-68	27-Apr-68		715,366			
NH45.maint.HD	26-Jan-66	08-Feb-68	236,247				
NH40.maint.HD	04-Feb-68	02-Mar-68	716,262				
NNSY.maint.HD	07-Feb-68	24-Feb-68		72,193			
NH45.maint	06-Apr-68	25-Jul-68	1,508,336				
CNN45.nw	08-Sep-68	01-Oct-68	230,630				
			4,320,720	787,559	858,061	5,966,340	66,618,821
NOB & D&S PIERS	14-Sep-68	28-Nov-68		538,103			
NH40&45.maint.HD	29-Jan-69	03-May-69	2,305,462				
CI FUEL DEPOT.nw	16-Feb-69	17-Apr-69		583,635			
CNN45.nw	13-May-69	30-Dec-69	1,898,300				
			4.203,762	1,121,738	0	5,325,500	71,944,321
D&S PIERS.maint	06-Nov-69	13-Feb-70		225,500			
NIT.VPR	06-Nov-69	18-Nov-69			115,925		
N&W.maint	23-Oct-69	05-Nov-69			180,967		
NNSY.maint.HD	02-Jan-70	03-Feb-70		71,200			
NH40&45.maint	02-Jan-70	10-May-70	1,378.980				
CNN.maint	10-May-70	16-May-70	188,610				
NP&IR	09-Jan-70	11-Feb-70			493.425		
RE BASIN.maint	07-Mar-70	11-May-70	800,407				
N&W.maint	30-Mar-70	13-May-70			112,476		
DESAUS RANGE	24-May-70	25-Aug-70		327,401			
NOB.PIER 12	11-Jul-70	11-Aug-70		228,775			
N&W.maint	23-Sep-70	01-Oct-70.			71,672		
NAVY POL.nw	01-Aug-70	22-Sep-70		525,138			
			2.967.997	1.376.014	974.465	5.318.476	77.262.797

Table A-2. CRANEY ISLAND DISPOSAL HISTORY

SPA, new	31-Aug-70	30-Sep-71	8,033,700				
CNN, maint, HD	29-Sep-70	29-Oct-70	370,690				
NIT, VPA, maint	03-Oct-70	12-Oct-70			131,988		
NH40, maint	29-Oct-70	27-Nov-70	890,285				
NH45, maint	11-Dec-70	16-May-71	1,852,999				
EXXON PIERS	13-Mar-71	19-Mar-71			50,104		
NOB, maint	05-Apr-71	22-Jun-71		485,175			
NNA40, new	16-Jul-71	22-Nov-71	4,828,174				
USCG, CI CR, new	16-Aug-71	20-Nov-71		671,202			
			15,981,848	1,156,377	182,092	17,320,317	94,583,114
SPA, new	01-Oct-71	01-Feb-72	2,673,887				
PMT, VPA, maint	16-Oct-71	14-Nov-71			322,389		
N&W, maint	20-Nov-71	09-Dec-71			166,698		
NH40&45, maint	02-Nov-71	04-Jan-72	1,489,000				
USCG, CI CR, maint	09-Feb-72	01-Aug-72		288,507			
RE BASIN, maint	25-Jun-72	19-Sep-72	892,487				
NOB & D&S PIERS	08-Aug-72	05-Sep-72		239,032			
ATLAS CEMENT	06-Sep-72	11-Sep-72			23,050		
NH45, maint	12-Sep-72	29-Oct-72	606,717				
			5,668,091	527,539	512,137	6,707,767	101,290,881
NIT, VPA, new	27-Jan-73	03-May-73			1,264,045		
NH40, maint, HD	07-Feb-73	28-Mar-73	862,800				
CNN, maint, HD	23-Feb-73	28-Mar-73	238,060				
NNSY, maint, HD	17-Feb-73	22-Mar-73		57,950			
HRBT, VDOT, new	27-Apr-73	05-May-73			183,406		
N&W, maint	09-May-73	23-May-73			152,170		
NNSB, maint	23-May-73	26-May-73			15,907		
C&O PIERS, maint	08-Jul-73	23-Jul-73			70,552		
NNSB, new	07-Aug-73	30-Sep-73			324,976		
			1,100,860	57,950	2,011,056	3,169,866	104,460,747
NNSB, new	02-Oct-73	31-Dec-73			956,776		
NOB&D&S, maint	10-Oct-73	01-Apr-74		916,855			
NH40&SB35, m, HD	13-Dec-73	29-Jan-74	852,544				
NNSY, maint, HD	19-Dec-73	29-Dec-73		54,623			
NNSB, new	01-Jan-74	26-May-74			659,742		
NNSB, new	01-Jan-74	26-May-74			769,928		
PMT, VPA	09-Jun-74	22-Aug-74			674,820		
NOB, maint	25-Jun-74	18-Sep-74		207,855			
D&S PIERS, maint	19-Jul-74	09-Sep-74		199,710			
			852,544	1,379,243	3,061,266	5,293,053	109,753,800
NIT, VPA, maint	08-Dec-74	24-Dec-74			199,174		
NH45, maint	29-Jan-75	16-Mar-75	1,522,300				
DEGAUS RANGE	15-Feb-75	23-Feb-75		36,825			
CARGILL GRAIN, BR	15-Feb-75	14-Mar-75			103,324		
NNSB, maint, BR	01-Mar-75	04-Mar-75			14,625		
YELLOW RIVER(LIM)	18-Mar-75	22-Mar-75			11,726		
NNSB, maint	22-Apr-75	30-May-75			263,948		
SO. BLOCK, SB	30-May-75	01-Jun-75			7,156		
US GYPSUM, SB	01-Jun-75	02-Jun-75			4,318		
NOB, maint	28-Jun-75	16-Sep-75		530,995			
RE BASIN, maint	07-Aug-75	17-Nov-75	770,254				
			2,392,554	567,820	604,271	3,564,645	113,318,445

Table A-2. CRANEY ISLAND DISPOSAL HISTORY

NNSY.maint,HD	06-Oct-75	27-Oct-75		73,695			
NH40,maint,HD	03-Oct-75	30-Oct-75	476,270				
CNN.maint,HD	03-Oct-75	30-Oct-75	120,863				
NNSB,nw	10-Oct-75	14-Dec-75			433,649		
C&O COAL PIER,BR	14-Dec-75	18-Dec-75			26,532		
NH45,maint	18-Nov-75	21-Jan-76	539,132				
NOB,12,maint	08-Feb-76	13-Mar-76		386,425			
N&W,maint	07-Mar-76	06-Apr-76			102,916		
NORSHIPCO	07-Apr-76	06-Jul-76			334,220		
NOB,25,nw&m	03-Jun-76	03-Jul-76		622,180			
VDOT,W NOR.BR	29-May-76	15-Jul-76			12,924		
NH45,maint	17-Jul-76	04-Oct-76	2,455,287				
N & W,maint	25-Aug-76	24-Sep-76			384,679		
NOB,BOAT BASIN	27-Jul-76	17-Sep-76		67,200			
			3,591,552	1,155,500	1,294,920	6,041,972	119,360,417
NNSB,maint	28-Nov-76	03-Jan-77			110,307		
NNSB,WAY5&6,m	23-Nov-76	30-Nov-76			37,205		
C&O COAL PIER	14-Feb-77	20-Feb-77			20,045		
VDOT,JRB	14-Feb-77	20-Feb-77			6,071		
NNSY,maint,BR	08-Feb-77	23-Feb-77		39,645			
NOB,20,maint	12-Feb-77	04-May-77		528,325			
NNSB,nw,BR	26-Apr-77	17-Jun-77			333,900		
SPA,maint	05-May-77	20-Jun-77	743,476				
VDOT,JRB	06-May-77	21-May-77			5,528		
WILLOUSHBY BAY	18-May-77	20-May-77	2,400				
DEGAUS RANGE	21-May-77	21-Jun-77		130,480			
DEEP CR,NN,m,BR	25-Jun-77	15-Jul-77	42,862				
			788,738	698,450	513,056	2,000,244	121,360,661
NORSHIPCO	01-Oct-77	25-Jan-78			222,230		
NNSB,W EXT,nw	17-Dec-77	31-Dec-77			53,646		
NOB,284,maint	30-Jan-78	21-Feb-78		211,245			
RE BASIN,maint	21-Feb-78	05-Jan-79	1,231,637				
NH40&SS35,m,HD	02-Mar-78	29-Mar-78	303,786				
NIT,VPA,nw	15-Mar-78	13-Aug-78			954,180		
CNN,maint,HD	16-Mar-78	01-Apr-78	129,160				
CNG,nw,BR	21-Mar-78	14-May-78			108,385		
NOB,12,maint	04-Apr-78	01-Jun-78		345,990			
NOB,12,nw	04-Apr-78	01-Jun-78		146,090			
FUEL LINE TRENCH	12-May-78	11-Jun-78		8,458			
C & O PIER14,BR	24-May-78	10-Jun-78			59,400		
NIT,VPA,maint	03-Jun-78	07-Jul-78			457,370		
NH45,maint	06-Jun-78	01-Nov-78	2,147,368				
ERT,maint,BR	12-Jun-78	15-Jun-78			2,250		
PMT,VPA,nw	15-Jun-78	17-Nov-78			601,176		
			3,811,951	711,783	2,458,641	6,982,375	128,343,035
EXXON PIER	15-Oct-78	24-Oct-78			76,091		
NOB,PIER24,nw	12-Dec-78	14-Feb-79		475,435			
NOB,D&S PIERS	06-Jan-79	20-Mar-79		337,630			
YORKTOWN NWS,HD	02-Jan-79	06-Mar-79		400,971			
NIT,VPA,maint	15-Jul-79	29-Jul-79			111,255		
			0	1,214,036	187,346	1,401,382	129,744,418

Table A-2. CRANEY ISLAND DISPOSAL HISTORY

WOT, JRE, nw	16-Oct-79	24-Oct-79			9,068		
DEEP CR, NN, maint	25-Oct-79	18-Jan-80	296,375				
SPR, maint	15-Aug-79	18-Nov-79	1,477,626				
NH45, maint	10-Nov-79	18-Jun-80	2,016,563				
NOB, PIERS, m	21-Nov-79	22-Feb-80		204,007			
NNA, maint	12-Apr-80	29-May-80	1,087,166				
NOB, 3-7, 22, 25m	21-Apr-80	18-Jun-80		407,375			
CONT GRAIN, nw&m	17-Jun-80	06-Aug-80			159,350		
N&W, nw&m	07-Jul-80	02-Aug-80			230,354		
NOB, 12, maint	12-Aug-80	03-Sep-80		251,738			
RE BASIN, maint	20-Feb-80	14-Oct-80	1,637,381				
NOB, 7, maint	04-Sep-80	06-Sep-80		25,092			
NIT, VPA, maint	19-Feb-80	22-Feb-80			14,823		
			6,515,111	888,212	413,595	7,816,918	137,561,336
NOB, AFDL, maint	12-May-81	05-Jul-81		247,155			
NOB PIERS, maint	23-Jul-81	14-Nov-81		651,882			
CI FUEL DEPOT, m	14-Sep-81	14-Oct-81		35,997			
			0	935,034	0	935,034	138,496,370
NH45, maint	14-Sep-81	22-Jan-82	2,228,076				
N&W, maint	19-Nov-81	01-Dec-81			96,024		
RE BASIN, maint	09-Jan-82	30-Sep-82	1,414,988				
CNN maint	24-Apr-82	23-Jun-82	648,722				
DOMINION TER, nw	25-Jul-82	30-Sep-82			330,000		
NOB, maint	22-Jan-82	19-Mar-82		891,629			
			4,291,786	891,629	426,024	5,609,439	144,105,809
RE BASIN, maint	01-Oct-82	08-Jun-83	1,414,988				
DOMINION TER, nw	01-Oct-82	09-Jun-83			989,925		
NH45, maint	14-Nov-82	24-May-83	2,183,692				
NOB PIERS, maint	28-Sep-82	11-Apr-83		366,479			
NOB, ADFL, maint	03-May-83	24-May-83		114,005			
NIT, VPA, maint	12-Jun-83	05-Jul-83			392,148		
			3,598,680	480,484	1,382,073	5,461,237	149,567,046
NOB PIERS, maint	19-Oct-83	26-Nov-83		363,098			
RE BASIN, maint	01-Apr-84	30-Sep-84	869,433				
NH45, maint	06-Apr-84	30-Sep-84	1,752,340				
NOB PIER 11, m	22-May-84	06-Jul-84		469,639			
SPR, maint	04-Feb-84	29-Sep-84	2,451,377				
			5,073,150	832,737	0	5,905,887	155,472,933
RE BASIN, maint	01-Oct-84	16-May-85	1,391,094				
NH45, maint	01-Oct-84	14-Dec-84	876,171				
NOB PIERS, maint	16-Sep-84	28-Nov-84		775,448			
N & W, maint	23-Oct-84	24-Nov-84			121,457		
NIT, maint&nw	03-Feb-85	02-Apr-85			600,095		
NNA, maint, HD	06-Feb-85	07-Mar-85	183,545				
NOB PIERS, maint	07-Mar-85	01-May-85		610,386			
EXXON PIER, maint	16-May-85	22-May-85			77,150		
LEHIGH CEMENT, m	22-May-85	24-May-85			45,400		
NNA, maint	31-Jul-85	11-Aug-85	251,987				
			2,702,798	1,385,834	844,102	4,332,734	160,405,667

Table A-2. CRANEY ISLAND DISPOSAL HISTORY

VDCT.I-66A.nw	07-Jan-86	19-Mar-86			997,142		
WB ELIZ R.maint	02-Feb-86	22-Mar-86	150,431				
NIT.nw	22-May-86	22-Jun-86			1,618,841		
NOB PIERS,maint	01-Jun-86	29-Jun-86		185,365			
H40,maint	15-Jul-86	14-Aug-86	192,055				
NH45,maint	15-Jul-86	30-Aug-86	529,325				
			871,811	185,365	2,615,983	3,673,159	154,078,826
NOB PIERS,nw	09-Jun-87	01-Aug-87		978,250			
NOB PIERS,nw	20-Jul-87	08-Aug-87		153,474			
RE BASIN,maint	08-May-87	23-Aug-87	1,681,024				
			1,681,024	1,131,724	0	2,812,748	156,891,57
			120,424,524	23,122,507	23,344,543		166,891,57

PROBABLE FUTURE SHOALING RATES

5. With the significant amount of waterborne commercial traffic through Hampton Roads, as well as the large water-related defense contingent, there has been a historic need to maintain the navigable waterways of the area. Therefore, throughout recent history, large quantities of sediment have been dredged from the waters of Hampton Roads; associated with dredging is the requirement to dispose of the material in an approved disposal site. Because of the large quantity of material dredged annually, a large disposal site capacity has been and will continue to be required in Hampton Roads. Much of the dredging has been conducted by the Norfolk District, although significant portions of the material have been dredged by other Federal agencies, especially the Navy, and by state and private firms.

6. The following table indicates the substantial quantities of new work and maintenance dredging for Norfolk Harbor and adjacent waters for the foreseeable future. These quantities include dredging Federal, state/local entities, and private interests.

DISTRIBUTION OF SEDIMENTS BY TYPE

7. There is little sand or coarse-grained material within the channels of the inner harbor. This is attested to by the fact that the area in Craney Island wherein suitable coarse grained material is located is small compared to the overall size of the disposal area. Good material is situated principally along the eastern section of the area. This results from the settlement of the heavier sandy material along the eastern side as dredged material is pumped either from the rehandling basin or direct into Craney Island. As the outer retaining dikes are strengthened and interior containment dikes are raised, the onsite requirement for coarse grained material has increased. Thus, recent deepening of the Newport News Channel to 50 feet resulted in sand, shell, small gravel, silts and clays located in portions of the channel. This material was pumped along the northern and western dikes to strengthen them.

Table A-3. ESTIMATED AMOUNT OF FUTURE DREDGING
(in 1,000 cubic yards)

	Outbound channels (a)		Elizabeth R. channels		Inbound channels (a)	
Year	50-foot	55-foot	45-foot	40-foot	50-foot	55-foot
			NEW WORK DREDGING			
1987	2,168					
1988	4,642					
1993		4,893				
1994		5,131				
1995		4,523				
1996			3,739 (b)			
1997			3,739 (b)	2,235(b)		
1998					1,228	
1999						3,974
			MAINTENANCE DREDGING			
1988 thru 1994	4,000 each year					
1995		4,200				
1996		4,200				
1997			4,295			
1998				4,313		
1999					4,313	
2000						4,474
Future						4,474

(a) See main report, plate 3. Inbound channels are in a deferred category.
(b) Based on 1980 Feasibility Report on Norfolk Harbor and Channels, VA.

8. By contrast, practically all of the material within the Norfolk Harbor 50-foot channel or anchorages contained fine-grained material. The same is true for the Elizabeth River 40-foot channel. The dredged material in the Southern Branch is basically unsuitable for ocean disposal although coarse-grained material is located below the unsuitable material.

DEBRIS REQUIREMENT

9. A project for the collection and removal of drift from Hampton Roads and the Harbors of Norfolk and Newport News was approved under authority of Section 102 of the River and Harbor Act of 1950. The project provides for the collection and removal of floating debris for the protection of navigation.

10. Vessels remove floating timbers, planking, and piles characteristic of the type of debris that would be generated by the breakup of deteriorating waterfront structures and derelict wooden vessels. The drift also includes small lumber pieces, plywood, fiberglass sheets, cargo pallets, rubber tires, and other trash material. Drift removal under this program is generally confined to the channel itself or the immediate adjacent waters. Drift and debris is not collected in shallow areas outside the channel or from along the shoreline.

11. The debris is loaded onto a barge at Fort Norfolk which is towed periodically to CIDA where it is unloaded or buried in the disposal area. Facilities are provided at CIDA for unloading debris from barges or vessels. These facilities consist of a steel sheet pile bulkhead providing a berthing area of approximately 400 feet long parallel to and 50 feet east of the east levee. An average volume of about 63,000 cubic feet of drift (2,300 cubic yards) is collected and disposed annually. Adjusting for quantity of voids results in a total of about 30,000 cubic feet of solid material.

12. In March 1982, a report was prepared by the Norfolk District in response to the following resolution adopted on April 14, 1964 by the Committee on Public Works, U.S. House of Representatives:

> "Resolved ... that the Board of Engineers for Rivers and Harbors is hereby requested to review the existing project for the collection and removal of drift in Hampton Roads ... with a view to determining if modification is advisable at this time, with particular reference to the desirability of determining the location and extent of potential hazards to navigation resulting from deteriorating waterfront structures, abandoned barges and scows, and other debris along the shores of Hampton Roads Harbor area."

13. The report indicated that sources of potential drift material include municipal and privately-owned deteriorated shore structures, derelict vessels in places where they do not directly obstruct general navigation, and debris on shore. In addition, areas above the mean high water mark are a common depository for refuse material and under combined high water and wind conditions much of this material enters the waterways . Sources of drift material generally relate to local property, and, as such, are in the area of local legislative jurisdictions. The existing state and local laws applicable to removing these structures have not been totally effective in eliminating the drift problem. Under existing laws, clean-up would be a "piece-meal" operation with numerous delays, if accomplished at all.

14. The results of a drift source survey conducted in 1980 is shown in the following table.

Table A-4. PRINCIPAL SOURCES OF FLOATABLE MATERIAL

Principal sources of floatable debris	Total available in cubic feet
Dilapidated shore structures (a)	403,400
Derelict structures	430,000
Loose drift along shoreline	35,000
Above mean high water	80,000
Total	948,400 (b)

(a) Piles cut off at shoreline.
(b) 948,400 cubic feet or 35,100 cubic yards.

15. The report recommended dismantling and removal of dilapidated piers, wharves, bulkheads, abandoned vessels, and floatable shoreline debris according to a programmed schedule. All piles would be cut off at the mudline, except in shallow areas, where they would be removed completely. Following removal, the material would be buried at the Corps of Engineers' CIDA. Such a

project was approved by Congress in the Water Resources Development Act of 1986.

16. Accordingly, although the amount of all types of debris to be removed in the foreseeable future is relatively small, some space and a dock must be available for this purpose either at CIDA or other inclosed area.

DREDGING METHODS

17. A dredge may be defined as a machine which removes material from the bottom of a waterway by means of scooping or suction devices. There are two primary methods in use today, hydraulic and mechanical.

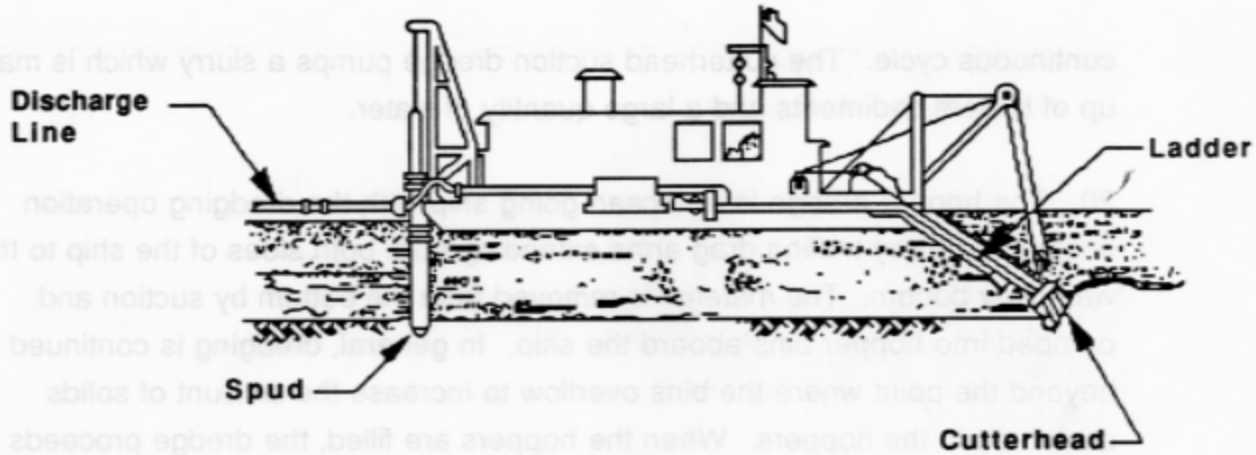
HYDRAULIC DREDGES

18. Dredges that operate hydraulically use water as a medium to convey the dredged material. The material to be excavated is mixed with water and conveyed through the system by a centrifugal pump as a slurry (generally 10 to 20 percent solids content by weight). The material is transported to a confined area and pumped therein where the sediments are allowed to settle out. Owing to the flows associated with this system, the disposal sites are designed to include areas for decanting the sediments, before discharge to the waterway or watercourse.

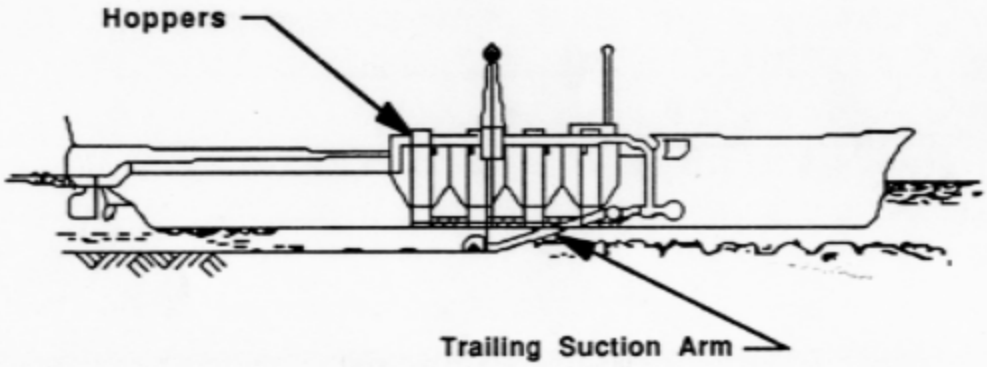
19. The hydraulic dredge utilized in the inner harbor of Hampton Roads includes the cutterhead suction and the hopper dredges. The cutterhead suction dredge excavates material by means of a rotating cutter at the end of a suction pipe. The cutter suspends material into a slurry which is then pumped hydraulically and discharged through a pipeline to shore. The dredge advances by swinging from side to side using spuds at the rear as pivots. Lateral movements are controlled by swing cables attaches to anchors. The depth of cut is manually controlled by the operator, who may raise or lower the ladder cutterhead. The use of booster pumps in the pipeline allows material transport over relatively long distances from the waterway to the disposal site. Large volumes of material can be moved economically because of a virtually

continuous cycle. The cutterhead suction dredge pumps a slurry which is made up of bottom sediments and a large quantity of water.

20. The hopper dredge is an ocean-going ship with the dredging operation accomplished by trailing drag arms extending from both sides of the ship to the waterway bottom. The material is removed from the bottom by suction and pumped into hopper bins aboard the ship. In general, dredging is continued beyond the point where the bins overflow to increase the amount of solids contained in the hoppers. When the hoppers are filled, the dredge proceeds to deep water dumping grounds, where the bins are opened, and the material discharged. As an alternative, the bins may be pumped out, and the slurry discharged to upland disposal areas, as in conventional hydraulic dredging practice.



CUTTERHEAD SUCTION DREDGE



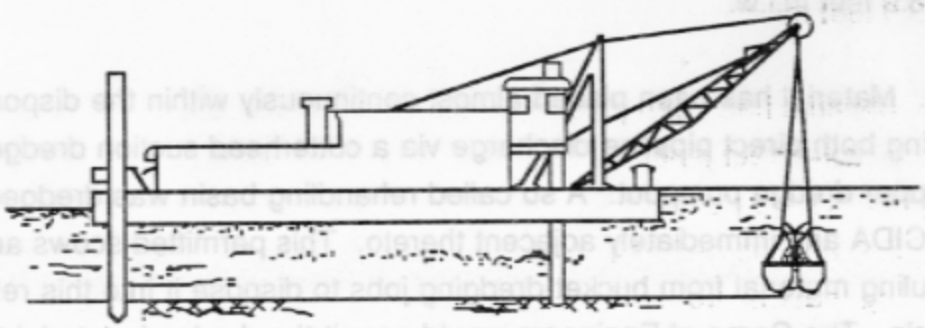
HOPPER DREDGE

Figure A-1 Hydraulic Dredges

MECHANICAL DREDGES

21. Mechanical dredges remove the bottom material with excavation devices, but do not transport it to the disposal site. Barges and tugs are used for this purpose. All mechanical dredges resemble dry land equipment. In fact, in some cases surface equipment is floated on a barge and used for dredging.

22. One typical mechanical dredge is the clamshell dredge. This basically consists of a derrick mounted on a barge with a "clamshell" bucket for excavation. The material is removed by forcing the opposing bucket edges into the sediment. The bucket is lifted out of the water and deposits the material on an adjacent barge. The dredge itself, as in the case of the cutter suction dredge, remains at the dredging site. The barge when filled is towed by a tug to an unloading site. This could be either the rehandling basin at CIDA or the barge could be towed to sea where it is unloaded. Eventually, the Corps empties the rehandling basin by having this material (and others placed therein) pumped hydraulically into CIDA.



CLAMSHELL DREDGE

Figure A-2 Mechanical Dredge

CRANEY ISLAND DISPOSAL AREA

DESCRIPTION OF PROJECT

23. The River and Harbor Act of 24 July 1946 provided the authority for construction of a dredged material disposal area of approximately 2,500 acres in Hampton Roads adjacent to and north of Craney Island, including the necessary appurtenances and facilities. It is located adjacent to the city of Portsmouth as shown on figure A-3. The area is trapezoidal in shape, with its easterly limit parallel to and 3,500 feet west of the Norfolk Harbor authorized 55-foot channel and extending 11,050 feet north from the northerly limit of Craney Island. It has widths of 9,000 and 11,100 feet at its offshore and inshore ends, respectively. The river bottom consists of soft marine clays predominantly, as shown in figure A-4. The disposal area was enclosed by hydraulically pumped sand levees to elevation +5.0 feet m.l.w. with a base width of 850 feet and an approximate length of 30,930 feet. This levee was further raised to elevation +8.0 feet m.l.w. by mechanical means. The levee slopes from elevation +1.0 feet to +8.0 feet were protected from wave action by placement of stone rip-rap both inside and out. Construction started in July 1954 and was completed in August 1958 with the dredging of a rehandling basin for use by scows and barges hauling material from bucket dredging jobs. The original design estimated 20 years of life and 96,000,000 cubic yards of capacity to elevation +18.0 feet m.l.w.

24. Material has been placed almost continuously within the disposal area using both direct pipeline discharge via a cutterhead suction dredge and/or a hopper dredge pumpout. A so called rehandling basin was dredged to the east of CIDA and immediately adjacent thereto. This permitted scows and/or barges hauling material from bucket dredging jobs to dispose it into this rehandling basin. The Corps of Engineers would permit the dredged material to accumulate in the rehandling basin and eventually pumped it into CIDA. Over 130 million cubic yards, considerably more than the original estimated volume, was placed within the containment by March 1980, when the average elevation over the entire disposal area was about +15.0 m.l.w.

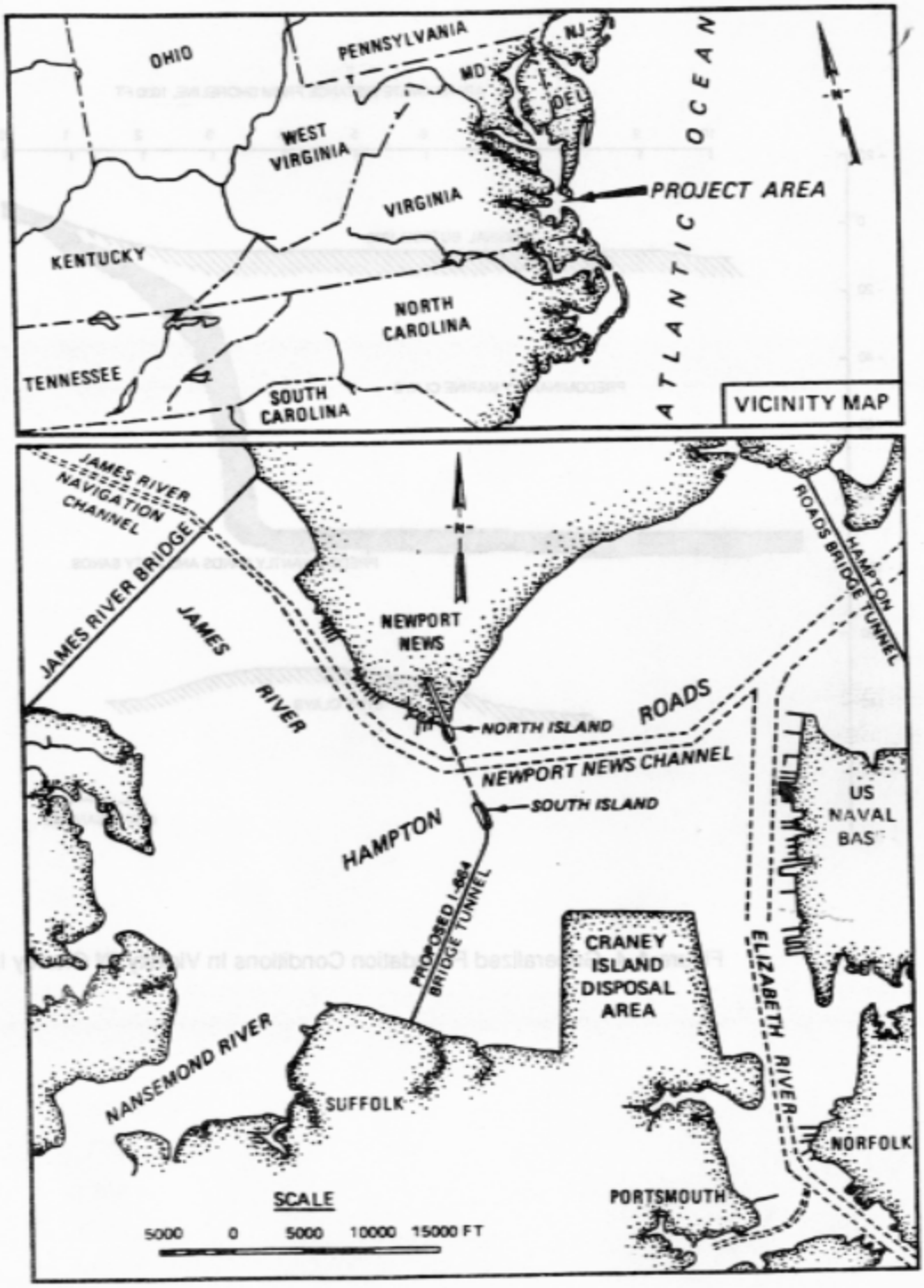


Figure A-3 Craney Island project location

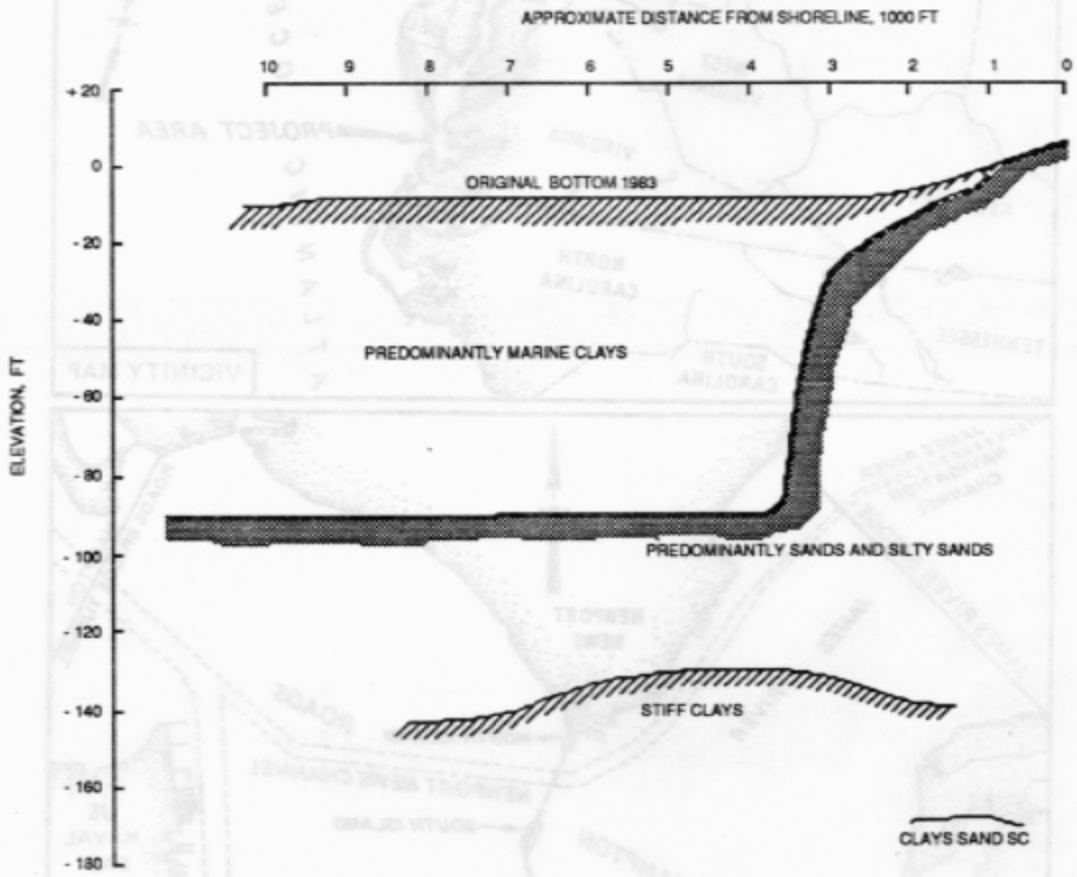


Figure A-4 Generalized Foundation Conditions In Vicinity Of Craney Island

25. At the request of the District office, the U.S. Army Engineer Waterways Experiment Station prepared a technical report dated December 1981 (EL-81-11) recommending certain improvements in the operation and management of CIDA. The report is entitled "Development of a Management Plan for Craney Island Disposal Area." A summary of the recommended plan is contained in the main report. One of the recommendations was that new retaining dikes along alignments benched in from the exterior levees be constructed to allow dredged material placement to +30 m.l.w. Figure A-5 shows a typical cross section of the main retaining dikes as initially constructed. Since their initial construction, the main retaining dikes have generally been raised by constructing interior dike sections stepped or benched in at varying distance.

26. Management of confined dredged material disposal areas to provide maximum storage capacity is becoming more necessary as both the storage capacity of existing sites, such as CIDA, and the availability of land for creation of new sites decrease. Dewatering dredged material is a common practice that is employed to increase the useful life of an existing disposal site. Interim surface trenching are effective ways to achieve a greater degree of dewatering than can be done through natural drainage.

27. Thus in accordance with the management plan developed by WES, construction of two interior dikes was completed which effectively separated the disposal area into three subcontainments or cells, of approximately equal size. The management of CIDA involves annual rotation of dredged disposal between the three cells, thus allowing two years of drying in any particular cell before disposal is again allowed in that cell. The surface ditches primary function begins long after the disposal operation is complete. The purpose is to remove precipitation from the surface before it has a chance to recharge the dredged material. By placing trenches adjacent and parallel to the perimeter dikes as well as throughout the interior of the site, water is quickly moved from all parts of the site to the spillways and then offsite. As the dredged material dries and settles, the trenches are progressively deepened.

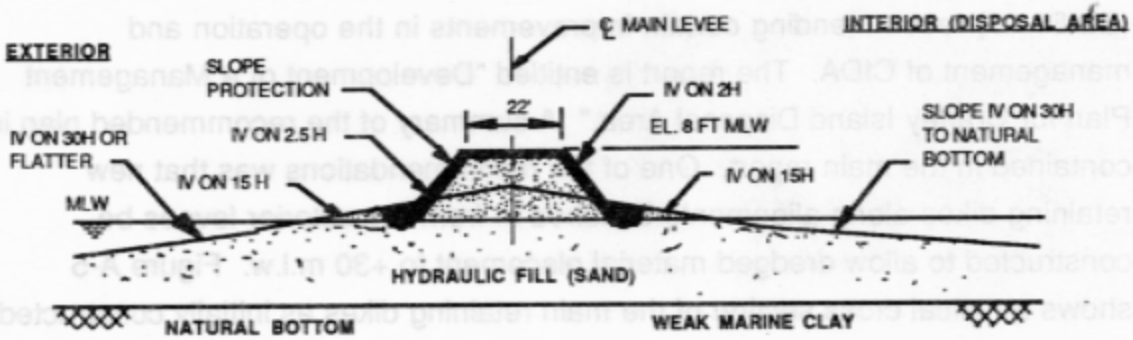


Figure A-5. Typical dike cross section used for slope stability studies

28. Figure A-6 shows a plan view of the interior levees as planned in the management plan referred to in the 1981 report. It includes the two levees subdividing Craney Island into three large subcontainment areas. Six new weir (spillway) structures, each with an effective weir length of 75 feet, were recommended. Their locations are shown on figure A-6.

29. Completion of the interim dikes in 1984 resulted in formation of three separate cells in CIDA. Each cell has been operated independently of the others since that time. Disposal operations have generally been rotated through the three cells on an annual basis. By rotating disposal operations, one year of active disposal followed by two years of drying has generally occurred in each cell.

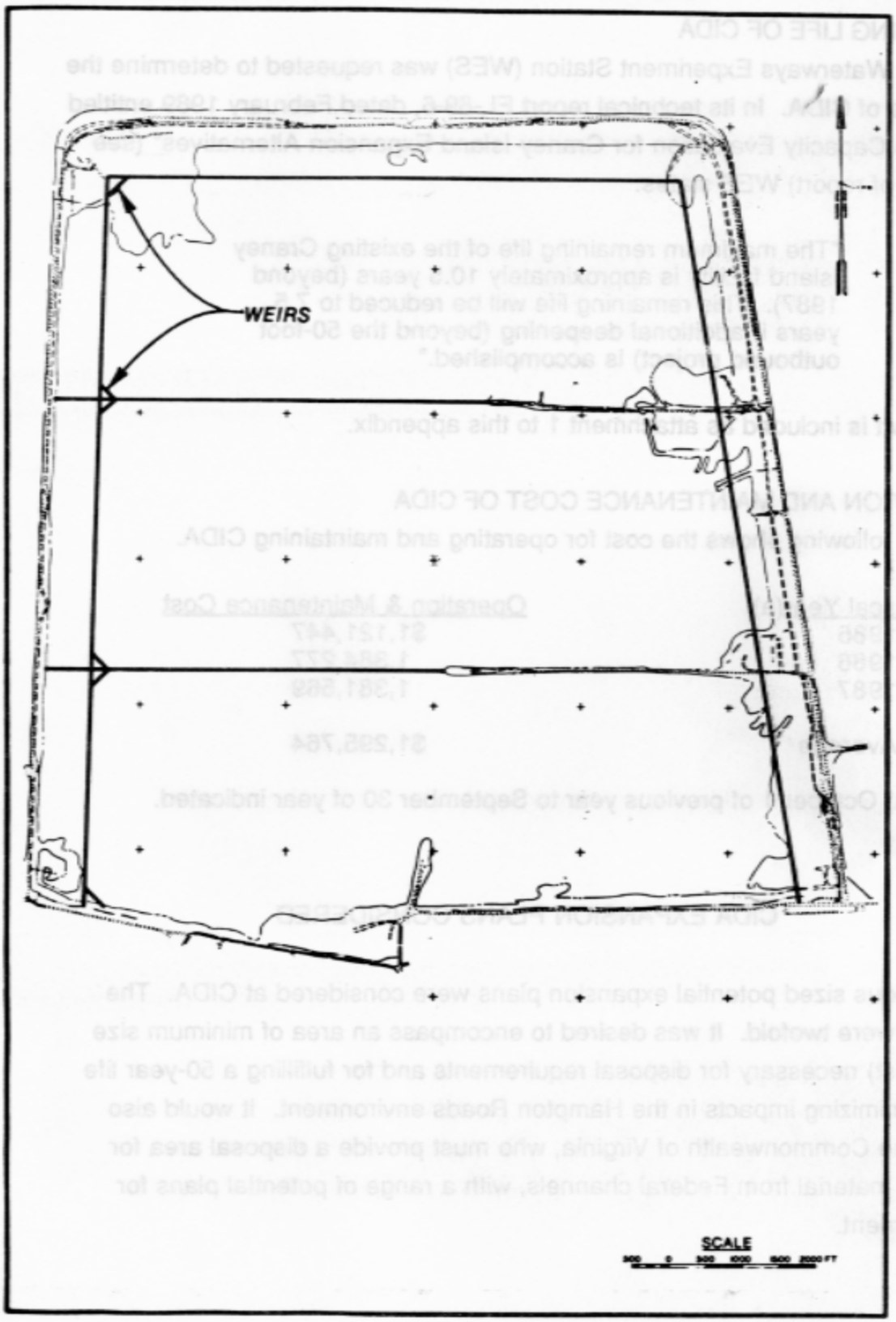


Figure A-6 Plan view of interior levees and weir locations

REMAINING LIFE OF CIDA

30. The Waterways Experiment Station (WES) was requested to determine the future life of CIDA. In its technical report EL-89-6, dated February 1989 entitled "Storage Capacity Evaluation for Craney Island Expansion Alternatives" (see page 31 of report) WES states:

> "The maximum remaining life of the existing Craney Island facility is approximately 10.5 years (beyond 1987). This remaining life will be reduced to 7.5 years if additional deepening (beyond the 50-foot outbound project) is accomplished."

The report is included as attachment 1 to this appendix.

OPERATION AND MAINTENANCE COST OF CIDA

31. The following shows the cost for operating and maintaining CIDA.

Fiscal Year(a)	Operation & Maintenance Cost
1985	$1,121,447
1986	1,384,277
1987	1,381,569
Average	$1,295,764

(a) October 1 of previous year to September 30 of year indicated.

CIDA EXPANSION PLANS CONSIDERED

32. Various sized potential expansion plans were considered at CIDA. The reasons were twofold. It was desired to encompass an area of minimum size (least cost) necessary for disposal requirements and for fulfilling a 50-year life while minimizing impacts in the Hampton Roads environment. It would also permit the Commonwealth of Virginia, who must provide a disposal area for dredged material from Federal channels, with a range of potential plans for development.

33. Six potential expansion sites were considered as shown in figure A-7. Figures A-8 through A-13 show them in greater detail. Each of these sites abutted the existing facility on the north or west side or both. Expansion to the east was impossible because of the proximity of the Elizabeth River ship channel. Thus, expansion possibilities were limited to the west and north.

WATERWAYS EXPERIMENT STATION

34. The Waterways Experiment Station of the Corps of Engineers (WES) was requested to evaluate various aspects of expansion alternatives.

a. The Geotechnical Laboratory developed the material requirements for each expansion site. This included the volume of the dikes, the areas requiring riprap, the stability of the dikes, etc.

b. The Environmental Laboratory developed the volumetric storage capacity of each alternative and its life, taking into account proper management thereof. Laboratory procedures for testing slurried sediments (sediments containing substantial amounts of water) have been developed at WES. These procedures can provide compressibility and permeability data for the large quantities of very soft materials dredged annually. The computer model which WES utilized to estimate the useful life and storage volume of each alternative is referred to as "Primary Consolidation and Desiccation of Dredged Fill."

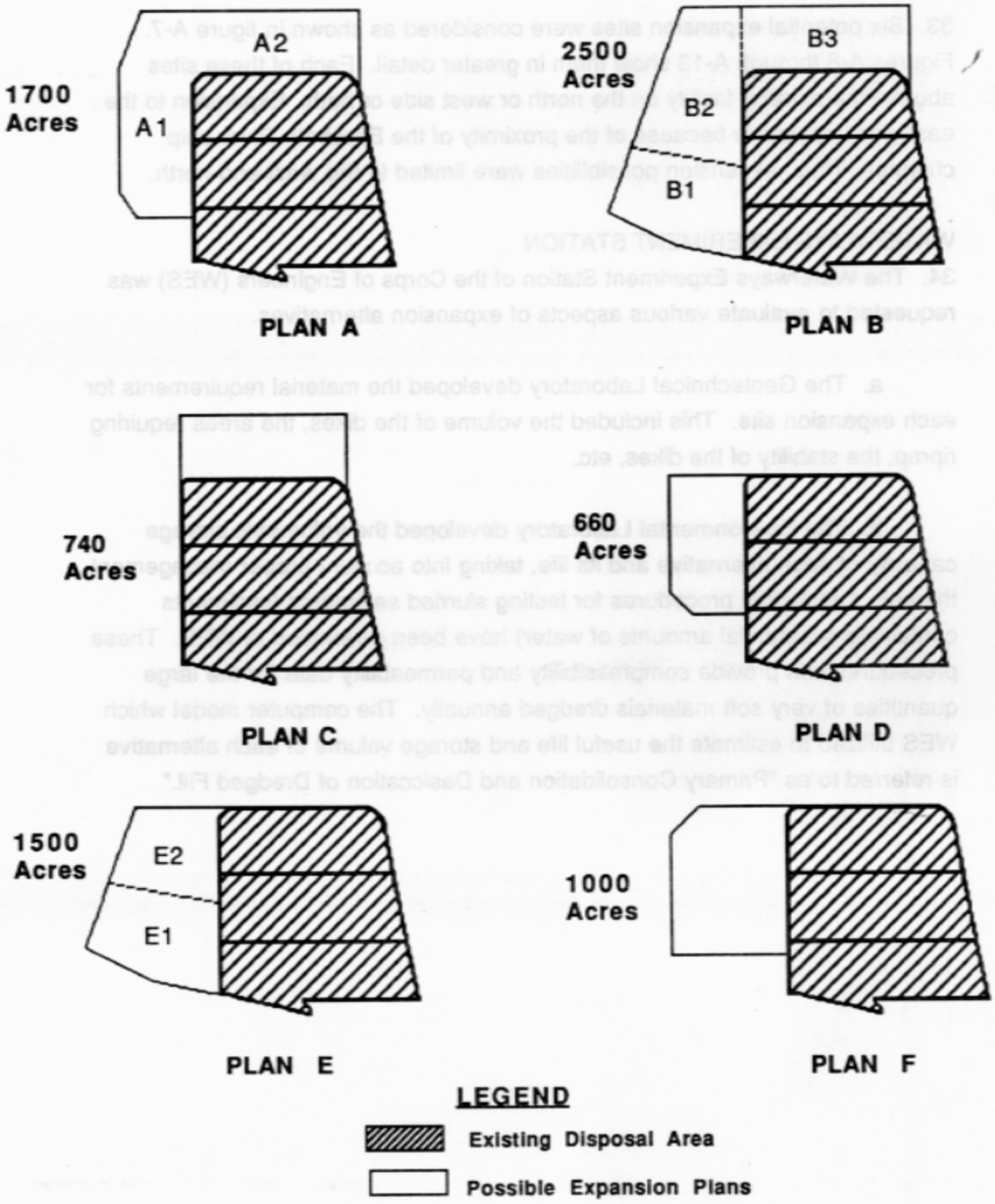


Figure A-7. Alternative configurations for expansion of Craney Island

c. The Hydraulics Laboratory determined the hydrodynamic impacts of each expansion alternative on the flow regime in the Hampton Roads area.

35. Items a and b are included with this appendix. They are entitled:

a. "Geotechnical Feasibility Study - Replacement or Extension of Craney Island Disposal Area, Norfolk, Virginia," June 1987, Miscellaneous Paper GL-87-9. Also, addendum 1.

b. "Storage Capacity Evaluation for Craney Island Expansion Alternatives", February 1989, GL-89-6.

36. The hydrodynamic report is included with the environmental appendix.

PHYSICAL DATA OF EXPANSION ALTERNATIVES

37. The six expansion alternatives were developed with the following two basic concepts previously mentioned.

- All new work dredging for the inner harbor (55 outbound channel and an increase in depth in the Southern Branch from 35 and 40 feet to 40 and 45 feet.

- Table A-3 which includes the probable future dredging from Federal channels and from other Federal, state/local organizations and private companies.

Basic conceptual layouts were developed by the Norfolk District with representatives from the Waterways Experiment Station's laboratories that would be involved with the work. The concepts were taken back to WES for development of quantities, capacities and longevities using computer models.

38. The Environmental Laboratory developed the physical features of the expansion plans as shown in the following table. Further data on each alternative are provided in later paragraphs. The total storage capacity for each

expansion plan was calculated as the product of the available surface area for each phase and the average depth for each phase. Storage capacity is defined as the total unoccupied volume minus the volume associated with ponding and freeboard requirements.

DREDGING SCENARIOS CONSIDERED

39. The following dredging scenarios were considered by WES in determining the storage capacities and associated useful lives for each expansion plan. They are based on table A-3 which includes the probable future dredging from Federal channels and from other Federal, state/local organizations, and private interests.

Scenario 1. Assuming the Federal channels including the existing 50-foot channel are not further improved.

Scenario 2. Same as scenario 1. In addition, the 55-foot outbound channel is dredged.

Scenario 3. Same as scenario 1. In addition, the entire 55-foot inbound and outbound channels are dredged.

Scenario 4. Same as scenario 1. In addition, the Elizabeth River and its Southern Branch are increased in depth from 35 and 40 feet to 40 and 45 feet respectively.

Scenario 5. Same as scenario 4. In addition, the 55-foot outbound channel is dredged.

Scenario 6. Same as scenario 5. In addition, the entire 55-foot inbound and outbound channels are dredged.

40. In the WES study (see attachment 1), the above scenarios are referred to as indicated.

Scenario 1. (S1) Existing project; 50 foot OB
Scenario 2. (S2) 55 foot OB
Scenario 3. (S3) Entire 55 foot
Scenario 4. (S4) 50 foot OB + SB 40 and 45
Scenario 5. (S5) 55 foot OB + SB 40 and 45
Scenario 6. (S6) Entire 55 foot + SB 40 and 45

STORAGE CAPACITY EVALUATIONS

41. The following are important factors considered by WES in its computer analysis for estimating the life of CIDA and/or extensions thereof.

a. After dredged material (with its considerable water content) is placed within a confined disposal site, it immediately undergoes sedimentation which is completed within a few days. The dredged material then enters the more time-consuming process of self-weight consolidation. If a site is well managed to eliminate surface water, the dredged material will be subjected to evaporative drying and may undergo significant settlement resulting from this drying. Computer analyses must predict dredged material settlement due to both consolidation and desiccation. Projections made by WES of availability of storage for dredged material (on the life of CIDA or any of the extensions thereto) assumed that maximum management (maximum dewatering) is accomplished. Thus an active dewatering program was assumed to be planned and implemented. Therefore, the results by WES are based on maximum dewatering resulting in a maximization of storage capacity.

b. An initial point in time was taken as the beginning of 1987 for CIDA. The final elevation to which dredged material could be placed was assumed to be 30 m.l.w.

c. It was assumed that the existing CIDA will be the only available disposal site until 1993, which represents the earliest data an expansion plan could be available. Therefore CIDA will receive all material dredged in the Hampton Roads area from 1987 through 1992. This includes 4 million cubic yards or more of maintenance material dredged from Federal, state/local organizations and private interests.

RESULTS OF LABORATORY ANALYSIS

42. Evaluations were made of the useful life and storage of CIDA and its expansion options taking into account (a) the scenarios previously described, (b) the corresponding dredging quantities established in table A-3, and (c) the year that any one of the expansion plans was assumed to be available for the storage of dredged material (1993). The following table indicates the results thereof.

Table A-5. RESULTS BY WES OF USEFUL LIFE STUDY

Expansion plan		Year expansion alternative fills based on following scenarios					
		No further harbor deepening (S1)		Deepening of 45' and 40' SB only (S4)		Deepening of 45' and 40' SB plus 55' OB channel (S5)	
		without CIDA	with CIDA	without CIDA	with CIDA	without CIDA	with CIDA
None		--	1997	--	1994	--	1994
A	(1)	2031	2038	2026	2032	2017	2025
B	(2)	2048	2054	2043	2048	2035	2042
C	(3)	2004	2011	2000	2006	1996	1998
D	(4)	2002	2008	1997	2003	1995	1997
E	(5)	2021	2028	2017	2024	2009	2019
F	(6)	2007	2012	2002	2009	1997	2004

NOTE: S1, S4, and S5 refer to dredging scenarios in WES report.

43. The amount of dredged material that could be placed therein follows:

Table A-6. RESULTS OF USEFUL LIFE STUDY
AMOUNT OF DREDGED MATERIAL TO BE STORED

	Total dredged material that can be placed in million cubic yards		
		Deepening of 45' and 40'SB	
Expansion plan	No further harbor deepening (S1)	only (S4)	plus 55' OB channel (S5)
A (1)	156	149	131
B (2)	224	219	209
C (3)	48	42	31
D (4)	40	30	27
E (5)	116	112	97
F (6)	60	50	43

NOTE: S1, S4, and S5 refer to dredging scenarios in WES report.

44. Table A-5 indicates the following:

If CIDA expansion plan B were completed in 1993, disposal of dredged material could be placed therein:

- Without further harbor deepening until filled in year 2048 (o about 59 years hence).

- With further deepening (55-foot outbound channel plus 45 and 40-foot channels in Southern Branch) until filled in year 2035 (or about 46 years hence).

45. The new work required to dredge the 55-foot channel consists of clean material. If it were placed at sea, there would be space available for 50 years or possibly longer at expansion plan B.

DESIGN DATA

46. Figures A-8 through A-13 show each of the individual expansion alternatives in more detail and in relation to the general bathymetry of the area

and dike alignment of the proposed expansions. Soundings and elevations are based on Corps of Engineer Craney Island Low Water datum.

47. A dike profile or section was assumed similar to the existing Craney Island for elevations up to +8.0 feet m.l.w. Because of the soft, marine clay foundation, very broad, gradual slopes are required for stability of the first construction phase up to elevation +8.0 feet m.l.w. The initial construction estimates are based on the typical section shown in figure A-5 and in WES report "Geotechnical Feasibility Study, Replacement or Extension of the Craney Island Disposal Area, Norfolk, Virginia."

48. Because of the large volume requirements of sand to construct the initial dike section, numerous sources were investigated to assure sufficient quantity for each expansion alternative. The geotechnical investigations and results are described in detail in Appendix B. Since no one source had a sufficient quantity of sand to construct three of the six expansions, the construction estimates include costs for moving to each of the borrow sources. The Geotechnical appendix B indicates sources of suitable sand (borrow) for construction of levees. A maximum of 19.1 mcy of sand is required. Based on preliminary geotechnical studies, this volume of material can be obtained from the top five of six optimum sources within an economical dredging and pumping distance of the proposed expansion plans. The Pig Point area does not appear to be environmentally acceptable.

UTILITY INVENTORY

49. A utility inventory was performed to determine the impact of the expansions on any existing utilities. The only utility located during the inventory was the Hampton Roads Sanitation District's (HRSD) 54-inch sewer outfall line shown on figures A-8 through A-13. Each of the alternative dike alignments that did not allow a 1,000-foot clear zone from the outfall pipe was modified to provide the suggested clear zone. The architectural engineering firm that performed the inventory recommended against moving the pipeline because of cost and the need for it to stay in operation.

50. The inventory also addressed the joint use of the existing Craney Island with each of the expansion alternatives with respect to operation and

modification to the weir structures in Craney Island Plans A, B, D, E, and F, if used jointly with the existing Craney Island weirs. The utility inventory, performed as part of this study, recommended two alternatives for this item. One was an open ditch; the other was the use of large diameter pipes to intercept existing weir outflow pipes and carry flow out to the river. Of the two, it appears the pipelines would be the choice from a construction and operational viewpoint. The report of the architectural firm that performed this inventory is included with this appendix (attachment 3) and is entitled "Inventory of Existing Utilities and Adjustments Recommendations Related to Replacement or Extension of Craney Island Disposal Area" dated July 15, 1988.

51. The Virginia Department of Transportation's (VDOT) Interstate 664 trestle lies at the western edge of the proposed expansions and limits expansion to the west. VDOT requires a 2,000-foot clear zone from the trestle. During future detailed engineering and design of the proposed expansion of Craney Island, special design features may allow a reduction of these clear-zones. This would allow larger westward and smaller northward expansions at a reduced cost.

DESCRIPTION OF EXPANSION ALTERNATIVES

52. Five individual expansion alternatives were roughed-out by personnel from the Norfolk District and the Waterways Experiment Station (WES). The expansion alternatives were laid out to take advantage of the existing Craney Island containment dikes and shallow water whenever possible. The five alignments (later a sixth was added) were taken to the Hydraulics, Geotechnical and Environmental Laboratories for development of individual details. The following is a description of the expansion plans.

Plan A (referred to as Plan 1 in the WES reports)

53. This alternative is approximately 1700 acres in area, has a capacity between 131 and 156 million cubic yards of dredged material and is located in water depths that range between 7.0 and 30.0 feet deep at mean low water. The initial construction phase will bring the containment dike to elevation +8.0 feet above mlw and will require approximately 19 million cubic yards (mcy) of sand and 163,000 square yards of rip-rap. Once the dredged material within the area rises above the water surface, division dikes required to subdivide the area will be constructed under operation and maintenance features. Upgrading

of the outflow structures will also be accomplished and operation of the facility will switch to intensive management of the dredged material crust with annual rotation of disposal actions between the subdivided areas. Incremental raising of the perimeter and division dikes would be accomplished to contain the current year dredging.

Plan B (referred to as Plan 2 in the WES reports)

54. This alternative is approximately 2500 acres in area, has a capacity between 209 and 224 million cubic yards of material and is located in water depths that range between 0.0 and 30.0 feet deep at mean low water. The initial construction phase will bring the containment dike to elevation +8.0 feet above mlw and will require approximately 18.6 million cubic yards of sand and 181,000 square yards of rip-rap. Once the dredged material within the area rises above the water surface, division dikes required to subdivide the area will be constructed under operation and maintenance features. Up-grading of the outflow structures will also be accomplished and operation of the facility will switch to intensive management of the dredged material crust with annual rotation of disposal actions between the subdivided areas. Incremental raising of the perimeter and division dikes will be accomplished to contain the current year dredging.

Plan C (referred to as Plan 3 in the WES reports)

55. This alternative is approximately 740 acres in area, has a capacity between 31 and 48 million cubic yards of material and is located in water depths that range between 10 and 30 feet deep at mean low water. The initial construction phase will bring the containment dike to elevation +8.0 feet above mlw and require approximately 14 million cubic yards of sand and 88,000 square yards of rip-rap. Since this area is not large enough to subdivide, division dikes will not be required. Operations and maintenance will occur on the main perimeter dike and upgrade of outflow structures. When the dredged material surface rises above the water level within the area, the surface crust will be managed during periods of no inflow.

Plan D (referred to as Plan 4 in the WES reports)

56. This alternative is approximately 660 acres in area, has a capacity between 27 and 40 million cubic yards of material and is located in water depths that

range between 7 and 15 feet deep at mean low water. The initial construction phase will bring the containment dike to elevation +8.0 feet above mlw, and require approximately 5 million cubic yards of sand and 81,000 square yards of rip-rap. Since this area is not large enough to subdivide, division dikes will not be required. Operation and maintenance will incrementally raise the perimeter dikes to contain the current year dredging and will upgrade the outflow structures as needed. When the dredged material surface rises above the water level within the area, the surface crust will be managed during periods of no inflow.

Plan E (referred to as Plan 5 in the WES reports)

57. This alternative is approximately 1450 acres in area, has a capacity between 97 and 116 million cubic yards of material and is located in water depths between 0 and 15 feet deep at mean low water. The initial construction phase will bring the containment dike to elevation +8.0 feet above mlw, and require approximately 4.5 million cubic yards of sand and 99,000 square yards of rip-rap. Once the dredged material within the area rises above the water surface, division dikes required to subdivide the area will be constructed under operation and maintenance features. Upgrading of outflow structures will also be accomplished and operation of facility will switch to intensive management of the dredged material crust with annual rotation of disposal actions between subdivided areas. Incremental raising of the perimeter and division dikes will be accomplished to contain current year dredging.

Plan F (referred to as Plan 6 in the WES reports)

58. This alternative is approximately 1,000 acres in area, has a capacity between 43 and 60 million cubic yards of material and is located in water depths that range between 0 and 15 feet deep at mean low water. The initial construction phase will bring the containment dike to elevation +8.0 feet above mlw, and require approximately 5.8 million cubic yards of sand and 101,000 square yards of rip-rap. Since this area is not large enough to subdivide, division dikes will not be required. Perimeter dikes and outflow structures will be upgraded, maintained and incrementally raised under operation and maintenance features. When the dredged material surface rises above the water level within the area, the surface crust will be managed during periods of no inflow.

59. Table A-7 summarizes the design data for each of the expansion plans.

CONSTRUCTION COST

60. Tables A-8 through A-13 provide estimates of cost of the extension alternatives. Costs are as of October 1987.

Table A-7. DESIGN DATA FOR CIDA EXPANSION PLANS

Item	Plan A	Plan B	Plan C	Plan D	Plan E	Plan F
Water depth @ mlw, ft	7 to 30	0 to 30	10 to 30	7 to 15	0 to 15	0 to 15
Levee						
Length, ft	29,670	37,475	16,100	14,790	22,595	18,455
Volume of sand (a) mcy	19.1	18.6	14.0	5.0	4.5	5.8
Riprap (a), cy						
Exterior	89,066	87,732	48,366	44,063	43,112	55,365
Interior	73,475	92,831	39,840	36,596	55,987	45,533
Area, acres	1,700	2,500	740	660	1,450	1,000
Capacity (b) mcy	131 to 15(	209 to 224	31 to 48	27 to 40	97 to 116	43 to 60
Construction time, days	1,095	1,080	782	426	412	395

(a) Initial construction phase to bring containment dike to elevation 8 m.l.w.

(b) Dredged material that can be deposited based on scenario and proper management of area.

Table A-8. EXPANSION OF CRANEY ISLAND
ESTIMATED FIRST COST, PLAN A

Description	Quantity	Units	Unit Costs	Cost Subtotal	Total Cost
A. DIKE					
Mobilization & Demobilization		Lump Sum		1,100,000	
Dredging, Dike Fill	19,130,000	C.Y.	1.62	30,991,000	
Riprap	162,541	S.Y.	47.50	7,721,000	
Weirs	3	Each	40,000	120,000	
Hopper Dredge Pump Out	2,000	L.F.	151.00	302,000	
Road Around Dike (a)				N/A	
Subtotal				40,234,000	
Contingency (15%)				6,035,000	
Subtotal				46,269,000	
S&A, E&D (9%)				4,164,000	
Total Cost of Dike					50,433,000
B. WEIR MODIFICATION AT EXISTING CRANEY ISLAND					
Twin 72" pipe	7,600	L.F.	335.00	2,546,000	
Basins	5	Each	2,600	13,000	
Subtotal				2,559,000	
E&D, S&A, Contingencies (20%)				512,000	
Total Cost of Weir Modification					3,071,000
C. ENVIRONMENTAL MITIGATION (b)				9,017,000	
Contingency and Administration				902,000	
Total Cost of Mitigation					9,919,000
D. REAL ESTATE (c)				386,000	
Contingency (20%)				77,000	
Administration				116,000	
Total Cost of Real Estate					579,000
Total Cost of Expansion, Plan A					64,002,000

(a) Included in cost of operation and maintenance.
(b) From Appendix E
(c) From Real Estate Appendix

Table A-9. EXPANSION OF CRANEY ISLAND
ESTIMATED FIRST COST, PLAN B

Description	Quantity	Units	Unit Costs	Cost Subtotal	Total Cost
A. DIKE					
Mobilization & Demobilization		Lump Sum		1,100,000	
Dredging, Dike Fill	18,590,000	C.Y.	1.62	30,116,000	
Riprap	180,563	S.Y.	46.10	8,324,000	
Weirs	3	Each	40,000	120,000	
Hopper Dredge Pump Out	2,000	L.F.	151.00	302,000	
Road Around Dike (a)				N/A	
Subtotal				39,962,000	
Contingency (15%)				5,994,000	
Subtotal				45,956,000	
S&A, E&D (9%)				4,136,000	
Total Cost of Dike					50,092,000
B. WEIR MODIFICATION AT EXISTING CRANEY ISLAND					
Twin 72" pipe	13,500	L.F.	335.00	4,522,000	
Basins	6	Each	2,600	16,000	
Subtotal				4,538,000	
E&D, S&A, Contingencies (20%)				908,000	
Total Cost of Weir Modification					5,446,000
C. ENVIRONMENTAL MITIGATION (b)				13,300,000	
Contingency and Administration				1,286,000	
Total Cost of Mitigation					14,586,000
D. REAL ESTATE (c)				2,003,000	
Contingency (20%)				401,000	
Administration				233,000	
Total Cost of Real Estate					2,637,000
Total Cost of Expansion, Plan B					72,761,000

(a) Included in cost of operation and maintenance.
(b) From Appendix E
(c) From Real Estate Appendix

Table A-10. EXPANSION OF CRANEY ISLAND
ESTIMATED FIRST COST, PLAN C

Description	Quantity	Units	Unit Costs	Cost Subtotal	Total Cost
A. DIKE					
Mobilization & Demobilization		Lump Sum	-	653,000	
Dredging, Dike Fill	14,010,000	C.Y.	2.22	31,102,000	
Riprap	88,206	S.Y.	47.50	4,190,000	
Weirs	2	Each	40,000	80,000	
Hopper Dredge Pump Out		L.F.		N/A	
Road Around Dike (a)				N/A	
Subtotal				36,025,000	
Contingency (15%)				5,404,000	
Subtotal				41,429,000	
S&A, E&D (9%)				3,729,000	
Total Cost of Dike					45,158,000
B. WEIR MODIFICATION AT EXISTING CRANEY ISLAND				N/A	
Twin 72" pipe					
Basins					
Subtotal					
E&D, S&A, Contingencies (20%)					
Total Cost of Weir Modification					N/A
C. ENVIRONMENTAL MITIGATION (b)				3,925,000	
Contingency and Administration				392,000	
Total Cost of Mitigation					4,317,000
D. REAL ESTATE (c)				0	
Contingency (20%)					
Administration					
Total Cost of Real Estate					0
Total Cost of Expansion, Plan C					49,475,000

(a) Included in cost of operation and maintenance.
(b) From Appendix E
(c) From Real Estate Appendix

Table A-11. EXPANSION OF CRANEY ISLAND
ESTIMATED FIRST COST, PLAN D

Description	Quantity	Units	Unit Costs	Cost Subtotal	Total Cost
A. DIKE					
Mobilization & Demobilization		Lump Sum		390,000	
Dredging, Dike Fill	5,070,000	C.Y.	2.34	11,864,000	
Riprap	80,659	S.Y.	46.00	3,710,000	
Weirs	2	Each	40,000	80,000	
Hopper Dredge Pump Out	2,000	L.F.	151.00	302,000	
Road Around Dike (a)				N/A	
Subtotal				16,346,000	
Contingency (15%)				2,452,000	
Subtotal				18,798,000	
S&A, E&D (9%)				1,692,000	
Total Cost of Dike					20,490,000
B. WEIR MODIFICATION AT EXISTING CRANEY ISLAND					
Twin 72" pipe	4,700	L.F.	335.00	1,575,000	
Basins	5	Each	2,600	13,000	
Subtotal				1,588,000	
E&D, S&A, Contingencies (20%)				318,000	
Total Cost of Weir Modification					1,906,000
C. ENVIRONMENTAL MITIGATION (b)				3,501,000	
Contingency and Administration				350,000	
Total Cost of Mitigation					3,851,000
D. REAL ESTATE (c)				386,000	
Contingency (20%)				77,000	
Administration				116,000	
Total Cost of Real Estate					579,000
Total Cost of Expansion, Plan D					26,826,000

(a) Included in cost of operation and maintenance.
(b) From Appendix E
(c) From Real Estate Appendix

Table A-12. EXPANSION OF CRANEY ISLAND
ESTIMATED FIRST COST, PLAN E

Description	Quantity	Units	Unit Costs	Cost Subtotal	Total Cost
A. DIKE					
Mobilization & Demobilization		Lump Sum		390,000	
Dredging, Dike Fill	4,530,000	C.Y.	2.38	10,781,000	
Riprap	99,099	S.Y.	46.00	4,559,000	
Weirs	3	Each	40,000	120,000	
Hopper Dredge Pump Out	2,000	L.F.	151.00	302,000	
Road Around Dike (a)				N/A	
Subtotal				16,152,000	
Contingency (15%)				2,423,000	
Subtotal				18,575,000	
S&A, E&D (9%)				1,672,000	
Total Cost of Dike					20,247,000
B. WEIR MODIFICATION AT EXISTING CRANEY ISLAND					
Twin 72" pipe	11,000	L.F.	335.00	3,685,000	
Basins	6	Each	2,600	16,000	
Subtotal				3,701,000	
E&D, S&A, Contingencies (20%)				740,000	
Total Cost of Weir Modification					4,441,000
C. ENVIRONMENTAL MITIGATION (b)				7,956,000	
Contingency and Administration				796,000	
Total Cost of Mitigation					8,752,000
D. REAL ESTATE (c)				2,003,000	
Contingency (20%)				401,000	
Administration				233,000	
Total Cost of Real Estate					2,637,000
Total Cost of Expansion, Plan E					36,077,000

(a) Included in cost of operation and maintenance.
(b) From Appendix E
(c) From Real Estate Appendix

Table A-13. EXPANSION OF CRANEY ISLAND
ESTIMATED FIRST COST, PLAN F

Description	Quantity	Units	Unit Costs	Cost Subtotal	Total Cost
A. DIKE					
Mobilization & Demobilization		Lump Sum		390,000	
Dredging, Dike Fill	5,750,000	C.Y.	2.30	13,225,000	
Riprap	100,898	S.Y.	48.50	4,894,000	
Weirs	2	Each	40,000	80,000	
Hopper Dredge Pump Out	2,000	L.F.	151.00	302,000	
Road Around Dike (a)				N/A	
Subtotal				18,891,000	
Contingency (15%)				2,834,000	
Subtotal				21,725,000	
S&A, E&D (9%)				1,955,000	
Total Cost of Dike					23,680,000
B. WEIR MODIFICATION AT EXISTING CRANEY ISLAND					
Twin 72" pipe	5,130	L.F.	335.00	1,719,000	
Basins	5	Each	2,600	13,000	
Subtotal				1,732,000	
E&D, S&A, Contingencies (20%)				346,000	
Total Cost of Weir Modification					2,078,000
C. ENVIRONMENTAL MITIGATION (b)				5,304,000	
Contingency and Administration				530,000	
Total Cost of Mitigation					5,834,000
D. REAL ESTATE (c)				431,000	
Contingency (20%)				86,000	
Administration				140,000	
Total Cost of Real Estate					657,000
Total Cost of Expansion, Plan F					32,249,000

(a) Included in cost of operation and maintenance.
(b) From Appendix E
(c) From Real Estate Appendix

COST OF OPERATION AND MAINTENANCE

61. The cost of operating and maintaining (O&M) the expansion alternatives has been based on the cost of similar activities at CIDA. The O&M costs at CIDA for the fiscal years 1985 through 1987 have averaged $1,296,000 per year. Based on this, the estimate for operating the expansion alternatives are as follows.

Table A-14. COST OF OPERATION AND MAINTENANCE

Expansion Alternative	Average Annual Cost without CIDA	Average Annual Cost with CIDA
A	959,000	1,900,000
B	1,196,000	2,085,000
C	518,000	1,632,000
D	463,000	1,606,000
E	700,000	1,774,000
F	556,000	1,684,000

DREDGING COSTS

62. It is necessary to compare the cost of removing dredged material from channels, docks, naval areas, etc., and disposing the material either (a) into a containment area, or (b) at sea in Dam Neck (DNODS) or Norfolk Disposal Sites (NDS).

63. For enclosed areas the overall cost includes (a) its construction, (b) its operation and maintenance, and (c) the dredging of material and its movement to and placement in the contained area.

64. In the case of an ocean site, the cost includes (a) monitoring the site to insure its proper use and adequacy, and (b) the dredging of material, its transport to sea and placement in the ocean disposal site.

65. There are two methods for disposal of dredged material into an enclosed area such as CIDA. One method involves dumping the dredged material into a storage area immediately outside of CIDA and referred to as the Craney Island Rehandling Area. This area can store as much as 1.3 million cubic yards of dredged material. Material is dumped into this basin by contractors using bucket and scow equipment that is not capable of pumping directly into CIDA. The amount of material dredged and disposed into the rehandling basin varies from as little as 1,000 cubic yards or less to over 250,000 cubic yards. As the rehandling basin is filled, the Corps periodically pumps the material into CIDA.

66. A second method involves disposal directly into CIDA. A great deal of the dredging done by the Corps and other Federal interests, by the state, and by private interests is performed with hydraulic dredging equipment that can pump directly into CIDA.

67. In the case of ocean disposal, mechanical dredges (bucket and scow) and/or hydraulic dredges (hopper) are utilized.

COST DATA

68. Unit cost data was developed by Rich and Associates whose report is attached to this appendix (attachment 4). This data includes the cost of new work and maintenance dredging. It also includes the disposition of the material into a contained site such as CIDA (either via the rehandling basin or direct) or at sea such as DNODS and NDS.

METHOD OF ANALYSIS

69. A 10-year record for the period from 1978 - 1987, was used to establish the probable future dredging by Federal, state/local entities, and private interests in the inner harbor. The appropriate unit cost was applied to the individual dredging accomplished during this period depending on which plan was under study, i.e., whether the dredged material was placed in a contained area such as CIDA or taken to sea. In the case of a containment area, the cost would be based on disposing all material therein. For ocean disposal, only clean dredged material can be disposed in DNODS or NDS. In this case, it was necessary to place the unsuitable dredged material into the available remaining space in CIDA.

70. The above data were utilized to establish the cost of dredged disposal operations based on various dredging scenarios. Refer to appendix C.

REMOVAL OF MATERIAL FROM CRANEY ISLAND

71. Consideration was given to emptying Craney Island. One plan would be to place dredged material onto scows and transport them with tugs to DNODS or NDS. This would be accomplished by excavating and transporting the material with mechanical equipment to a constructed scow mooring facility, thence loading the scows and transporting them to the ocean sites. Such an operation requires that the dredged material be sufficiently dried so that heavy land equipment (trucks, scrapers, bulldozers, conveyers, etc.) could operate. Unfortunately, only about 20 percent of the material in Craney Island is satisfactory for this purpose. As the confined area was emptied, it would be necessary to continue to place 4,000,000 cubic yards or more of material each year into CIDA or elsewhere.

72. Three methods of operation were considered for the removal of dredged material from CIDA:

a. By mechanically hauling the dredged material to a scow. This involved loading 25 c.y. trucks with front end loaders and hauling the material to scow mooring facilities. In lieu of trucks, consideration was given to scrapers to load and haul the material to scow loading facilities constructed adjacent to CIDA. Here the material would be transferred to large scows by clam shell buckets. The scows would then be towed to Dam Neck Ocean Disposal Site or Norfolk Disposal Site and emptied.

b. An alternative mechanical hauling method would be to utilize bulldozers and belt conveyers to load the material and/or to unload it onto the scows.

c. A third and hydraulic method would be to breach the levee confining the material in CIDA and to then have a bucket dredge remove the material and

place it on scows to be transported to sea. This method requires a channel into CIDA for the dredge to enter. It would involve a thorough design and considerable construction of sheet piling, tie-back system, etc., to insure that the levee surrounding CIDA does not fail and thus have material therein flow into the existing channels in the immediate area.

73. A preliminary analysis of dredging output and cost of the above plans were made by Rich and Associates. The study indicates that the mechanical hauling of dredged material to scows and then taking the material to sea would remove only about 1.5 m.c.y. of material each year with a single shift operation. This compares to 4 m.c.y. or more dredged each year.

74. If the levee at CIDA were properly breached and a channel created therein, a bucket dredge could remove about 4 m.c.y. per year and have scows and tugs remove the material to sea. The dredge might just keep up with the 4 m.c.y. per year entering CIDA but would not empty the area of dredged material. It would result in a continuous deposition of material into CIDA, thence its transfer to the ocean rather than its movement at lesser cost directly to sea following the dredging of channels and piers.

75. Further details are included in attachment 5 to this appendix.

76. A similar preliminary evaluation performed by Great Lakes Dredge and Dock Company for the Virginia Port Authority indicated similar results. The following are excerpts from a memorandum entitled "Norfolk Harbor Ocean Disposal - Budget Guidelines.

> "Scow Loading - the other method that falls within our area of expertise and therefore, within the scope of this study, is mechanically loading scows from within Craney Island and disposing of the material at the Ocean Disposal Area.
>
> To access the North Cell, the East Division Dike must be breached with a hydraulic dredge, pumping the material into another cell. Once suitable depth for effective scow loading is reached, a Bucket Dredge can then be floated in and start loading scows. The cost is similar to Ocean Disposal

for any other project in the area. The problem associated with this method is the same as that of the Direct Pump method; at 13,500 cubic yard per day maximum average production, it would still take 6.5 years to empty the North Cell, during which time an alternative method must still be found.

Other methods of removing material from within Craney Island and loading scows for ocean disposal include loading conveyor belts with either a crane on a flexifloat barge or with a saurman bucket system. These methods do not involve breaching the exterior dikes but do have the same drawback in that production is very slow, so it would be years before any effective increase in disposal area capacity is realized. In fact, at 10,000 cy/day for any of these methods, the resulting 3,500,000 cy/year production does not keep pace with the anticipated inflow of 4,000,000 cy/year. In any case, therefore any alternative disposal, such as ocean disposal, must be applied whatever the future of Craney Island."

CHESAPEAKE BAY PLANS

77. Development of three alternative island locations were considered in the lower Chesapeake Bay. They are in the horseshoe area off Buckroe Beach, Ocean View, and at the Chesapeake Bay Bridge-Tunnel as shown on plate 8 of the main report. Preliminary data were developed, therefor.

PHYSICAL DATA

78. The following table presents dimensions for these plans.

Table A-15. DIMENSIONS OF HORSESHOE AREA OFF BUCKROE BEACH, OCEAN VIEW AND CHESAPEAKE BAY BRIDGE-TUNNEL

Alternative	Average depth, feet	Total surface area, acres	Ultimate fill height, m.l.w.	Storage capacity m.c.y. (a)
Horseshoe Area off Buckroe Beach	14	2500	30	224
Ocean View	24	2000	30	224
Chesapeake Bay Bridge-Tunnel	28	2000	30	224

(a) Comparable to expansion plan B.

DREDGING SCENARIO AND LIFE OF PLAN

79. For comparison purposes, the dredging scenarios considered were the same as those for the Craney Island expansion plans (i.e., S1, S2, S4 and S5).

80. Based on the above and the need for the future as indicated in table 16 of the main report, each alternative would provide sufficient storage to permit disposal of dredged material for a period approaching 50 years. This takes into account an estimate for consolidation of the material, as determined by the Waterways Experiment Station.

DESIGN DATA

81. The levee length for the Ocean View and Chesapeake Bay disposal areas was about 37,300 feet. For the Buckroe Beach area was about 42,000 feet. Substantial quantities of sand and rock revetment would be required to construct the levees. It was assumed that sufficient sand was available within a reasonable distance of each island. A rehandling basin would be constructed immediately adjacent to the levee for the disposal of material by bucket dredge dump scows and towed by tug to the disposal area. Rehandling facilities including a barge rehandler would be provided at the site. Construction facilities would also be provided for dredged material deposited directly into the

disposal area by hopper into the three enclosed areas and by pipeline for Ocean View and Buckroe. Environmental mitigation costs were made comparable to the Craney Island site B.

COST ESTIMATES

82. Tables A-17, A-18, and A-19 provide estimates of cost for the horseshoe area off Buckroe Beach, Ocean View, and Chesapeake Bay Bridge-Tunnel. They are summarized in the following table which also includes estimates of cost of operation and maintenance as well as the cost of dredging and disposal of material into the islands.

Table A-16. COST ESTIMATES FOR CHESAPEAKE BAY SITES

Item	Ocean View	Horseshoe Area off Buckroe Beach	Chesapeake Bay Bridge-Tunnel
Cost of Construction	108,213,000	124,377,000	196,116,000
Annual cost of operation and maintenance	1,235,000	1,381,000	1,235,000

83. The above data was utilized to establish the overall cost for a period of about 50 years. See the appendix on economic analysis and a summary thereof in the main report.

Table A-17. ESTIMATED COST OF CONSTRUCTION
OCEAN VIEW

Description	Quantity	Units	Unit Cost	Cost Subtotal	Total Cost
A. DIKE					
Mobilization & Demobilization		lump sum		$1,100,000	
Dredging, Dike Fill	19,808,000	C.Y.	1.62	32,089,000	
Riprap					
Armor stone	439,900	tons	60.00	26,394,000	
	90,600	tons	40.00	3,624,000	
Bedding layer	393,000	tons	35.00	13,355,000	
Geotextile fabric	300,700	sq. yds.	2.00	601,000	
Weirs	3	Each	40,000	120,000	
Rehandling facilities		lump sum		8,400,000	
Range marker		lump sum		85,000	
Road Around Dike (a)				N/A	
Subtotal				86,168,000	
Contingency (20%)				17,234,000	
Subtotal				103,402,000	
S&A, E&D (9%)				9,306,000	
Total Cost of Dike					112,708,000
B. ENVIRONMENTAL MITIGATION					
Contingency and Administration				10,640,000	
Total cost of mitigation				1,029,000	11,669,000
Total Cost					124,377,000

(a) Included in cost of operation and maintenance.

Table A-18. ESTIMATED COST OF CONSTRUCTION
HORSESHOE AREA OFF BUCKROE BEACH

Description	Quantity	Units	Unit Cost	Cost Subtotal	Total Cost
A. DIKE					
Mobilization & Demobilization		lump sum		$1,100,000	
Dredging, Dike Fill	11,200,000	C.Y.	1.62	18,144,000	
Riprap					
Armor stone	361,580	tons	60.00	21,695,000	
	126,550	tons	40.00	5,062,000	
Bedding layer	383,330	tons	35.00	13,417,000	
Geotextile fabric	322,500	sq. yds.	2.00	645,000	
Weirs	3	Each	40,000	120,000	
Rehandling facilities		lump sum		11,312,000	
Range marker		lump sum		85,000	
Road Around Dike (a)				N/A	
Subtotal				71,580,000	
Contingency (20%)				14,316,000	
Subtotal				85,896,000	
S&A, E&D (9%)				7,731,000	
Total Cost of Dike					93,627,000
B. ENVIRONMENTAL MITIGATION					
Contingency and Administration				13,300,000	
Total cost of mitigation				1,286,000	14,586,000
Total Cost					108,213,000

(a) Included in cost of operation and maintenance.

Table A-19. ESTIMATED COST OF CONSTRUCTION
CHESAPEAKE BAY-BRIDGE-TUNNEL

Description	Quantity	Units	Unit Cost	Cost Subtotal	Total Cost
A. DIKE					
Mobilization & Demobilization		lump sum		$1,100,000	
Dredging, Dike Fill	28,186,000	C.Y.	1.62	45,661,000	
Riprap					
Armor stone	913,100	tons	80.00	73,048,000	
Bedding layer	298,200	tons	35.00	10,437,000	
Geotextile fabric	251,000	sq. yds.	2.00	502,000	
Weirs	3	Each	40,000	120,000	
Rehandling facilities		lump sum		10,058,000	
Range marker		lump sum		85,000	
Road Around Dike (a)				N/A	
Subtotal				141,011,000	
Contingency (20%)				28,202,000	
Subtotal				169,213,000	
S&A, E&D (9%)				15,229,000	
Total Cost of Dike					184,447,000
B. ENVIRONMENTAL MITIGATION					
Contingency and Administration				10,640,000	
Total cost of mitigation				1,029,000	11,669,000
Total Cost					196,116,000

(a) Included in cost of operation and maintenance.

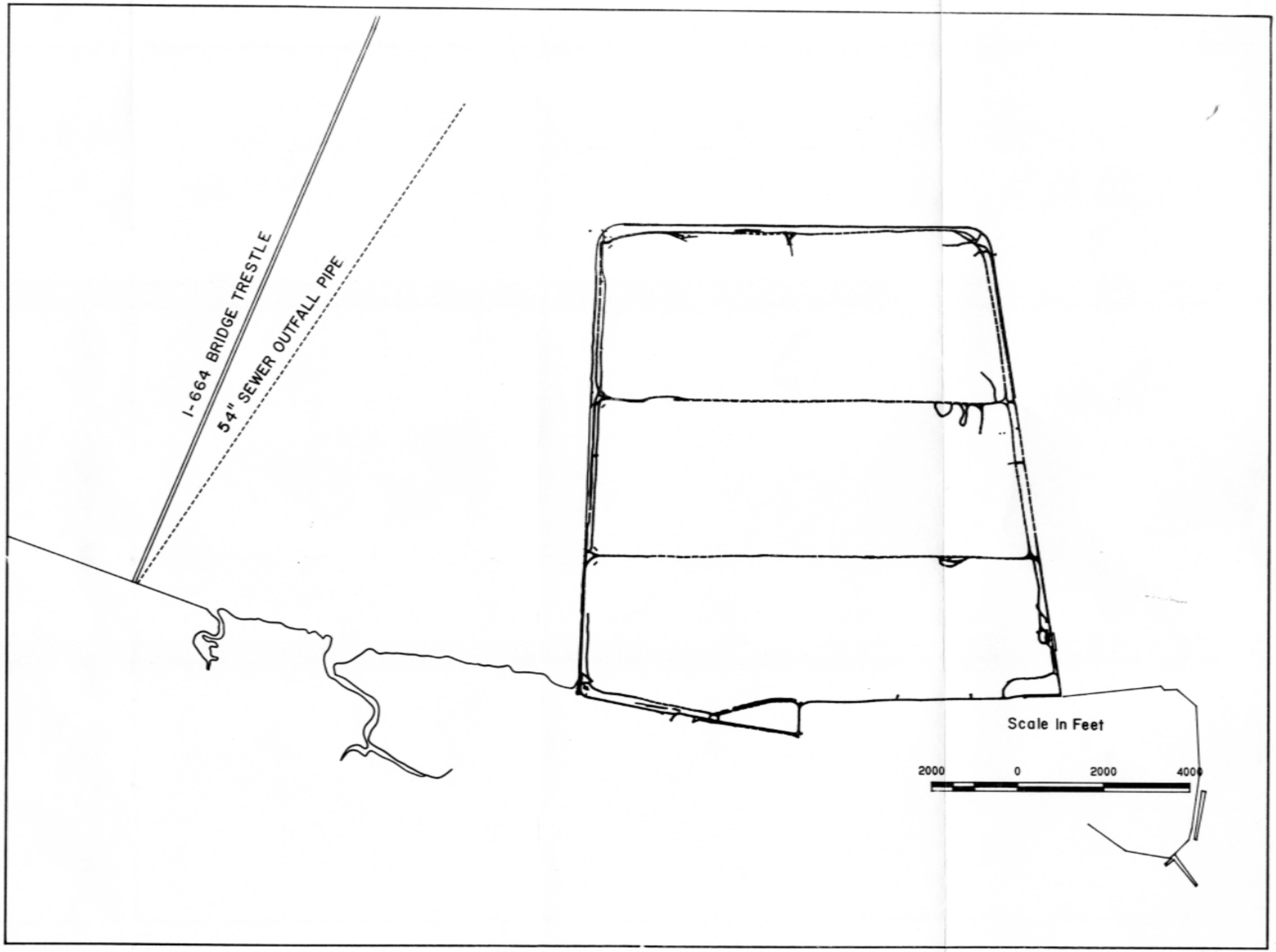


Figure A-8 Craney Island Existing Plan

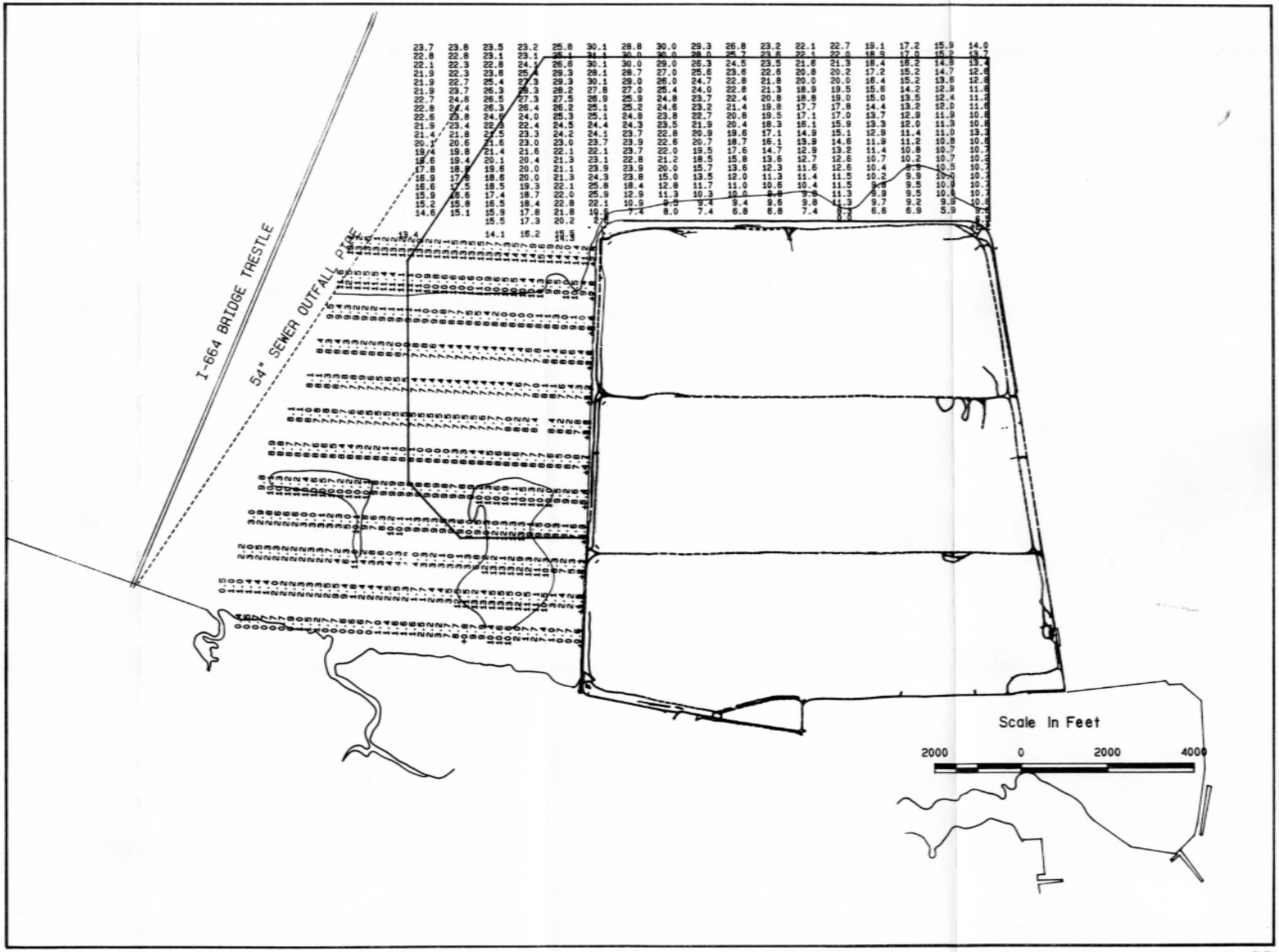


Figure A-9 Craney Island Expansion Plan A

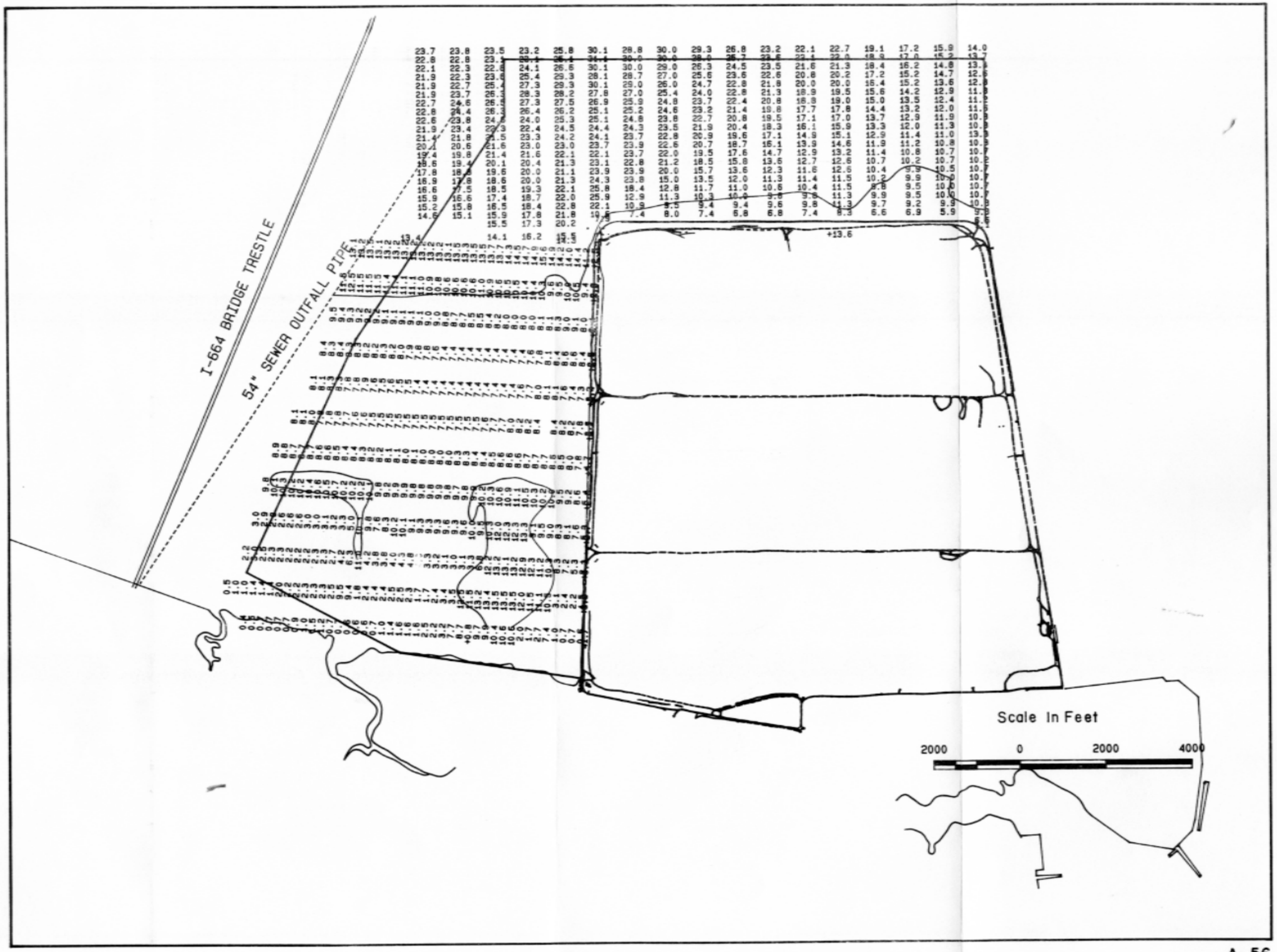


Figure A-10 Craney Island Expansion Plan B

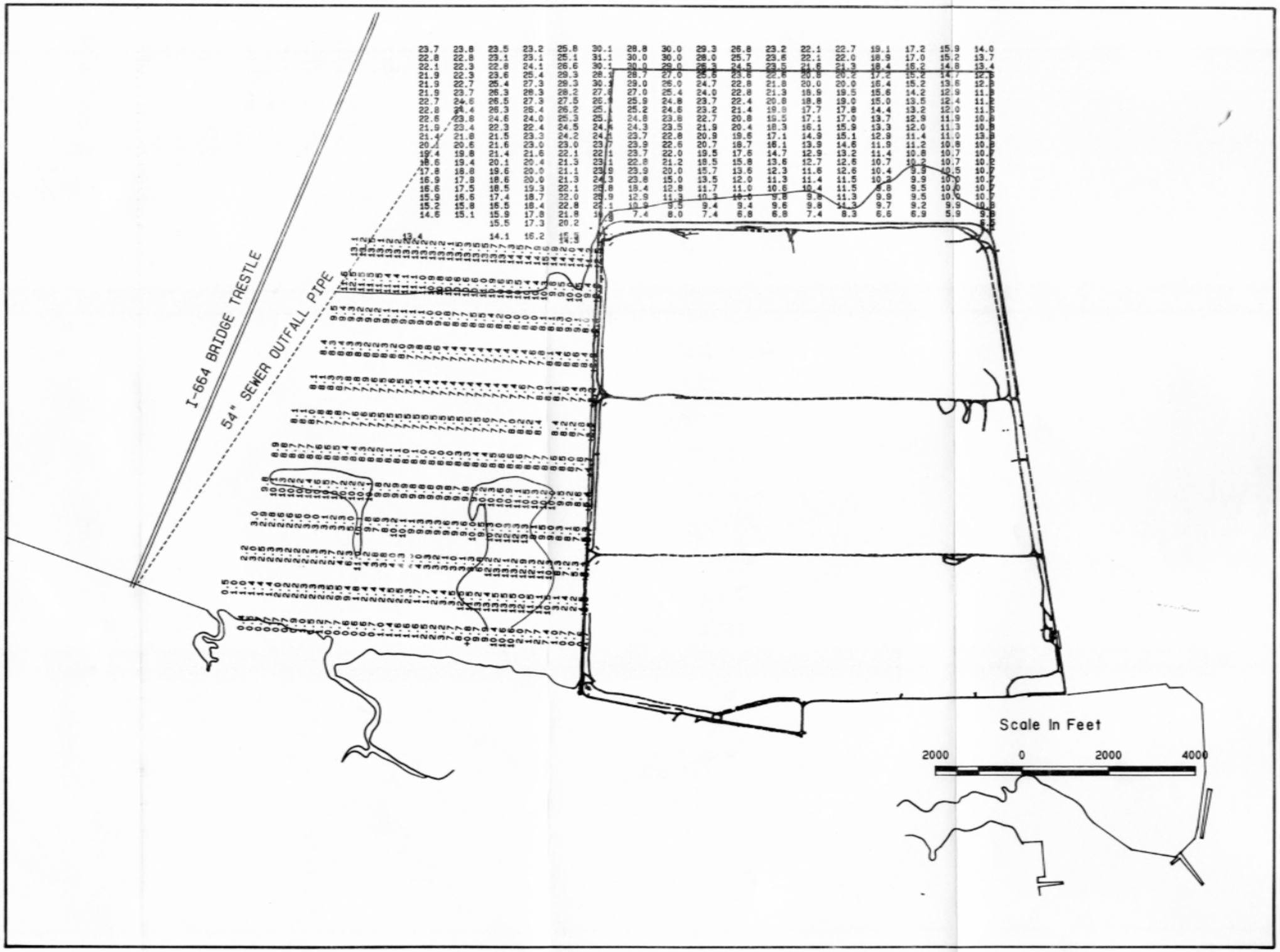


Figure A-11 Craney Island Expension Plan C

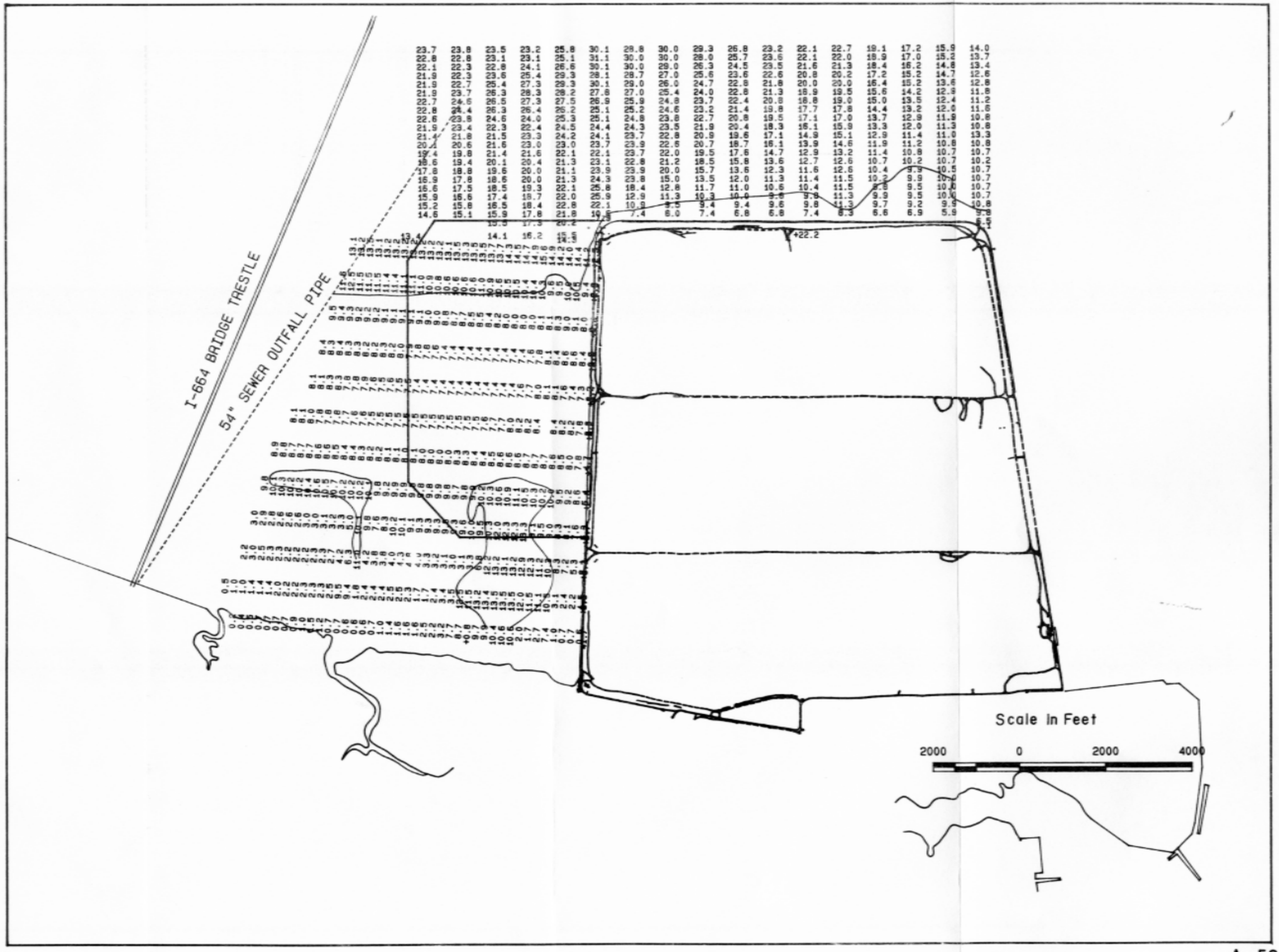


Figure A-12 Craney Island Expension Plan D

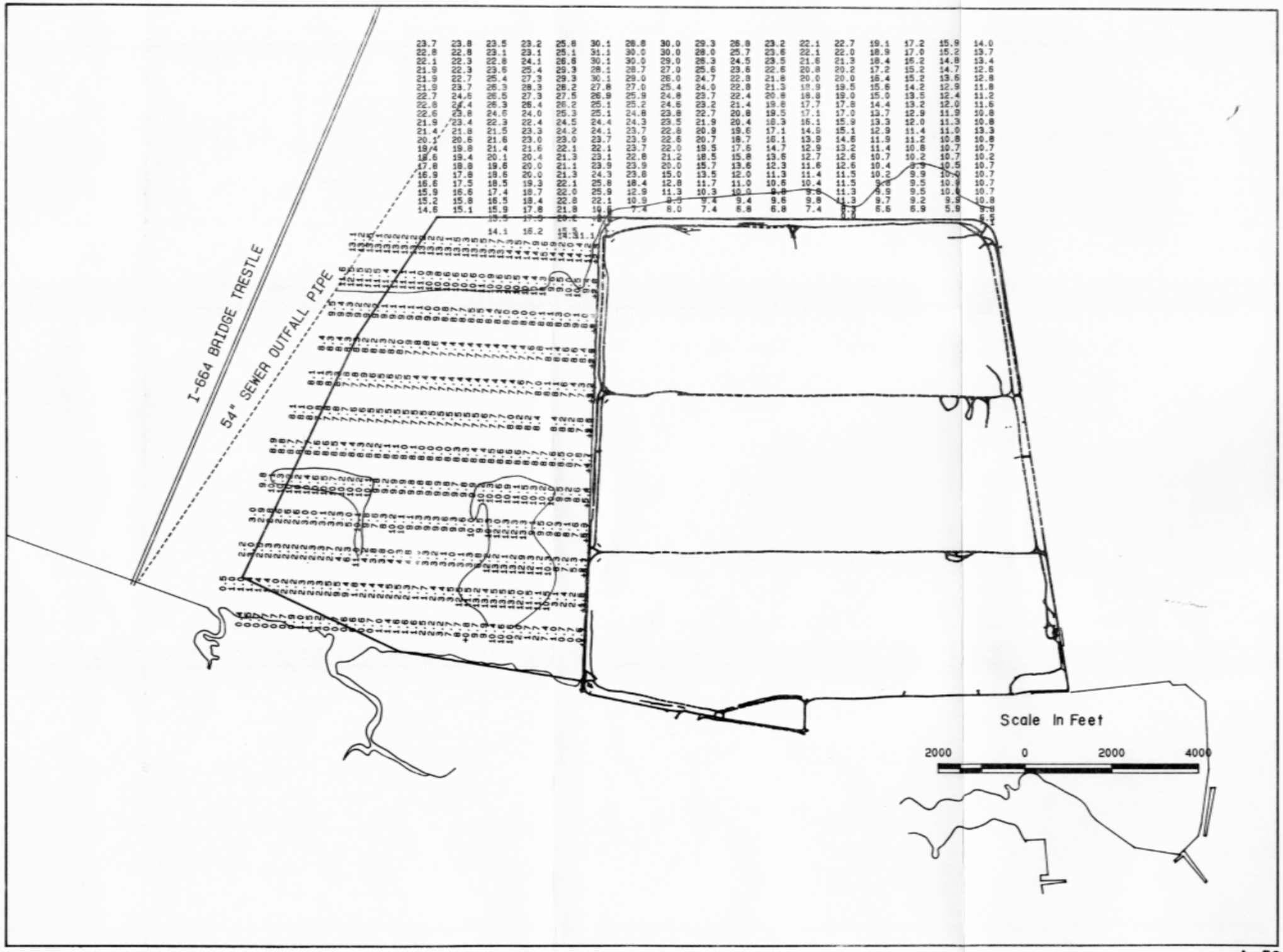


Figure A-13 Craney Island Expension Plan E

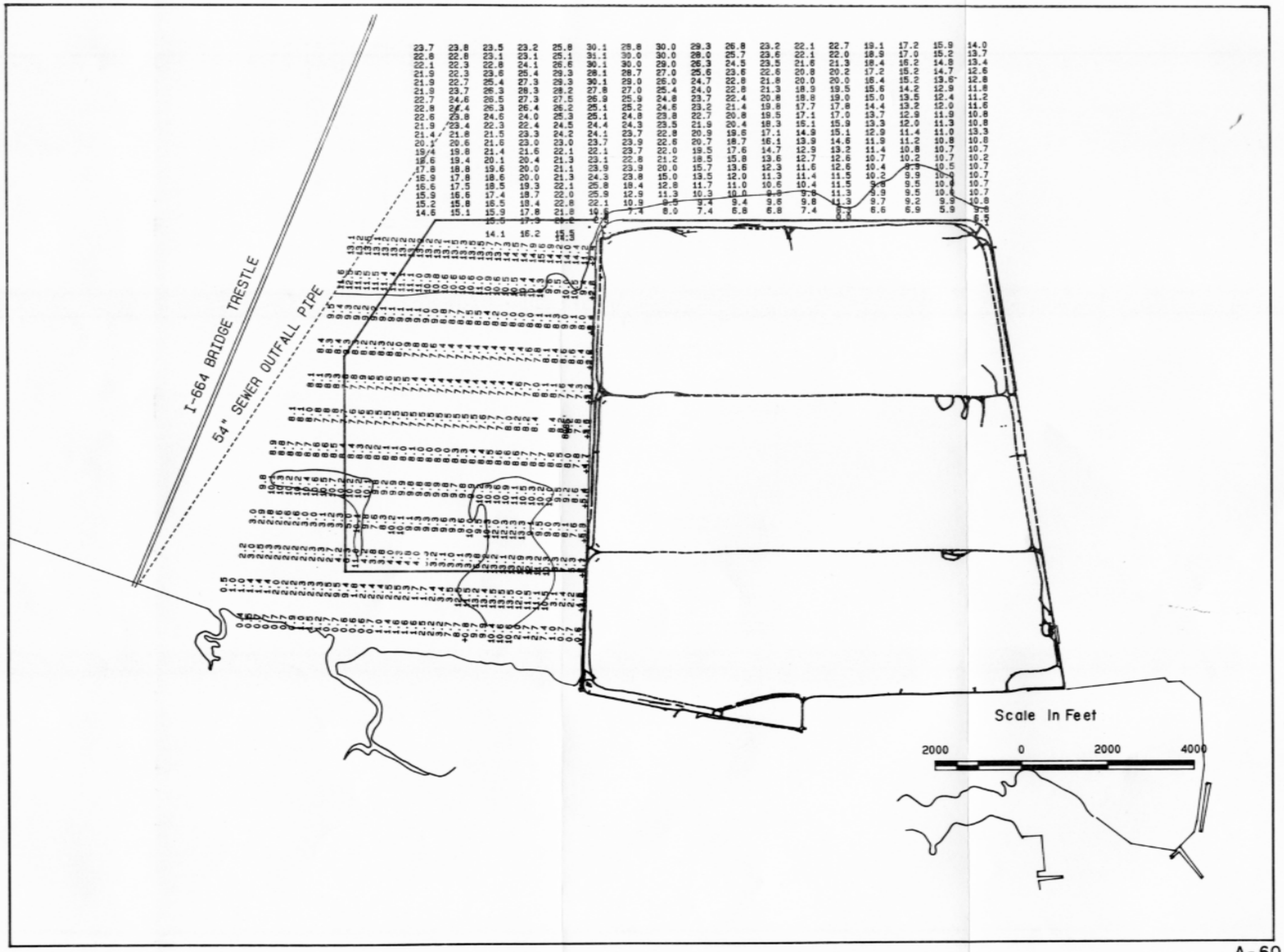
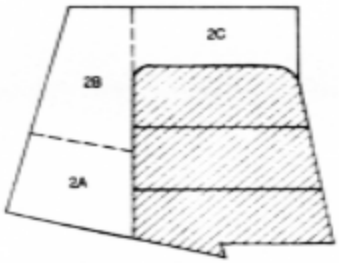


Figure A-14 Craney Island Expension Plan F

ATTACHMENT 1

US Army Corps of Engineers



ALTERNATIVE 2

ENVIRONMENTAL LABORATORY

TECHNICAL REPORT EL-89-6

STORAGE CAPACITY EVALUATION FOR CRANEY ISLAND EXPANSION ALTERNATIVES

by

Marian E. Poindexter-Rollings

Environmental Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
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US ARMY ENGINEER WATERWAYS EXPERIMENT STATION

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Since the 1950s the Craney Island disposal facility has been used for containment of dredged material from the navigable channels and harbors of Hampton Roads, VA. The site has annually received between 3 million and 4 million cu m of maintenance dredged material. The existing site, which was subdivided into three compartments in 1984, is nearing maximum capacity. Therefore, the US Army Engineer District, Norfolk, initiated studies to evaluate potential expansion alternatives in an effort to identify the alternative that will maximize existing storage capacity (and provide approximately 50 years of additional storage capacity) while minimizing environmental impacts.

This study is one of three concurrent studies to evaluate various aspects of the expansion alternatives. The focus of this study was the volumetric storage capacity of each alternative, while the other studies evaluated separately (a) the hydrodynamic impacts of

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18. SUBJECT TERMS (Continued).

Confined disposal	Disposal life	Site capacity
Consolidation	Dredged material	Storage capacity
Craney Island	Dredging	
Disposal	Expansion alternatives	

19. ABSTRACT (Continued).

each expansion alternative on the flow regime in the Hampton Roads area and (b) the geotechnical feasibility of constructing retaining dikes for each alternative.

The storage capacity, and thus the remaining active disposal life, of the existing Craney Island facility was determined as well as that of each expansion alternative, both with and without considering the existing facility. The scenarios were evaluated assuming an active dewatering program. The influence of subdividing the expansion facility into multiple compartments was also evaluated.

The available dredged material storage capacity of each configuration was subsequently calculated from considerations of dike volume requirements. The filling history of each configuration was simulated with the computer program Primary Consolidation and Desiccation of Dredged Fill. Input requirements necessitated compilation of the consolidation characteristics of the foundation soil and dredged material as well as the appropriate values to simulate site dewatering. The active disposal life of each facility was ultimately determined from the filling simulations and anticipated maximum dike heights.

PREFACE

This report was prepared by the Environmental Laboratory (EL), US Army Engineer Waterways Experiment Station (WES), for the US Army Engineer District (USAED), Norfolk. Funding was authorized by Intra-Army Order No. (IAO) BB-87-3011, 20 April 1988, and IAO BB-88-3001, 13 October 1988.

The report was prepared by Dr. Marian E. Poindexter-Rollings, under the general supervision of Dr. John J. Ingram, Chief, Water Resources Engineering Group (WREG), EL; Dr. Raymond L. Montgomery, Chief, Environmental Engineering Division (EED), EL; and Dr. John Harrison, Chief, EL. Acknowledgment is made to Mr. Mark Howard, WREG, for his assistance in computer program modification and initial data reduction; to Mr. Thomas E. Schaefer, WREG, for his assistance in creating the numerous computer input data files and making the computer runs; and to Mrs. Cheryl M. Lloyd and Mr. Anthony Gibson, WREG, for tabulating and plotting the output data. Technical review was provided by Dr. Ingram and Dr. Michael R. Palermo, EED. The report was edited by Mrs. Jessica S. Ruff of the WES Information Technology Laboratory.

Operational considerations, including schedules for dredging and disposal and projected quantities of sediment to be dredged, were provided by numerous personnel of the USAED, Norfolk, with the major input coming from the Engineering and Planning Divisions.

Commander and Director of WES was COL Dwayne G. Lee, EN. Technical Director was Dr. Robert W. Whalin.

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CONTENTS

	Page
PREFACE	1
CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT	3
PART I: INTRODUCTION	4
Background	4
Objectives	7
Scope of Work	7
PART II: HISTORICAL AND FUTURE DREDGING AND DISPOSAL REQUIREMENTS FOR HAMPTON ROADS	9
Historical Requirements	9
Future Requirements	10
PART III: POTENTIAL EXPANSION SITES	12
Expansion Site Conditions	12
Spatial Dimensions of the Expansions	14
PART IV: MODELING TECHNIQUE	16
Theoretical Basis	16
Computer Model Description	17
PART V: DREDGED MATERIAL PROPERTIES	19
Required Laboratory Testing	19
Determination of Dredged Material Properties	20
PART VI: STORAGE CAPACITY EVALUATIONS	24
Assumptions	27
Method of Analysis	29
Simulation Results	31
Remaining Life of Existing Facility	31
Service Life of Expansion Projects Without Craney Island	32
Service Life of Expansion Projects With Craney Island	34
PART VII: CONCLUSIONS AND RECOMMENDATIONS	37
Conclusions	37
Recommendations	37
REFERENCES	39
TABLES 1-12	
APPENDIX A: HISTORICAL DREDGING AND DISPOSAL RECORDS	A1
APPENDIX B: SIMULATED FILLING HISTORIES FOR INDIVIDUAL DISPOSAL CELLS - TABULATED RESULTS	B1
APPENDIX C: SIMULATED FILLING HISTORIES FOR INDIVIDUAL DISPOSAL CELLS - GRAPHICAL PRESENTATION	C1

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
acres	4,046.873	square metres
cubic yards	0.7645549	cubic metres
feet	0.3048	metres
pounds (force) per square foot	47.88026	pascals

STORAGE CAPACITY EVALUATION FOR CRANEY ISLAND EXPANSION ALTERNATIVES

PART I: INTRODUCTION

Background

1. Craney Island is a 2500-acre* dredged material containment facility located in Portsmouth, VA, adjacent to the harbor of the Hampton Roads area. As shown in Figure 1, it is located at the confluence of the James and Elizabeth Rivers. Planning for this facility began in the early 1940s when a need was identified for a long-term disposal site to receive materials dredged from the navigation channels and berthing areas in Hampton Roads. The facility was designed to (a) provide sufficient storage volume for dredged material during the design life of the facility and (b) provide adequate sedimentation of dredged material solids to maintain acceptable effluent water quality.

2. Actual work on the Craney Island facility began in August 1954 with construction of the confining dikes. After 2-1/2 years, construction was completed in January 1957. Since that time, the dikes have been raised incrementally to elevations between +26.0 and +33.0 mlw. Construction of two interior dikes was completed in 1984 and effectively separated the disposal area into three subcontainments, or cells, of approximately equal size. Construction of the interior dikes was begun prior to 1980 and was accomplished across one half to one third of the disposal facility using debris and end-dumped sand as fill material. Completion of the two interior dikes was accomplished in 1984, using geotextiles under the diking material to effectively float the dike across the soft dredged material. Although the initial portions of the interior dikes were built to help prevent short circuiting, they were completed for the express purpose of separating the site into individual compartments for management purposes.

3. The need to actively manage the Craney Island facility was recognized as the site began to fill and the need to identify future disposal sites was anticipated. Because of concern in the Norfolk District about disposal

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

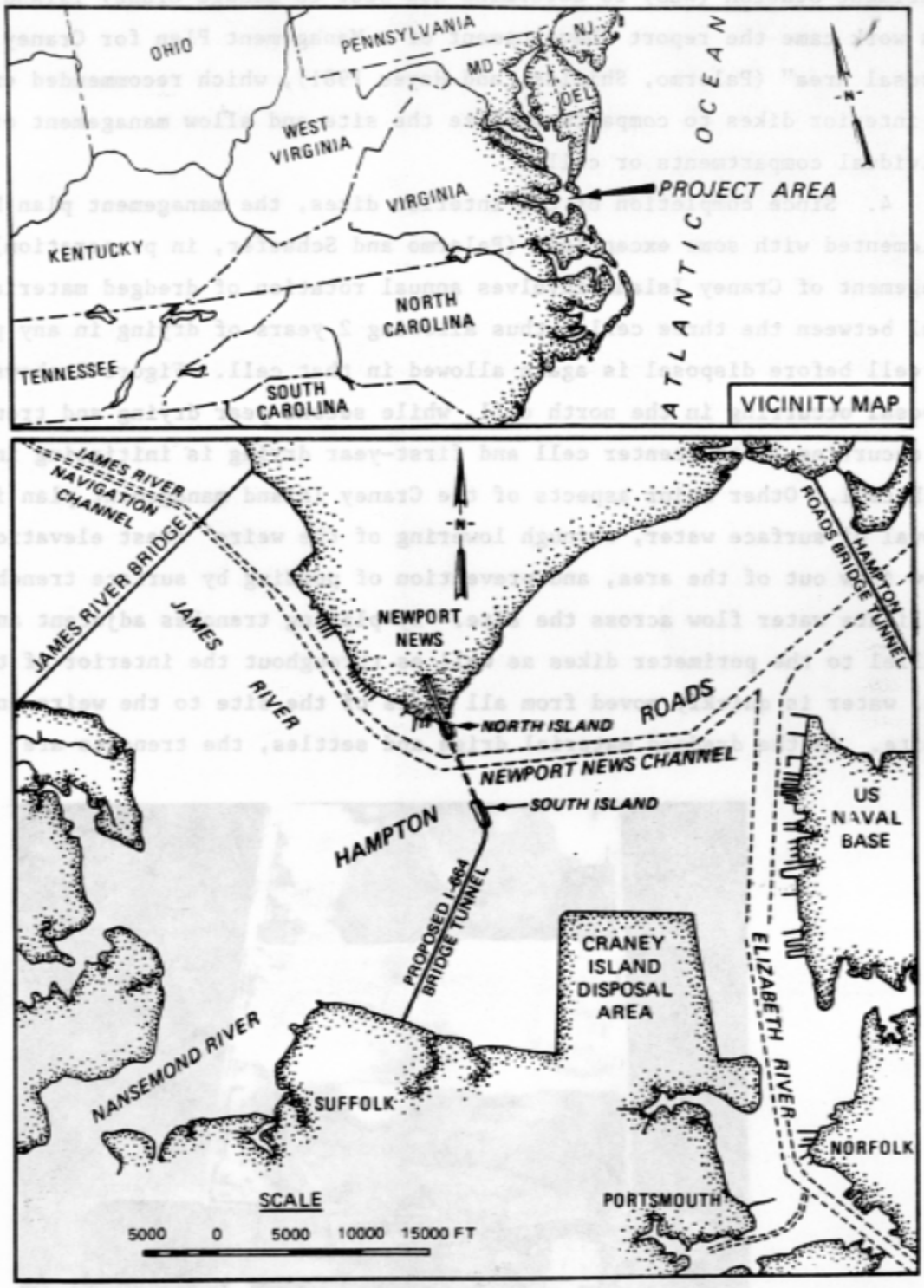

Figure 1. Craney Island project location

area management and operation to maximize the useful life of Craney Island, the Norfolk District funded an investigation by the US Army Engineer Waterways Experiment Station (WES) to determine how best to manage Craney Island. From this work came the report "Development of a Management Plan for Craney Island Disposal Area" (Palermo, Shields, and Hayes 1981), which recommended extending the interior dikes to compartmentalize the site and allow management of the individual compartments or cells.

4. Since completion of the interior dikes, the management plan has been implemented with some exceptions (Palermo and Schaefer, in preparation). The management of Craney Island involves annual rotation of dredged material disposal between the three cells, thus allowing 2 years of drying in any particular cell before disposal is again allowed in that cell. Figure 2 shows active disposal occurring in the north cell, while second-year drying and trenching are occurring in the center cell and first-year drying is initiating in the south cell. Other major aspects of the Craney Island management plan include removal of surface water, through lowering of the weirs' crest elevations to allow flow out of the area, and prevention of ponding by surface trenching to facilitate water flow across the site. By placing trenches adjacent and parallel to the perimeter dikes as well as throughout the interior of the site, water is quickly moved from all parts of the site to the weirs and then offsite. As the dredged material dries and settles, the trenches are

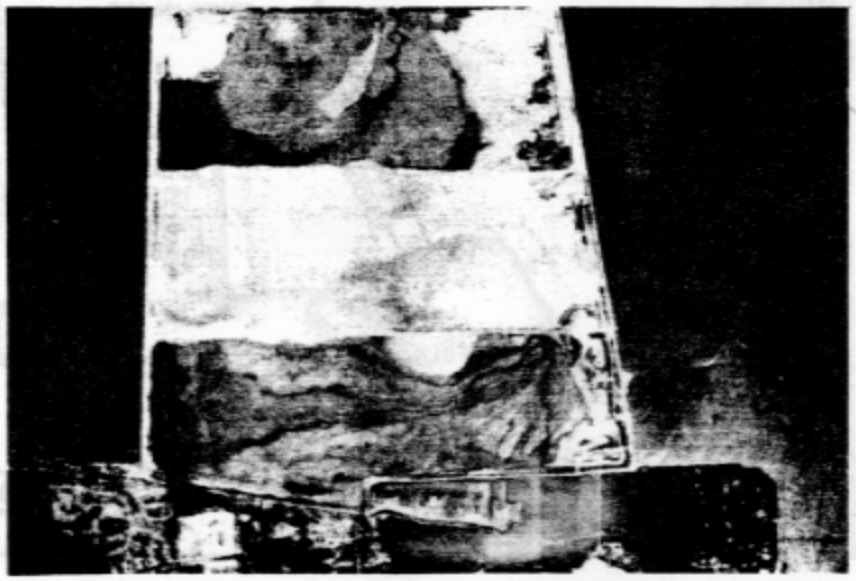

Figure 2. Existing Craney Island facility, after subdivision into three compartments

progressively deepened; thus, the term "progressive trenching" is applied to this operation. The management plan also calls for (a) installation of instrumentation during inactive (drying) periods and monitoring and (b) removal of coarse-grained and dry fine-grained material.

5. Through implementation of the Craney Island management plan under the authority of Section 148 of Public Law (PL) 94-587, much of the 4 to 5 million cubic yards of fine-grained material placed annually into Craney Island has been significantly dewatered. As a result, the useful life of the site has been extended. Despite this fact, the planned harbor deepening around Hampton Roads will result in placement of additional dredged material in Craney Island, which will reduce considerably the active life of the site. Therefore, an alternative disposal site must be located.

6. Because acquiring new dredged material disposal sites in the vicinity of Hampton Roads would be difficult, the Norfolk District has determined that expansion of the existing Craney Island facility is a practicable alternative. Six potential expansion configurations have been identified and are being evaluated for their hydraulic, geotechnical, and containment capacity feasibility. The latter evaluation is the subject of this report, while the former two evaluations were conducted concurrently by the Hydraulics and Geotechnical Laboratories, respectively, of the WES (Heltzel 1986, Spigolon and Fowler 1987).

Objectives

7. The objective of this work was to determine the active dredged material disposal life and the storage capacity of the existing Craney Island facility, as well as that of each expansion alternative both with and without the existing facility. The various scenarios were evaluated assuming an active dewatering/management program. The influence of subdividing the expansion facility into two or three subcontainments was also evaluated.

Scope of Work

8. To meet the project objectives, several associated tasks were performed. Initially, the physical dimensions of each of the six alternative

configurations were determined from large-scale (1:20,000) bathymetric maps, discussions with Norfolk District personnel, and coordination with the hydrodynamic and geotechnical engineering analyses conducted concurrently at WES. The available dredged material storage capacity of each configuration was subsequently calculated accounting for dike volume requirements. The filling history of each configuration was simulated with the computer program Primary Consolidation and Desiccation of Dredged Fill (PCDDF). Input requirements necessitated the compilation of the consolidation characteristics of the foundation soil and dredged material as well as the appropriate values to simulate site dewatering. The active disposal life of each facility was ultimately determined from the filling simulations and anticipated maximum dike heights.

PART II: HISTORICAL AND FUTURE DREDGING AND DISPOSAL REQUIREMENTS FOR HAMPTON ROADS

9. The Hampton Roads area of Virginia is a heavily populated region along the eastern coast of the United States. It is located on the James River near the mouth of the Chesapeake Bay. The Hampton Roads Harbor is surrounded by several cities, including Norfolk, Portsmouth, Newport News, and Hampton, with Virginia Beach, Chesapeake, Suffolk, and Poquoson also in the vicinity. Not only are there significant industrial developments and population centers in the area, but Norfolk is home to the North Atlantic Fleet of the United States Navy.

10. With the significant amount of waterborne commercial traffic through Hampton Roads, as well as the large water-related defense contingent, there has been an historic need to maintain the navigable waterways of the area. Therefore, throughout recent history, large quantities of sediment have been dredged from the waters of Hampton Roads; associated with dredging is the requirement to dispose of the material in an approved disposal site. Because of the large quantity of material dredged annually, a large disposal site capacity has been and will continue to be required in Hampton Roads.

Historical Requirements

11. Craney Island is a 2,500-acre confined disposal facility that is used to contain dredged material. It is by far the largest disposal facility in the Hampton Roads area and has historically been used to contain most sediments dredged from the area. This includes material from the Norfolk Harbor entrance channel, the Southern Branch navigation channel in the Elizabeth River, and the Newport News navigation channel, as well as numerous turning basins, anchorages, and piers.

12. Much of the dredging has been conducted by the Norfolk District, although significant portions of the material have been dredged by other Federal agencies, especially the Navy, and by private firms. Most of the dredging that occurred between 1956 and 1987 has involved maintenance work, although periodic new work dredging has been accomplished during channel widenings and deepenings and for development of new berthing areas. A summary of the sources, quantities, and times of placement of dredged material into

Craney Island is given in Appendix A. On the average, approximately 5 million cubic yards of material has been placed into Craney Island annually.

13. From completion of construction of Craney Island in 1956 until closure of the interior cross dikes in 1984, the entire site was operated as one large containment cell. Dredged material was normally pumped into the site along the eastern dike, and clarified effluent was released from weirs along the western dike. Since dredged material was almost continuously being pumped into Craney Island, the site was usually inundated with water, and no drying of the dredged material surface could occur.

14. Completion of the interior dikes in 1984 resulted in formation of three separate cells at Craney Island. Each cell has been operated independently of the others since that time. Disposal operations have generally been rotated through the three cells on an annual basis. The rotation sequence has been north cell, center cell, and south cell, with disposal in 1987 occurring into the south cell. By rotating disposal operations, 1 year of active disposal followed by 2 years of drying has generally occurred in each cell.

Future Requirements

15. With implementation of the Federal navigation channel deepening, which is authorized under the 1986 Water Resources Development Act (PL 99-662), dredging requirements in Hampton Roads will increase significantly for the near future. The channel deepening is currently scheduled for incremental completion. Initial stages began in fiscal year (FY) 1987, and final stages will end in FY 1999. The sequence of channel deepening is scheduled as follows: (a) the outbound Norfolk Harbor entrance channel to a depth of 50 ft (designated "50OB"), (b) the outbound entrance channel to a depth of 55 ft (55OB), (c) the Southern Branch channel of the Elizabeth River to a depth of 45 ft (SB45), (d) the upstream portion of the Southern Branch to a depth of 40 ft (SB40), (e) the inbound Norfolk entrance channel to a depth of 50 ft (50IB), and (f) the inbound entrance channel to a depth of 55 ft (55IB).

16. With each stage of the deepening project, significant quantities of new work material will be dredged and will require disposal. As the deepening project progresses, the quantity of maintenance material to be dredged annually is also expected to increase. Table 1 summarizes the quantities of sediment to be dredged in the future. These quantities are, of necessity,

estimates that were developed by the Norfolk District and are based upon past experience, hydraulic modeling results, and best estimates of future conditions.

PART III: POTENTIAL EXPANSION SITES

17. Six potential expansion sites had previously been identified by Norfolk District personnel (see Figure 3). Each of these sites abutted the existing facility on the north or west side, or both. Expansion to the east was impossible because of the proximity of the Elizabeth River ship channel; to the south was located prime residential land. Thus, expansion possibilities were limited to the west and north.

Expansion Site Conditions

18. The initial task was to establish the initial water depths and diking configurations before determining the spatial dimensions of the alternative configurations for the expansion facility. The locations of the end points for each dike were obtained from the bay hydrodynamic study conducted as part of the overall expansion analysis (Heltzel 1986). Dike lengths and mean water depths were determined from the 1:20,000-scale National Oceanic and Atmospheric Administration bathymetric chart for Hampton Roads. Depths were adjusted to a common datum, as necessary, on the basis of a 1.5-ft differential between mean low water and mean sea level.*

19. The total volume available for dredged material storage within each configuration was influenced by the volumetric requirements of the perimeter and interior dikes. Preliminary information concerning the side slopes and crest dimensions and elevations were obtained from the associated geotechnical engineering study conducted for the expansion project and from a previous WES study (Palermo, Shields, and Hayes 1981; Spigolon and Fowler 1987). For perimeter dike construction in shallow water, i.e., less than 15 ft deep, a side slope of 1 ft vertical to 30 ft horizontal (1:30) will generally ensure slope stability. The greater depths of water encountered in the northern sections of Alternatives 1, 2, and 3 will require a more shallow side slope to maintain slope stability. An average slope of 1:80 was used for these perimeter dikes in the storage capacity calculations. A transition slope of 1:15 was assumed between el -2.0 mlw and el +4.0 mlw, while a slope of 1:2 was

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* Personal Communication, 1986, Tom Szelest, US Army Engineer District, Norfolk, Norfolk, VA.

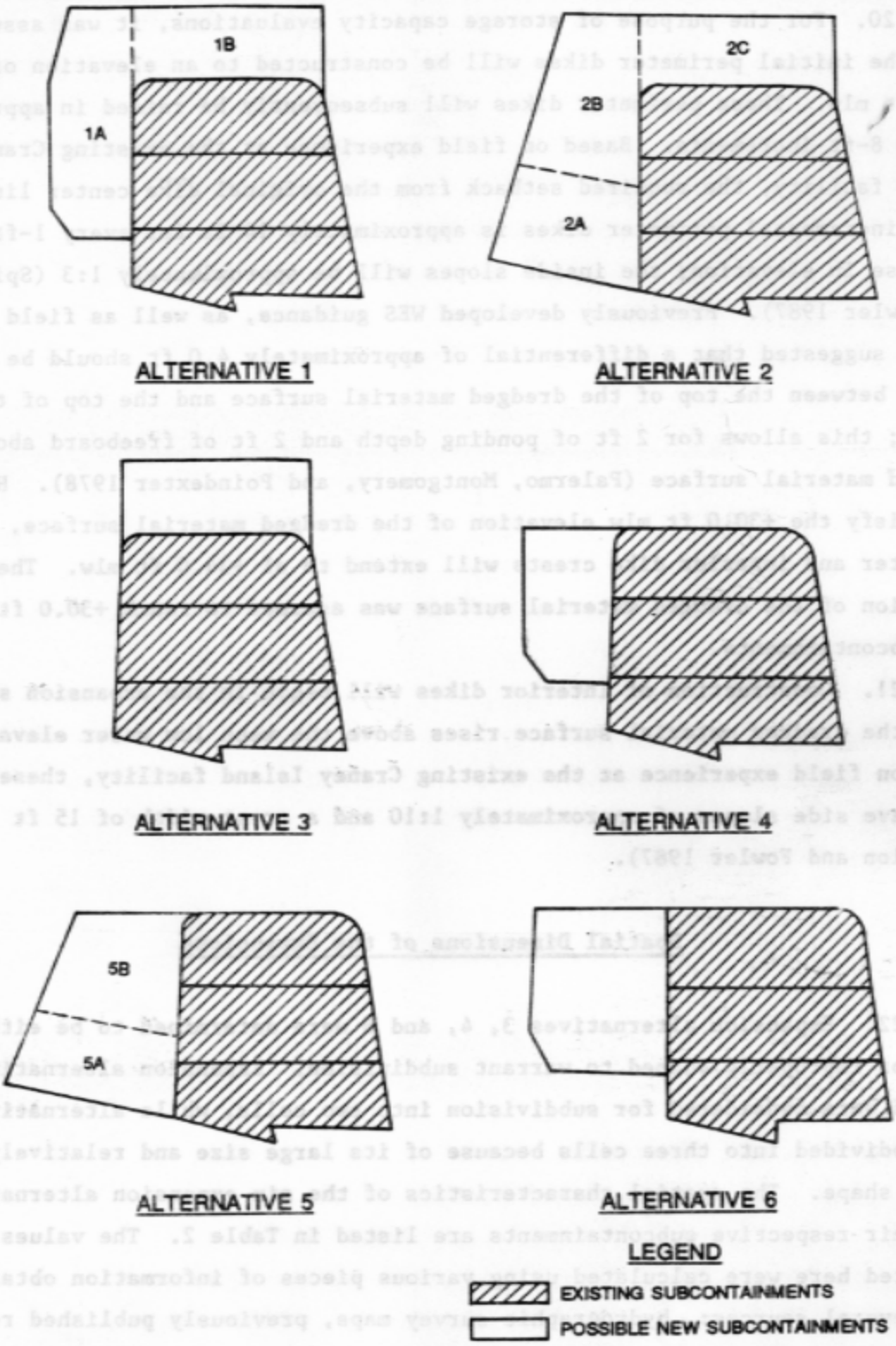

Figure 3. Alternative configurations for expansion of Craney Island

assumed from el +4.0 mlw to the top of the initial dike crest (Palermo, Shields, and Hayes 1981).

20. For the purpose of storage capacity evaluations, it was assumed that the initial perimeter dikes will be constructed to an elevation of +8.0 ft mlw. These perimeter dikes will subsequently be raised in approximately 8-ft increments. Based on field experience at the existing Craney Island facility, the required setback from the original dike center line for these incremental perimeter dikes is approximately 14 ft for every 1-ft increase in elevation; the inside slopes will be approximately 1:3 (Spigolon and Fowler 1987). Previously developed WES guidance, as well as field experience, suggested that a differential of approximately 4.0 ft should be maintained between the top of the dredged material surface and the top of the dike crests; this allows for 2 ft of ponding depth and 2 ft of freeboard above the dredged material surface (Palermo, Montgomery, and Poindexter 1978). Hence, to satisfy the +30.0 ft mlw elevation of the dredged material surface, the perimeter and interior dike crests will extend to el +34.0 ft mlw. The final elevation of the dredged material surface was assumed to reach +30.0 ft mlw in all subcontainments.

21. Construction of interior dikes will begin in the expansion sites after the dredged material surface rises above the mean low water elevation. Based on field experience at the existing Craney Island facility, these dikes will have side slopes of approximately 1:10 and a crest width of 15 ft (Spigolon and Fowler 1987).

Spatial Dimensions of the Expansions

22. Expansion alternatives 3, 4, and 6 were determined to be either too small or improperly shaped to warrant subdivision. Expansion alternatives 1 and 5 were considered for subdivision into two cells, while alternative 2 was subdivided into three cells because of its large size and relatively narrow shape. The spatial characteristics of the six expansion alternatives and their respective subcontainments are listed in Table 2. The values tabulated here were calculated using various pieces of information obtained from several sources: hydrographic survey maps, previously published reports, concurrent studies of the Hampton Roads area, and written and verbal communications with Norfolk District personnel. The entries in Table 2 are

arranged according to the projected disposal periods. The initial line of values for each alternative is associated with the initial perimeter dike construction to el +8 mlw, i.e., when the dredged material surface is below el +4.0 ft mlw. Directly below that line are additional lines of values corresponding to subsequent disposal periods when the dredged material surface will increase from el +4.0 mlw to el +30.0 mlw; one additional line is presented for each cell of each expansion alternative. The average bottom elevations presented in column 3 were determined from the areal-weighted average of the soundings within each cell, as determined from the bathymetric chart. The average depth corresponds to the distance from the lower datum of the expansion alternative to the upper surface elevation for the appropriate disposal period. For the initial disposal period, this distance is measured from the average bottom elevation to el +4.0 ft mlw; for the subsequent disposal period, this distance is measured from el +4.0 ft mlw to the maximum surface elevation.

23. The total surface area was calculated based on the center line of the perimeter dikes at el +8.0 ft mlw. The difference between total and available surface area for each line of data in Table 2 reflects the reduction in storage capacity due to the dike volumes and the small area (approximately 5 percent (Cargill 1985)) required for the deposition of the coarse-grained fraction. An initial value, representing conditions existing before interior dike construction, was calculated over the depths from the bottom to el +4.0 ft mlw; the second estimate covered the range from el +4.0 mlw to the final surface elevation. The total storage capacity for each alternative was calculated as the product of the available surface area for each phase and the average depth for each phase. The final column in Table 2 is the average lift thickness for each alternative corresponding to each of the two disposal periods. The values represent results of semiannual disposal of 2.125 million cu yd of fine-grained dredged material with an initial void ratio of 10.5; this information in the last column is included for comparison purposes only. In simulating the filling of the various cells, actual lift thicknesses were used based upon the quantity of material to be dredged during a particular dredging operation and the surface area of the disposal cell to be used for that operation.

PART IV: MODELING TECHNIQUE

24. Management of confined dredged material disposal areas to provide maximum storage capacity is becoming more necessary as both the storage capacity of existing sites and the availability of land for creation of new sites decrease. Maximum site capacity is achieved through densification of the dredged material by removal of interstitial water. The volume reduction, and the resulting increase in site capacity, is obtained through both consolidation and desiccation of the dredged material.

25. Long-term management of dredged material containment areas has been facilitated by development of predictive techniques that allow accurate projection of the containment area surface elevation for repetitive disposal operations. Use of large strain consolidation test data in a finite strain mathematical model permits prediction of surface elevations to within the accuracy of measurement of the constituent variables. Techniques for predicting volume reduction resulting from evaporative drying have been developed and incorporated in the mathematical model Primary Consolidation and Desiccation of Dredged Fill (PCDDF). A user-friendly version of PCDDF, in the Automated Dredging and Disposal Alternatives Management System, ADDAMS (Schroeder 1988), was used in this study. This version is referred to as the CONS (consolidation) module of ADDAMS.

Theoretical Basis

Finite strain consolidation

26. Because many soft, fine-grained dredged materials may eventually undergo 50-percent strain or more, Terzaghi's conventional small strain theory is not technically applicable to analyses of dredged material containment areas. A more appropriate approach involves use of a large, or finite, strain consolidation theory. The most general and least restrictive of the many one-dimensional primary consolidation formulations is the finite strain theory developed by Gibson, England, and Hussey (1967).

27. The governing equation for finite strain consolidation theory is based on the continuity of fluid flow in a differential soil element, Darcy's law, and the effective stress principle, similar to the conventional consolidation theory. However, finite strain theory can additionally consider

vertical equilibrium of the soil mass, place no restriction on the form of the stress-strain relationship, allow for a variable coefficient of permeability, and accommodate any degree of strain. The governing equation is

$$\left(\frac{\gamma_s}{\gamma_w} - 1\right) \frac{d}{de} \left[\frac{k(e)}{1 + e}\right] \frac{\partial e}{\partial z} + \frac{\partial}{\partial z} \left[\frac{k(e)}{\gamma_w (1 + e)} \frac{d\sigma'}{de} \frac{\partial e}{\partial t} + \frac{\partial e}{\partial t}\right] = 0 \quad (1)$$

where

γ_s = unit of weight of solids

γ_w = unit weight of water

e = void ratio

$k(e)$ = soil permeability as a function of void ratio

z = vertical material coordinate measured against gravity

σ' = effective stress as a function of void ratio

t = time

This approach is well suited for the prediction of consolidation in thick deposits of very soft dredged materials since it accounts for the large strains and nonlinear soil properties inherent in these materials.

Desiccation

28. The removal of water by desiccation from a normally consolidating dredged material layer will result in formation of a surface crust; this in turn will cause additional consolidation due to the surcharge created by crust formation. Since surface drying may be significant between disposal operations, it is essential to incorporate predictions of desiccation settlement in evaluations of disposal site capacity.

29. An empirical description of the desiccation process has been developed in terms of water balance in the upper portion of dredged material layers (Cargill 1985). Procedures for calculation of soil evaporation rates and depths of influence have been developed. Site-specific climatic conditions are incorporated in the analysis procedures. The predictive model developed uses void ratios instead of water contents in order to be compatible with the consolidation model.

Computer Model Description

30. Both the finite strain consolidation model and the empirical desiccation model have been programmed for computer solution (Cargill 1982,

1985). The program PCDDF incorporates an explicit finite difference mathematical approximation to describe the consolidation process. Monthly adjustments in the top boundary condition and location are made to account for the amount of desiccation that has occurred. In addition to material settlement that comes from a calculation of void ratio distribution, PCDDF also calculates the distribution of stresses and pore pressures throughout the dredged material layer. Any sequence of material deposition can be considered by the program. In order to use either the PCDDF or the CONS version of the computer program, laboratory test data must be obtained on representative sediment samples. Both the sediment compressibility and permeability characteristics are required by the computer model.

PART V: DREDGED MATERIAL PROPERTIES

31. Laboratory procedures for testing slurried sediments have been developed at the WES. These procedures can provide compressibility and permeability data for the large quantities of very soft materials dredged annually by the Corps of Engineers. These data are useful in analyzing the finite strain consolidation of dredged materials.

32. For very soft soils, use of a series of consolidation tests is necessary to obtain the void ratio-effective stress ($e - \sigma'$) and void ratio-permeability ($e - k$) relationships over the entire range of potential field conditions. Results of the individual laboratory tests are combined to form the appropriate $e - \sigma'$ and $e - k$ relationships for the soft materials. In this part, the necessary geotechnical laboratory data are mentioned, and the properties of the Hampton Roads dredged material, as obtained from the laboratory testing program, are presented.

Required Laboratory Testing

33. To predict the consolidation of dredged material by finite strain theory, several pieces of data are required which can be determined through a geotechnical laboratory testing program. The necessary data include specific gravity of the solid particles, the Atterberg limits (liquid limit and plastic limit), the void ratio-effective stress ($e - \sigma'$) relationship, and the void ratio-permeability ($e - k$) relationship. The specific gravity and the Atterberg limits can be determined by routine laboratory testing, while the $e - \sigma'$ and $e - k$ relationships must be determined from one or more of a number of laboratory consolidation tests.

34. For determining the $e - \sigma'$ and $e - k$ relationships, several consolidation test procedures are available; however, at present, there is no singularly recommended testing procedure for determining these relationships for soft dredged material (Poindexter 1987). The laboratory consolidation tests used by the Corps of Engineers for dredged material testing are the self-weight consolidation test, a large strain consolidation test, and the standard oedometer test. The laboratory testing procedures are presented by Cargill (1986) and Poindexter (1987, 1988); the applicability of the various tests is discussed by Poindexter (1987, 1988).

Determination of Dredged Material Properties

35. Representative samples of maintenance sediments from the Hampton Roads area were collected and subjected to geotechnical laboratory testing (Palermo, Shields, and Hayes 1981; Cargill 1985). Classification tests were performed on the dredged material sample. The material had a liquid limit of 143 and a plastic limit of 40, yielding a plasticity index of 103. This material had a specific gravity of 2.75. The material was classified according to the Unified Soil Classification System as a black highly plastic clay (CH).

36. Consolidation tests performed on the Craney Island dredged material included the oedometer, self weight, and large strain, controlled rate of strain tests. Results of these tests were combined to form the total $e - \sigma'$ and $e - k$ relationships for the dredged material, as shown in Figures 4 and 5, respectively. The oedometer test was used to get the $e - \sigma'$ and $e - k$ relationship for the foundation soil (see Figures 6 and 7). Values of individual data points for both the dredged material and the foundation are presented in Table 3.

37. For input to the computer program CONS, the void ratio-effective stress and void ratio-permeability relationships were described by fitted curves of the form $e = A\sigma^B + C$ and $e = Dk^E + F$, respectively, where A, B, C, D, E, and F are coefficients. The coefficients were determined statistically from laboratory data on the Craney Island dredged material. The equations used for the dredged material were

$$e = -3.0 + \left(\frac{\sigma'}{0.56 \times 10^{12}}\right)^{-0.09009} \tag{2}$$

and

$$e = -4.0 + \left(\frac{k}{0.279 \times 10^{-14}}\right)^{0.08065} \tag{3}$$

The equations used for the foundation soil were

$$e = \left(\frac{\sigma'}{1.52 \times 10^{5}}\right)^{-0.12019} \tag{4}$$

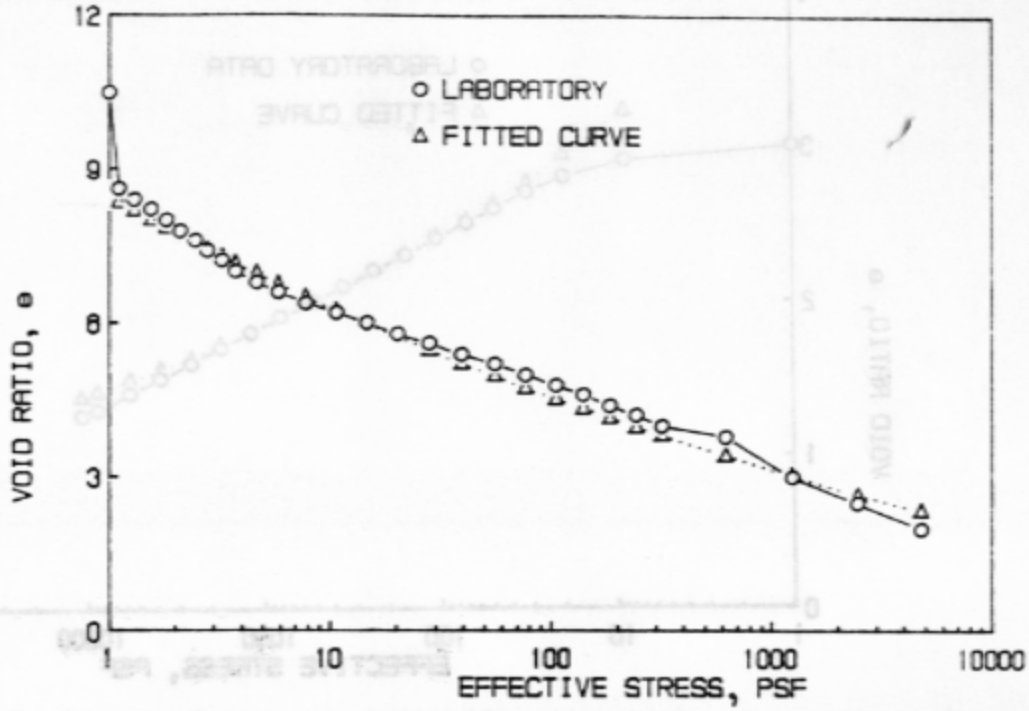

Figure 4. Void ratio-effective stress relationship for the Craney Island dredged material

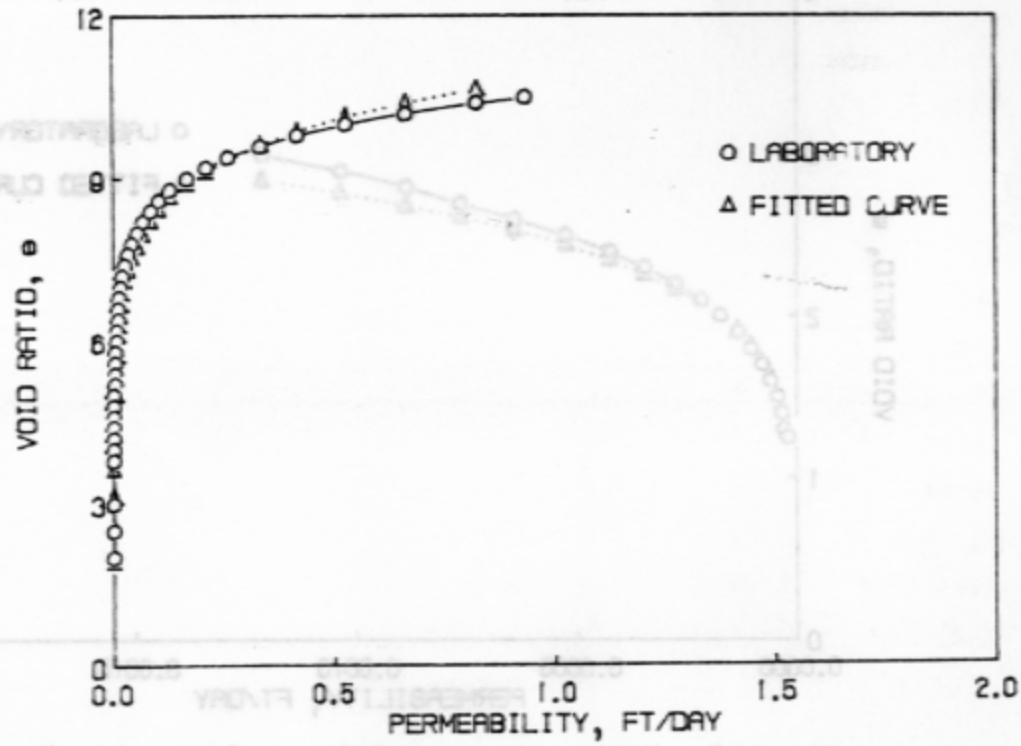

Figure 5. Void ratio-permeability relationship for the Craney Island dredged material

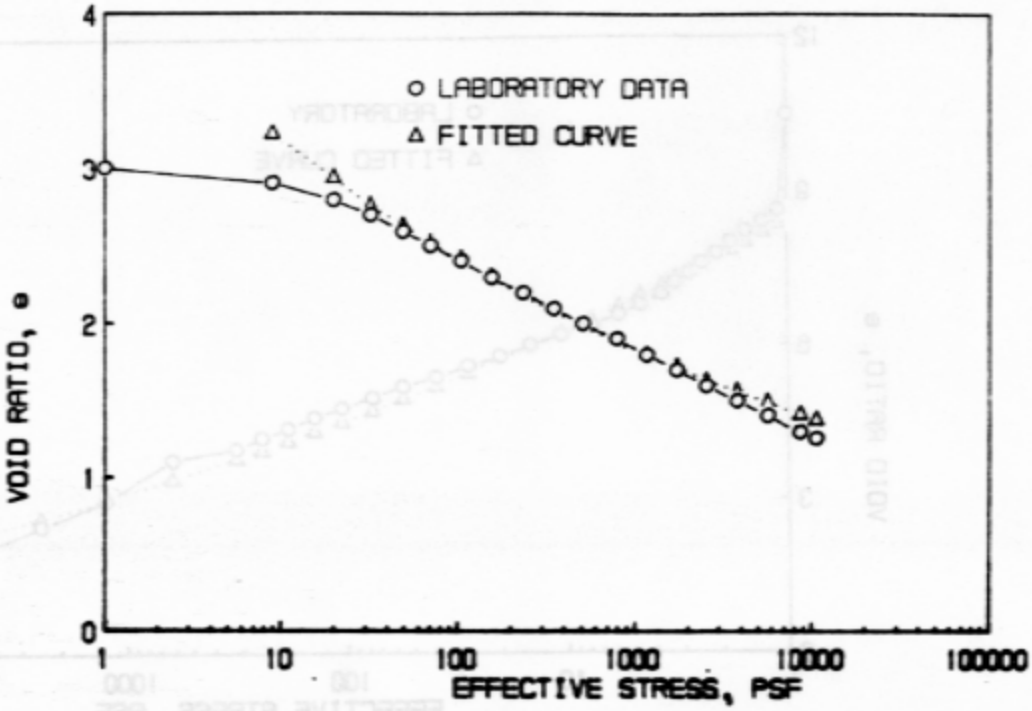

Figure 6. Void ratio-effective stress relationship for the Craney Island foundation soil

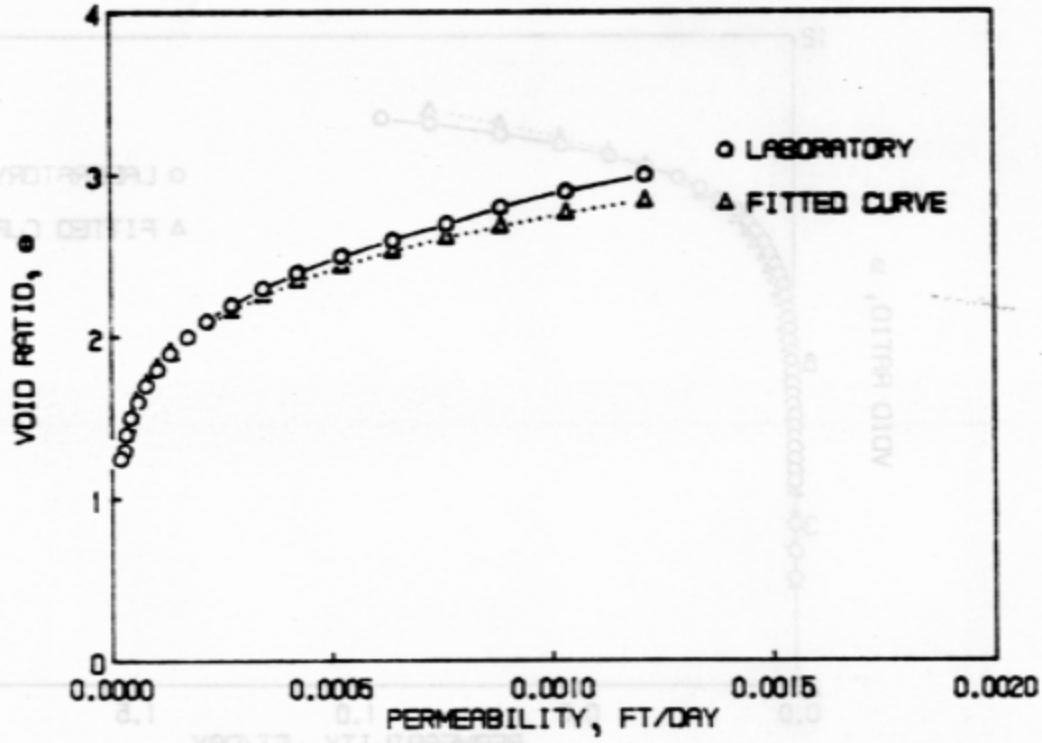

Figure 7. Void ratio-permeability relationship for the Craney Island foundation soil

and

$$e = \left(\frac{k}{3.97 \times 10^{-6}} \right)^{0.18282}$$

The curves that were fitted to the laboratory data using the above equations are shown in Figures 4-7.

PART VI: STORAGE CAPACITY EVALUATIONS

38. Containment areas intended for use in conjunction with recurring disposal operations must be sized for long-term storage capacity over the service life of the facility. Storage capacity is defined as the total volume available to hold additional dredged material and is equal to the total unoccupied volume minus the volume associated with ponding and freeboard requirements. The maximum available storage volume is dictated by the maximum dike height as determined by foundation conditions or other constraints and the containment surface area. Long-term storage capacity must consider not only the initial volume available for storage and the initial volume of dredged material, but also any long-term changes in the remaining storage volume available over time. The estimation of long-term storage capacity is an important consideration for long-term planning and design of new containment areas or evaluation of the remaining service life of existing sites.

39. After dredged material is placed within a confined disposal site, it immediately undergoes sedimentation, which is completed within a few days. The dredged material then enters the more time-consuming process of self-weight consolidation. Placement of the dredged material imposes a loading on the containment area foundation, which may result in consolidation of compressible foundation soils. Settlement due to consolidation of both the dredged material and foundation soils is therefore a major factor in the estimation of long-term storage capacity. Since the consolidation process is slow, especially in the case of fine-grained materials, it is likely that total settlement will not have taken place before the containment area is required for additional placement of dredged material. For this reason, the time-rate of consolidation must be considered in estimating long-term containment area storage capacity. Procedures to be used are applicable to both self-weight consolidation of dredged material and consolidation of foundation soils (Palermo, Montgomery, and Poindexter 1978; Cargill 1985; Poindexter 1987, 1988; US Army Corps of Engineers (USACE) 1987).

40. An additional factor that may affect containment area storage capacity is settlement due to desiccation of the dredged material surface. If a site is well managed to eliminate surface water, the dredged material surface will be subjected to evaporative drying and may undergo significant settlement resulting from this drying. In cases where desiccation occurs,

settlement as a function of time must be determined for dredged material subjected to the effects not only of self-weight consolidation but also of desiccation and the additional consolidation resulting from the surcharge created by formation of the desiccation crust. Procedures for prediction of dredged material settlement due to consolidation and desiccation have been developed (Cargill 1985).

41. Estimates of settlement caused by placement of subsequent lifts of dredged material should consider the continued consolidation of previously placed lifts and additional foundation consolidation. Because of the increasing complexity of calculations as additional lifts are placed, solution of all but the simplest problems is more easily accomplished through computer analysis.

42. The estimated time-settlements due to dredged material and foundation consolidation may be combined to yield a time-surface settlement relationship resulting from placement of a single lift (USACE 1986). These data are sufficient for estimation of the remaining capacity in the short term. However, if the containment area is to be used for long-term placement of subsequent lifts, a projected plot of dredged material surface height versus time (see Figure 8) should be developed (Palermo, Montgomery, and Poindexter 1978). This plot can be developed using time-settlement relationships for sequential lifts combined with surface height increases resulting from containment area filling operations. Such data may be used for preliminary estimates of the long-term service life of the containment area.

43. The saw-toothed curve shown in Figure 8 is typical of the dredged material surface elevation versus time curves obtained for containment areas that are used periodically. The time at which the containment area will fill can be determined by projecting the maximum allowable dredged material surface elevation to its intersection with the saw-toothed curve. In Figure 8, the horizontal line representing a surface elevation of 30 mlw first intersects the saw-toothed curve at approximately FY 1995, but because substantial initial consolidation will occur quickly and a minimum of 4 ft of freeboard is available between el 30 and el 34 (top of dikes), the entire FY 1995 disposal operation can be accommodated. The site is thus projected to fill during the next disposal operation (in FY 1998) when all of the dredged material cannot be contained.

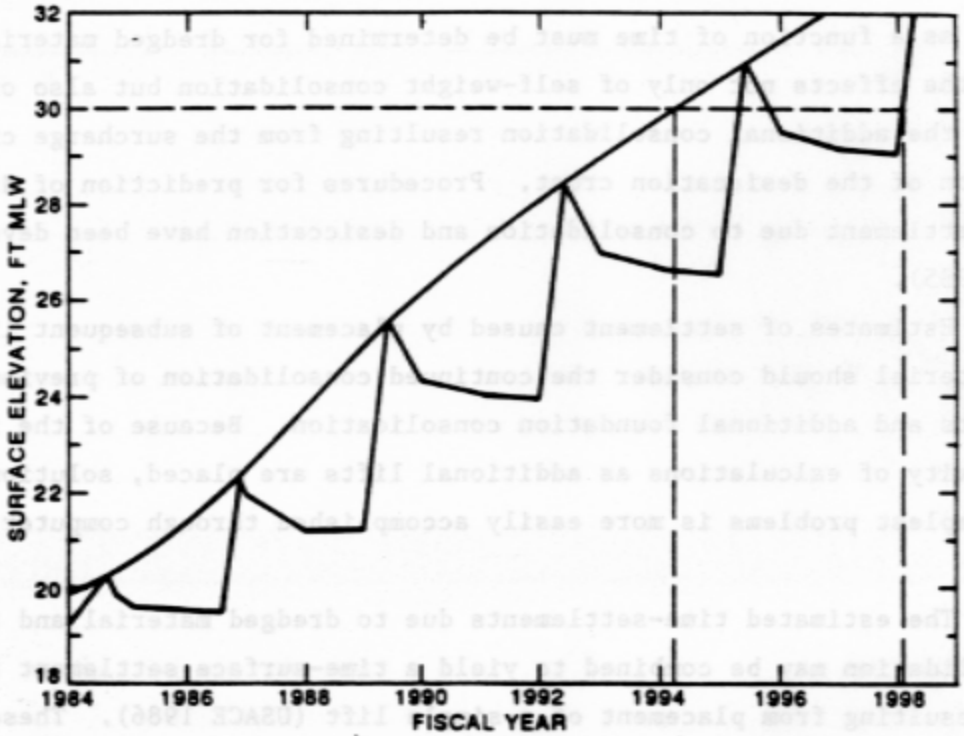

Figure 8. Comparison of typical saw-toothed curve obtained from periodic dredged material placement and smoothed curve used in this report

44. In this report, a smoothed curve will be used, instead of the saw-toothed curve, to represent the general filling trends projected for the various cells at Craney Island (see Figure 8). The smoothed curve makes it much simpler to compare numerous projections, allows the graphical data to be presented more concisely, and is much simpler for nonengineers to understand. The smoothed curve will be drawn through the peaks of the saw-toothed curves since this projection will provide a more conservative estimate of the future disposal life, i.e., a shorter disposal life. For instance, in Figure 8, the smoothed curve indicates that the site will fill during FY 1994. This projection is 4 years shorter (1994 versus 1998) than that obtained from the saw-toothed curve. In most instances, the difference in disposal life determined from smoothed and saw-toothed curves will vary by no more than approximately the length of time between disposal operations. Thus, differences between projections contained in this report and those contained in Palermo and Schaefer (in preparation) can be attributed in part to the graphical presentation method used. (Also, because the reports have very different purposes, different annual dredged material placement quantities were used in the two studies; this also directly affects the projected disposal life.)

Assumptions

45. To simulate the filling of confined dredged material containment areas, a number of assumptions must be made regarding initial site conditions, material characteristics, dredging volumes, and site operation and management. In this section, the assumptions used in the study are summarized for reference.

Initial site conditions

46. An initiation point in time was needed for the present study; this was taken as the beginning of FY 1987, with data provided by the Norfolk District. Any material present in the existing cells was considered to be soft, compressible foundation soil upon which subsequent dredged material deposits would be made. The surface elevation of each cell was determined from surveys conducted for the Norfolk District during September 1986; these elevations were then used in the filling simulations. The elevations used were as follows: north cell, el +20.0 mlw; center cell, el +15.4 mlw; and south cell, el +20.2 mlw. Furthermore, it was assumed that the interior surface of each cell was level, i.e., it was all at the stated elevation.

47. The final elevation to which dredged material could be placed was assumed to be el +30.0 mlw. This requires that all perimeter and interior dikes have a minimum final elevation of 34 mlw if 2 ft of freeboard and 2 ft of ponding depth are to be provided. Material for dike raising will come from the interior of the site; initial dike construction for the expansion site(s) is the only construction that will not use material from inside Craney Island.

Material properties

48. Over the years, the physical properties of maintenance dredged material in the Hampton Roads area have remained essentially constant. These same material properties (described in Part V) are assumed to be representative of all maintenance material to be placed in Craney Island in the future. Further, it is assumed that these properties (particularly compressibility and permeability) are also representative of the new work material that will be dredged during the various stages of the Norfolk deepening project.

49. For the purposes of this study is was assumed that the only difference in the maintenance and new work materials is the in situ void ratio at which the material exists in the channel before dredging. The in situ void ratio for the maintenance material was assumed to be 5.93 (Palermo, Shields,

and Hayes 1981; Cargill 1985) while the void ratio of the new work material was taken as 2.55 (Palermo, Shields, and Hayes 1981), based upon existing data from channel sediment samples. The quantities of material to be dredged were "bulked" from their in situ void ratios to the initial void ratio expected to exist in the containment area. An initial void ratio of 10.5 (Cargill 1985) was used for all of the hydraulically dredged materials.

Dredging and disposal quantities

50. Estimates were made by the Norfolk District regarding the quantities of new work and maintenance material to be dredged. These quantities were based upon historical data, previous hydraulic modeling studies, and best estimates of future conditions. The quantities provided by Norfolk were previously presented in Table 1.

51. The average dredged material deposit thickness was calculated for each alternative based on the available surface areas presented in Table 2. Two values for lift thickness were estimated for each configuration, consistent with the two-phase dike construction process. For the purpose of the simulations, it was assumed that the disposal volume was deposited semiannually in the entire expansion area until the dredged material surface reached approximately +4.0 ft mlw. An additional semiannual lift thickness was calculated to correspond to the construction of interior and incrementally raised perimeter dikes. For those configurations with subareas (1, 2, and 5), disposal was rotated after interior dike construction.

Site operation and management

52. It was assumed that the existing Craney Island facility will be the only available disposal site until 1993; therefore, it will receive all materials dredged in the Hampton Roads area from 1987 through 1992. This includes 4 million cu yd of maintenance dredged material plus the material from the 50-ft outbound channel deepening. (To keep terminology consistent with that used by the Norfolk District, the 4 million cu yd of maintenance material plus the 50-ft outbound deepening project are presently considered to be the "existing project.") Rotation of disposal into the three existing cells was assumed to occur in this order: the south cell in 1987, the north cell in 1988, and the center cell in 1989. This pattern of rotation was continued until one or all of the existing cells were filled or until an expansion alternative was available. For the case of Craney Island expansion, the selected expansion alternative was assumed to be available for use in 1993.

The disposal operations schedule was modified at that time to reflect sequential rotation of disposal through all cells of the particular disposal site scenario and dredging scenario of interest.

53. An active dewatering program was assumed to be planned and implemented at the Craney Island facility. The simulation of dredged material surface settlement allows flexibility in numerous input parameters describing the desiccation characteristics of a site. However, PCDDF cannot explicitly simulate specific dewatering management options, such as interior trenching. Rather, empirical coefficients are incorporated in PCDDF to provide a means to simulate the surface settlement due to desiccation of the dredged material. Thus, only one dewatering scenario was considered, as requested by the Norfolk District. This scenario assumed that maximum dewatering of the site would occur, resulting in a maximization of storage capacity. The desiccation input parameters are given in Table 4. Since the relative values of evaporation and precipitation have a major effect upon desiccation, monthly climatic data are needed in the calculations. Climatic data for Craney Island are tabulated in Table 5.

Method of Analysis

54. Evaluations were required regarding the useful life and storage capacity of Craney Island and its proposed expansion options. The useful life was determined for three disposal site scenarios. First, the disposal life of the existing Craney Island was determined without considering the expansion cell(s). Second, the disposal life of the expansion and Craney Island together was determined. Third, the disposal life of the expansion without Craney Island was determined.

55. Factored into this schedule of analysis were the six independent expansion alternatives. This resulted in 13 disposal site scenarios (one existing Craney Island, six expansions with Craney Island, six expansions without Craney Island) to be evaluated. There were also six dredging scenarios involving different aspects of the navigation channel deepening project which had to be considered for each disposal site scenario. In total, 78 evaluations were to be performed. For each evaluation, each cell of the disposal area had to be simulated and evaluated separately; the number of cells varied from one to six for the 78 evaluations. Figure 9 illustrates the

WES USEFUL LIFE STUDY
EXPANSION ALTERNATIVE #

DREDGING SCENARIOS	USEFUL LIFE IN YEARS		
	EXISTING C.I.	CRANEY ISLAND EXPANSION	
	(WITHOUT PROJECT)	WITHOUT C.I.	WITH C.I.
EXISTING PROJECT			
50 FT OUTBOUND			
55 FT OUTBOUND			
ENTIRE 55 FT			
50 FT OB+SB			
55 FT OB+SB			
ENTIRE 55 FT+SB			

Figure 9. Requested format for results of useful life evaluations (OB = outbound, SB = Southern Branch)

form in which the Norfolk District requested results of the analyses. To simplify the analysis, the format was modified to show the year in which the existing Craney Island facility will fill when used in conjunction with each expansion alternative, along with the year in which the expansion site fills both with and without considering the existing facility. One of the modified tables was completed for each of the six expansion alternatives. The year in which the existing Craney Island facility fills without use of the expansion cells is shown in a separate table.

56. The computer program CONS (the new user-friendly, personal computer version of PCDDF) was used to perform the disposal site filling simulations. Use of a computer program was required because of the numerous complicated calculations necessary to account for both consolidation and desiccation of very soft dredged materials. Because of the number and length of computer runs required in this study, the program was uploaded to the US Army Tank and Automotive Command Cray Supercomputer to facilitate the computations.

Simulation Results

57. For each dredging scenario, computer runs were made for each cell of each disposal site scenario. Results of the filling simulations for individual cells are tabulated in Appendix B. Summaries of the results are tabulated for the existing facility in Table 6 and by expansion alternative in Tables 7 through 12. It should be noted that these tables show the fiscal year in which each disposal option will fill for each dredging scenario. The actual number of years that each disposal option will be available for use can easily be calculated by either subtracting the year 1987 from the year shown for the existing Craney Island facility, or subtracting the year 1993 from the year shown for an expansion alternative, and then adding the portion of the final year during which the cell is used. For example, in Table 6, the existing Craney Island facility is projected to reach ultimate capacity in mid-FY 1997 for dredging scenario 1 (S1); the useful life of this disposal option is calculated as FY 1997 minus FY 1987 plus 0.5 year, for a useful life of 10.5 years.

Remaining Life of Existing Facility

58. If no expansion cells are constructed and the existing Craney Island facility is used to contain all material to be dredged from the Hampton Roads area (both maintenance and new work), then the site will be filled to capacity by the mid-1990s (see Table 6 and Table B1). If only the 50-ft outbound deepening project and annual maintenance dredging (dredging scenario 1) are done, the existing facility will be filled by about mid-1997 when the final existing cell (the center cell) reaches capacity. If any additional deepening is accomplished (dredging scenarios 2 through 6), the existing site will be filled to capacity in mid-1994.

59. Thus, the maximum remaining life of the existing facility is approximately 10.5 years. This remaining life will be reduced to 7.5 years if additional deepening (beyond the 50-ft outbound project) is accomplished. In summary, if the authorized deepening of Norfolk Harbor is attempted without providing an expansion of Craney Island, the existing facility will fill to capacity in 7.5 to 10.5 years, and the only portions of the deepening project

that can be contained in the facility are the 50-ft outbound and a portion of the 55-ft outbound.

60. It should be noted that all projections made in this study assume that maximum management (maximum dewatering) is accomplished at Craney Island. If intense management of the site is not accomplished each year of its remaining life, the site will fill earlier than projected in this study. Palermo and Schaefer (in preparation) found that the existing site has filled faster than projected in earlier studies partially as a result of exceptions to the management approaches presented in the Craney Island Management Plan (Palermo, Shields, and Hayes 1981) after completion of interior dike construction.

Service Life of Expansion Projects Without Craney Island

61. The existing Craney facility Island may be filled before the expansion site is completed. In this case, after completion of the selected expansion alternative, the new facility alone will then be used to contain all material dredged from the Hampton Roads area. For this analysis, it was assumed that the expansion cell will be completed and ready for use at the beginning of FY 1993. Material dredged from Hampton Roads will be placed into the new cell until the material surface reaches el +4 mlw. At this point, if the selected expansion is large enough to warrant subdivision, interior dike construction will begin and subsequent disposal operations will be rotated sequentially through the newly created subcontainments. The expansion projects considered for subdivision were alternatives 1, 2, and 5; expansion alternatives 3, 4, and 6 were not considered for subdivision but were analyzed as single cells. The results of the analyses are discussed below for each of the Craney Island expansion options.

Expansion Alternative 1

62. Completion and subsequent exclusive use of expansion alternative 1 for dredged material containment will provide adequate capacity to contain all new work and maintenance material to be dredged during the Norfolk Harbor deepening project, which is to be completed in FY 1999, plus several additional years of maintenance dredging. This expansion alternative will provide between 22.5 and 39 years of useful disposal life. A maximum of 39 years will be available if only the existing project (deepening to 50-ft outbound) is completed. If the entire deepening project is completed, then the expansion

site will be filled in mid-FY 2015, or 22.5 years after disposal is initiated into this site (see Tables 7 and B5).

Expansion Alternative 2

63. Expansion alternative 2 is considerably larger than the other proposed expansions; therefore, it has a proportionately longer useful disposal life. The projected disposal life for expansion alternative 2 ranges from 56 years for the existing 50-ft outbound deepening to 40.5 years if the entire deepening project is completed. If the latter occurs, the expansion cells will be filled during mid-FY 2033, as shown in Tables 8 and B5. This expansion alternative provides the greatest storage capacity and the longest useful life of any of the proposed alternatives.

Expansion Alternative 3

64. Expansion alternative 3 was considered to have only one cell; therefore, disposal operations could not be rotated through multiple cells. This fact, coupled with the smaller size of the expansion, will result in expansion alternative 3 filling much more quickly than the previously analyzed options. This expansion cell will be filled in mid-FY 2004 (after only 11.5 years of use) if only the existing 50-ft outbound deepening is completed. This portion of the deepening will be completed during FY 1987-88, and the remainder of the storage capacity will be consumed by maintenance material dredged between 1989 and 2004. If the existing project plus the Southern Branch deepening only (dredging scenario 4) is completed, this cell will fill by the end of FY 1999, giving a useful life of 7.5 years. If additional deepening is attempted, expansion alternative 3 will fill during deepening of the outbound channel to 55 ft; this will occur during FY 1996, only 3.5 years after the expansion cell begins receiving dredged material. Obviously, the remainder of the material from the deepening project could not be placed at the Craney Island expansion site.

Expansion Alternative 4

65. Expansion alternative 4 is slightly smaller than alternative 3 and will fill slightly sooner. Use of this expansion alternative for the existing project will result in filling of the site during mid-FY 2002 (providing 9.5 years of disposal capacity), while dredging of the existing project and the Southern Branch deepening will cause the site to fill during mid-FY 1997 (providing 4.5 years of capacity). Any of the other deepening scenarios (which include deepening of the outbound channel to 55 ft) will result in

filling of the site during mid-FY 1995, only 2.5 years after initiation of use of the site and before the deepening project is completed.

Expansion Alternative 5

66. Expansion alternative 5 was considered for subdivision into two cells, and disposal was rotated annually between the two cells. The useful life of this alternative ranges from 12.5 to 29 years. This alternative can contain all of the material from the entire deepening project. If all the project is dredged, the site will be filled during mid-FY 2005, providing a useful life of 12.5 years. If only the existing project and subsequent maintenance material are dredged, expansion alternative 5 will be able to receive material through FY 2021.

Expansion Alternative 6

67. Expansion alternative 6 is a somewhat larger version of alternative 4 and was considered to be operated as one cell. The disposal life of this alternative varied from 4.5 to 14.5 years, depending upon the dredging scenario considered. If only the existing project and maintenance material are dredged, the site will be filled in mid-FY 2007, providing 14.5 years of useful life. However, if additional portions of the deepening project are dredged, the useful life will be reduced proportionally to a minimum of 4.5 years (see Tables 12 and B5).

Service Life of Expansion Projects With Craney Island

68. The expansion cell may be completed before the existing facility is filled with dredged material, in which case disposal operations will be rotated through all cells of both the existing and new facilities. For this analysis, it was assumed that the expansion facility will be completed and ready for use in FY 1993. Dredged material will be placed into the new facility until the dredged material surface reaches el +4 mlw, at which time interior dike construction will begin if the site is large enough to warrant subdivision, and subsequent disposal operations will be rotated sequentially through all cells. As expected, when the existing facility can be used in conjunction with the expansion facility, the useful life of both facilities is increased since more time is allowed and more drying can occur between disposal operations in a particular cell.

Expansion Alternative 1

69. When expansion alternative 1 was analyzed with the existing facility, the useful life of the entire facility was predicted to extend through FY 2038 for dredging scenario 1 and through mid-2023 for dredging scenario 6, the two extremes of useful life. This represents an increase in disposal life for the Craney Island facility of approximately 6 to 10 years for the various dredging scenarios. The specific increase associated with a particular dredging scenario can be determined from Table 7; this table also lists the year in which the existing facility will be filled when used in conjunction with the expansion.

Expansion Alternative 2

70. Expansion alternative 2 was predicted to have the longest useful life of the alternatives considered. This expansion will last well into the 21st century. If all of the deepening is completed, the expanded Craney Island facility will be filled in FY 2037, 45 years after completion of the expansion facility. If only the 50-ft outbound deepening is completed, the life of the facility will be extended until approximately the end of FY 2054 with a useful life of 62 years from completion of the expansion.

Expansion Alternative 3

71. Use of the existing Craney Island with expansion alternative 3 will increase the disposal life of the entire facility by 2.5 to 7.5 years. If only the existing project (dredging scenario I) is completed, the expansion will be available for use through FY 2011, 7.5 years longer than the expansion will last if used alone. For the portions of the deepening project which include both the 55-ft outbound and the Southern Branch (dredging scenarios 5 and 6), alternative 3 will fill in FY 1988, 6 years after completion of the expansion and before the entire deepening project is completed.

Expansion Alternative 4

72. Being the smallest of the proposed expansions, alternative 4 will fill most rapidly, even when used in conjunction with the existing facility. This cell is projected to fill within 4.5 to 15.5 years after completion of the expansion. If only the existing project is dredged, the site will fill in mid-FY 2008, while it will reach capacity in mid-FY 1997 if attempts are made to dredge the entire deepening project. There is a 2- to 8.5-year increase in expansion site life when this site is used in conjunction with the existing facility.

Expansion Alternative 5

73. Expansion alternative 5 has a useful life that ranges from 23 to 36 years. This alternative will contain the entire quantity of new work material from the channel deepening, as well as all maintenance material dredged during the deepening and for some years afterwards. If the entire project is dredged, the site will be filled by the end of FY 2015 (within 23 years of completion). If only the existing project and subsequent maintenance material are dredged, this expansion alternative will provide storage capacity through FY 2028.

Expansion Alternative 6

74. If used together with the existing site, expansion alternative 6 will contain all material from the deepening project as well as the maintenance material that must be dredged during the same time period. In this case, the site will be filled by the end of FY 2001. Other dredging scenarios in which the quantity of material to be dredged is less will have a proportionately longer useful life. The maximum life for this alternative is 20 years and occurs if only the existing project and maintenance work are dredged.

PART VII: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

75. Expansion of the existing Craney Island will be necessary in the very near future since the existing facility will fill in the mid-1990s. If a new facility is available for use before the existing site is filled, the quantity of material that can be placed in the various cells will be increased as a result of additional time available for dredged material drying between disposal operations.

76. The larger expansion alternatives can provide significantly longer useful life than can some of the smaller alternatives, such as alternatives 3 and 4. Expansion alternative 2 will provide disposal capacity for the longest time of any of the expansions considered in this study. Therefore, from a site capacity perspective, alternative 2 would be the expansion alternative of choice.

77. If the entire deepening project is to be completed, and all of the material dredged after completion of the expansion (in about 1993) is to be contained within the expansion cell(s), then only expansion alternatives 1, 2, and 5 can be considered for construction since they have adequate capacity to contain the necessary quantity of dredged material. Expansion alternatives 3, 4, and 6 will fill before the deepening project is completed.

78. In selecting an expansion alternative, consideration must be given not only to the disposal site capacity but also to the geotechnical, hydraulic, social, and political factors.

Recommendations

79. An expansion alternative should be selected and constructed as soon as possible. It is recommended that the expansion be completed before the existing site is filled. This will provide a disposal site in the immediate future as the existing site reaches ultimate capacity from containment of materials dredged during the Norfolk Harbor deepening project and annual channel maintenance.

80. Both the existing and new confined disposal facilities should be operated to maximize their useful life. Procedures recommended in the Craney

Island Management Plan (Palermo, Shields, and Hayes 1981) should be followed in all cells. This should include timely initiation of surface trenching following cessation of disposal operations in a particular cell.

81. Representative samples of the materials to be dredged should be taken from each portion of the deepening project, and the material properties should be determined. If these properties are significantly different from those used in this study, the projected useful life of the selected expansion alternative should be reevaluated. Representative samples should be also be taken annually of maintenance material to be dredged since the characteristics of these materials may change as the deepening project alters the sources, quantities, and deposition locations of sediments.

82. If projected quantities of material or schedules for dredging are altered significantly, reevaluation of the predicted useful life should be undertaken.

83. Monitoring within the Craney Island facility and its expansion should be accomplished no less frequently than annually. During the deepening project, it is recommended that monitoring be accomplished quarterly. The monitoring should include aerial surveys and settlement plate and piezometer data collection. Field data should be compared with the predictions in this study. If good agreement is not obtained, the reason for the discrepancy should be determined and corrected.

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Table 1

Quantities of Sediment To Be Dredged

FY	500B	550B	SB45	SB40	501B	551B
			New Work Dredging Quantities (1,000 cu yd)			
1987	2,168					
1988	4,642					
1993		4,893				
1994		5,131				
1995		4,523				
1996			3,739			
1997			3,739	2,235		
1998					1,228	
1999						3,974
			Maintenance Dredging Quantities (1,000 cu yd)			
1988	4,000					
1989	4,000					
1990	4,000					
1991	4,000					
1992	4,000					
1993	4,000					
1994	4,000					
1995		4,200				
1996		4,200				
1997			4,295			
1998				4,313		
1999					4,313	
2000						4,474

Table 2

Summary of Spatial Dimensions of the Alternative Configurations

Expansion Alternative No.	Unit	Average Bottom Elevation ft, mlw	Average Depth ft	Total Surface Area acres	Available Surface Area acres	Storage Capacity*	Average Lift Thickness ft*
1	1	-15.02	19.02	1,698.40	1,250.03	38.36	1.65
	1A	4.00	26.00	958.00	894.20	37.51	2.30
	1B	4.00	26.00	740.40	702.25	29.46	2.93
	Total					105.33	
2	2	-11.62	15.62	2,485.60	1,972.36	43.47	1.04
	2A	4.00	26.00	885.90	828.01	34.73	2.48
	2B	4.00	26.00	872.60	819.36	34.37	2.51
	2C	4.00	26.00	740.40	702.47	29.47	2.93
	Total					142.04	
3	3	-12.60	16.60	740.40	484.86	12.99	4.24
	3	4.00	26.00	740.40	694.66	29.14	2.96
	Total					42.13	
4	4	-6.80	10.80	662.60	463.71	8.08	4.44
	4	4.00	26.00	662.60	613.83	25.75	3.36
	Total					33.83	
5	5	-7.29	11.29	1,456.40	1,206.11	21.97	1.71
	5A	4.00	26.00	720.20	664.44	27.87	3.10
	5B	4.00	26.00	736.20	693.36	29.08	2.96
	Total					78.92	
6	6	-5.00	9.00	998.40	743.00	10.79	2.77
	6	4.00	26.00	998.40	937.91	39.34	2.20
	Total					50.13	

Note: The initial line of values for each alternative applies from the bottom elevation for that alternative to el +4 mlw; subsequent lines apply from el +4 mlw to el +30 mlw and are presented for each cell of the expansion alternative.

* Expressed in millions of cubic yards.

** Lift thickness refers to 6-month disposal volumes of 2.125 million cu yd at an initial void ratio of 10.5; actual lift thickness will vary for the particular dredging scenario of interest.

Table 3

Consolidation Characteristics of the Foundation and Dredged Material

Foundation			Dredged Material		
Void Ratio	Effective Stress psf	Permeability ft/day	Void Ratio	Effective Stress psf	Permeability ft/day
3.00	0.00	1.21E-03	10.50	0.00	9.36E-01
2.90	8.80	1.03E-03	10.40	0.08	8.21E-01
2.80	19.60	8.85E-04	10.20	0.15	6.62E-01
2.70	32.00	7.61E-04	10.00	0.22	5.26E-01
2.60	48.00	6.39E-04	9.80	0.30	4.18E-01
2.50	70.00	5.22E-04	9.60	0.40	3.31E-01
2.40	104.00	4.23E-04	9.40	0.50	2.59E-01
2.30	154.00	3.45E-04	9.20	0.62	2.09E-01
2.20	232.00	2.73E-04	9.00	0.76	1.66E-01
2.10	344.00	2.16E-04	8.80	0.92	1.30E-01
2.00	510.00	1.71E-04	8.60	1.10	1.05E-01
1.90	780.00	1.32E-04	8.40	1.30	8.35E-02
1.80	1160.00	1.03E-04	8.20	1.54	6.48E-02
1.70	1700.00	7.70E-05	8.00	1.80	5.18E-02
1.60	2540.00	5.80E-05	7.80	2.10	4.10E-02
1.50	3750.00	4.30E-05	7.60	2.44	3.24E-02
1.40	5540.00	3.10E-05	7.40	2.80	2.59E-02
1.30	8500.00	2.70E-05	7.20	3.20	2.02E-02
1.25	10400.00	1.90E-05	7.00	3.70	1.61E-02
			6.80	4.60	1.28E-02
			6.60	5.80	1.01E-02
			6.40	7.80	7.99E-03
			6.20	10.60	6.31E-03
			6.00	14.60	5.03E-03
			5.80	20.00	3.96E-03
			5.60	28.00	3.15E-03
			5.40	39.00	2.46E-03
			5.20	55.00	1.94E-03
			5.00	75.60	1.56E-03
			4.80	105.00	1.23E-03
			4.60	139.00	9.72E-04
			4.40	183.00	7.63E-04
			4.20	240.00	6.05E-04
			4.00	316.00	4.75E-04
			3.80	618.00	2.46E-04
			3.00	1240.00	1.11E-04
			2.50	2420.00	3.80E-05
			2.00	4740.00	1.00E-05

Table 4

Desiccation Input Parameters

Parameter	Active Dewatering
Surface drainage efficiency, percent	100
Maximum evaporation efficiency, percent	100
Saturation at end of desiccation, percent	80
Maximum crust thickness, ft	0.75
Time to desiccation after filling, days	180
Month when desiccation begins	June, December
Elevation of fixed water table, ft msl	+1.5
Void ratio at saturation limit	6.5
Void ratio at end of desiccation	3.2

Table 5

Norfolk, VA, Climatic Data, Average Monthly Values

Month	Pan Evaporation ft	Precipitation ft
January	0.00	0.28
February	0.00	0.28
March	0.00	0.29
April	0.39	0.23
May	0.57	0.28
June	0.57	0.30
July	0.67	0.48
August	0.51	0.49
September	0.34	0.35
October	0.26	0.26
November	0.00	0.25
December	0.00	0.26
Total	3.31	3.75

Table 6

WES Useful Life Study - Existing Facility

Dredging Scenario No.	Dredging Scenario Description	Year in Which Site Fills Existing Craney Island Without Project
S1	Existing project 50 ft OB	1997*
S2	55 ft OB	1994*
S3	Entire 55 ft	1994*
S4	50 ft OB+SB	1994*
S5	55 ft OB+SB	1994*
S6	Entire 55 ft+SB	1994*

Note: OB = outbound; SB = Southern Branch.

* Predicted to fill before end of listed year.

Table 7

WES Useful Life Study - Expansion Alternative 1 (See Figure 3)

Dredging Scenarios		Year in Which Site Fills		
		Craney Island (C.I.) Expansion		Existing Craney Island
No.	Description	Without C.I.	With C.I.	With Project
S1	Existing project 50 ft outbound	2031	2038	2015*
S2	55 ft outbound	2021	2033*	2012
S3	Entire 55 ft	2018	2028*	2011
S4	50 ft OB+SB	2026*	2032	2011*
S5	55 ft OB+SB	2017*	2025	2006*
S6	Entire 55 ft+SB	2015*	2023*	2006*

* Predicted to fill before end of listed fiscal year.

Table 8

WES Useful Life Study - Expansion Alternative 2 (See Figure 3)

Dredging Scenarios		Year in Which Site Fills		
		Craney Island (C.I.) Expansion		Existing Craney Island
No.	Description	Without C.I.	With C.I.	With Project
S1	Existing project 50 ft outbound	2040* (2048)	2040* (2054)	2021**
S2	55 ft outbound	2040* (2041)	2040* (2050)	2019
S3	Entire 55 ft	2039**	2040* (2045)	2017
S4	50 ft OB+SB	2040* (2043)	2040* (2048)	2017
S5	55 ft OB+SB	2035	2040* (2042)	2015**
S6	Entire 55 ft+SB	2033**	2037	2007**

* The year 2040 was the last year considered in the computer simulation. Therefore, the useful life is somewhat greater; the projected year in which the cell will fill is shown in parentheses.

** Predicted to fill before end of listed fiscal year.

Table 9

WES Useful Life Study - Expansion Alternative 3 (See Figure 3)

Dredging Scenarios		Year in Which Site Fills		
		Craney Island (C.I.) Expansion		Existing Craney Island
No.	Description	Without C.I.	With C.I.	With Project
S1	Existing project 50 ft outbound	2004*	2011	2004*
S2	55 ft outbound	1996	2005	2001
S3	Entire 55 ft	1996	2002*	1999*
S4	50 ft OB+SB	2000*	2006	2002
S5	55 ft OB+SB	1996*	1998	1997*
S6	Entire 55 ft+SB	1996*	1998	1997*

* Predicted to fill before end of listed year.

Table 10

WES Useful Life Study - Expansion Alternative 4 (See Figure 3)

Dredging Scenarios		Year in Which Site Fills		
		Craney Island (C.I.) Expansion		Existing Craney Island
No.	Description	Without C.I.	With C.I.	With Project
S1	Existing project 50 ft outbound	2002*	2008*	2003*
S2	55 ft outbound	1995*	2003	2000
S3	Entire 55 ft	1995*	1999*	1998*
S4	50 ft OB+SB	1997*	2003	1998*
S5	55 ft OB+SB	1995*	1997*	1996*
S6	Entire 55 ft+SB	1995*	1997*	1996*

* Predicted to fill before end of listed year.

Table 11

WES Useful Life Study - Expansion Alternative 5 (See Figure 3)

Dredging Scenarios		Year in Which Site Fills		
		Craney Island (C.I.) Expansion		Existing Craney Island
No.	Description	Without C.I.	With C.I.	With Project
S1	Existing project 50 ft outbound	2021	2028	2010
S2	55 ft outbound	2015	2023*	2009
S3	Entire 55 ft	2011	2019*	2003
S4	50 ft OB+SB	2017	2024*	2006
S5	55 ft OB+SB	2009	2019	2000
S6	Entire 55 ft+SB	2005	2015	2000

* Predicted to fill before end of listed fiscal year.

Table 12

WES Useful Life Study - Expansion Alternative 6 (See Figure 3)

Dredging Scenarios		Year in Which Site Fills		
		Craney Island (C.I.) Expansion		Existing Craney Island
No.	Description	Without C.I.	With C.I.	With Project
S1	Existing project 50 ft outbound	2007*	2012	2004
S2	55 ft outbound	2000*	2009*	2000
S3	Entire 55 ft	1997*	2005	1998*
S4	50 ft OB+SB	2002*	2009*	2002
S5	55 ft OB+SB	1997*	2004	1996*
S6	Entire 55 ft+SB	1997*	2001	1996*

* Predicted to fill before end of listed fiscal year.

APPENDIX A: HISTORICAL DREDGING AND DISPOSAL RECORDS

CRANEY ISLAND DISPOSAL HISTORY

LOCATION & TYPE	DATES BEGIN	DATES END	USAED	OTHER FED	COMMERICAL	YEARLY TOTAL	TOTAL DEPOSITS
PERMIT	Oct-56 -	Dec-56			982,566		
RE BASIN,NW	Jan-57 -	Aug-57	2,414,467				
RE BASIN,maint	Feb-57 -	May-57	302,243				
			2,716,710	0	982,566	3,699,276	3,699,276
NH,maint,HD	Oct-57 -	Nov-57	1,468,894				
NH,nw widen	Jul-58 -	Dec-58	4,708,210				
RE BASIN,maint	Jul-58 -	Sep-58	371,090				
			6,548,194	0	0	6,548,194	10,247,470
NH,SB,maint&nw	Jan-59 -	Apr-59	5,159,218				
NOB APPROACH	Jun-59 -	Aug-59		1,964,503			
RE BASIN,maint	Aug-59 -	Sep-59	940,351				
			6,099,569	1,964,503	0	8,064,072	18,311,542
NH,maint&nw	27-Oct-59 -	01-Jan-60	2,099,627				
CI ANCH,nw	25-Nov-59 -	22-May-60	4,643,020				
N&W PIERS A&B	10-Dec-59 -	27-Dec-59			127,630		
NAVY,DEGAUS	11-May-60 -	20-May-60		41,368			
			6,742,647	41,368	127,630	6,911,645	25,223,187
NH,SB,maint,HD	04-Oct-60 -	10-Nov-60	674,431				
RE BASIN,maint	20-May-61 -	20-Aug-61	1,042,693				
N&W PIERS,nw	02-May-61 -	30-Sep-61			687,634		
D&S PIERS,maint	01-Aug-61 -	17-Nov-61		817,673			
			1,717,124	817,673	687,634	3,222,431	28,445,618
N&W PIERS,nw	01-Oct-61 -	02-Mar-62			825,161		
S of N&W	24-Mar-62 -	02-Apr-62			119,740		
NH,maint, HD	03-Apr-62 -	25-Apr-62	1,258,530				
ESCI,barge reha	31-Aug-62 -	05-Sep-62			55,939		
CNN,maint,HD	05-Sep-62 -	11-Sep-62	766,893				
N&W PIERS,maint	14-Sep-62 -	10-Oct-62			156,645		
			2,025,423	0	1,157,485	3,182,908	31,628,526
NH,maint,HD	22-Sep-62 -	21-Oct-62	1,910,338				
NNSY	15-Oct-62 -	21-Oct-62		26,376			
RE BASIN,maint	05-Jan-63 -	01-Apr-63	795,559				
N&W PIERS	11-Feb-63 -	24-Feb-63			67,924		
NNSB	24-Feb-63 -	02-Mar-63			26,500		
NOB & D&S PIERS	02-Mar-63 -	13-Jun-63		521,419			
			2,705,897	547,795	94,424	3,348,116	34,976,642
NOB,maint	14-Jan-64	12-Mar-64		357,575			
NH,maint,HD	07-May-64	29-Jun-64	1,579,115				
RE BASIN,maint	02-Jun-64	30-Sep-64	603,878				
THIMBLE SHOALS,HD	23-Jun-64	02-Jul-64	63,920				
NOB,maint	27-Jul-64	12-Sep-64		371,275			
N&W,maint	10-Sep-64	02-Oct-64			148,853		
			2,246,913	728,850	148,853	3,124,616	38,101,258

RE BASIN,maint	01-Oct-64	05-Jan-65	603,878				
NH 40,maint,HD	03-Mar-65	02-Jun-65	2,618,550				
NNSY,maint,HD	14-May-65	22-May-65		107,900			
ESCI,BR	12-Jul-65	24-Jul-65			64,755		
NOB,maint	26-Jul-65	07-Oct-65		602,060			
HRSD,TP	03-Aug-65	31-Aug-65			1,096		
N&W,maint	11-Sep-65	12-Sep-65			4,770		
			3,222,428	709,960	70,621	4,003,009	42,104,267
N&W PIERS,maint	08-Oct-65	12-Oct-65			28,613		
NOB,D&S PIERS	10-Oct-65	07-Dec-65		466,515			
NH45maint,HD	03-Sep-65	01-Dec-65	2,333,940				
NH45,nw	23-Mar-66	30-Sep-66	2,931,330				
CI FUEL DEPOT	20-Aug-66	19-Nov-66		360,815			
			5,265,270	827,330	28,613	6,121,213	48,225,480
NH45,nw	01-Oct-66	16-Jan-67	1,465,600				
RE BASIN,maint	24-Sep-66	21-Apr-67	1,032,198				
NH45,nw	26-Oct-66	22-Dec-66	176,575				
NH40,maint,HD	29-Oct-66	19-Dec-66	1,197,650				
N&W,nw	20-Nov-66	11-Jan-67			281,960		
PMT,VPA,nw	17-Jan-67	17-Apr-67			1,004,959		
CNN45,nw	25-Mar-67	30-Sep-67	3,258,490				
NH45,nw	22-Apr-67	22-Aug-67	3,588,859				
C&O,NN,nw	27-Aug-67	22-Oct-67			420,710		
			10,719,372	0	1,707,629	12,427,001	60,652,481
CNN45,nw	01-Oct-67	11-Jan-68	1,629,245				
ATLAS CEMENT	15-Jan-68	20-Jan-68			46,590		
NP&IA	12-Jan-68	13-Feb-68			811,471		
NOB,maint	20-Feb-68	27-Apr-68		715,366			
NH45,maint,HD	26-Jan-68	08-Feb-68	236,247				
NH40,maint,HD	04-Feb-68	02-Mar-68	716,262				
NNSY,maint,HD	07-Feb-68	24-Feb-68		72,193			
NH45,maint	06-Apr-68	25-Jul-68	1,508,336				
CNN45,nw	08-Sep-68	01-Oct-68	230,630				
			4,320,720	787,559	858,061	5,966,340	66,618,821
NOB & D&S PIERS	14-Sep-68	28-Nov-68		538,103			
NH40&45,maint,HD	29-Jan-69	03-May-69	2,305,462				
CI FUEL DEPOT,nw	16-Feb-69	17-Apr-69		583,635			
CNN45,nw	13-May-69	30-Dec-69	1,898,300				
			4,203,762	1,121,738	0	5,325,500	71,944,321
D&S PIERS,maint	06-Nov-69	13-Feb-70		225,500			
NIT,VPA	06-Nov-69	18-Nov-69			115,925		
N&W,maint	23-Oct-69	05-Nov-69			180,967		
NNSY,maint,HD	02-Jan-70	03-Feb-70		71,200			
NH40&45,maint	02-Jan-70	10-May-70	1,978,980				
CNN,maint	10-May-70	16-May-70	188,610				
NP&IA	09-Jan-70	11-Feb-70			493,425		
RE BASIN,maint	07-Mar-70	11-May-70	800,407				
N&W,maint	30-Mar-70	19-May-70			112,476		
DEGAUS RANGE	24-May-70	25-Aug-70		327,401			
NOB,PIER 12	11-Jul-70	11-Aug-70		226,775			
N&W,maint	23-Sep-70	01-Oct-70			71,672		
NAVY POL,nw	01-Aug-70	22-Sep-70		525,138			
			2,967,997	1,376,014	974,465	5,318,476	77,262,797

SPA,nw	31-Aug-70	30-Sep-71	8,039,700				
CNN,maint,HD	29-Sep-70	29-Oct-70	370,690				
NIT,VPA,maint	03-Oct-70	12-Oct-70			131,988		
NH40,maint	29-Oct-70	27-Nov-70	890,285				
NH45,maint	11-Dec-70	16-May-71	1,852,999				
EXXON PIERS	13-Mar-71	19-Mar-71			50,104		
NOB,maint	05-Apr-71	22-Jun-71		485,175			
NNA40,nw	16-Jul-71	22-Nov-71	4,828,174				
USCG,CI CR,nw	16-Aug-71	20-Nov-71		671,202			
			15,981,848	1,156,377	182,092	17,320,317	94,583,114
SPA,nw	01-Oct-71	01-Feb-72	2,679,887				
PMT,VPA,maint	16-Oct-71	14-Nov-71			322,389		
N&W,maint	20-Nov-71	09-Dec-71			166,698		
NH40&45,maint	02-Nov-71	04-Jan-72	1,489,000				
USCG,CI CR,maint	09-Feb-72	01-Aug-72		288,507			
RE BASIN,maint	25-Jun-72	19-Sep-72	892,487				
NOB & D&S PIERS	08-Aug-72	05-Sep-72		239,032			
ATLAS CEMENT	06-Sep-72	11-Sep-72			23,050		
NH45,maint	12-Sep-72	29-Oct-72	606,717				
			5,668,091	527,539	512,137	6,707,767	101,290,881
NIT,VPA,nw	27-Jan-73	03-May-73			1,264,045		
NH40,maint,HD	07-Feb-73	28-Mar-73	862,800				
CNN,maint,HD	23-Feb-73	28-Mar-73	238,060				
NNSY,maint,HD	17-Feb-73	22-Mar-73		57,950			
HRBT,VDOT,nw	27-Apr-73	05-May-73			183,406		
N&W,maint	09-May-73	23-May-73			152,170		
NNSB,maint	23-May-73	26-May-73			15,907		
C&O PIERS,maint	08-Jul-73	23-Jul-73			70,552		
NNSB,nw	07-Aug-73	30-Sep-73			324,976		
			1,100,860	57,950	2,011,056	3,169,866	104,460,747
NNSB,nw	02-Oct-73	31-Dec-73			956,776		
NOB&D&S,maint	10-Oct-73	01-Apr-74		916,855			
NH40&SB35,m,HD	13-Dec-73	29-Jan-74	852,544				
NNSY,maint,HD	19-Dec-73	29-Dec-73		54,823			
NNSB,nw	01-Jan-74	26-May-74			659,742		
NNSB,nw	01-Jan-74	26-May-74			769,928		
PMT,VPA	09-Jun-74	22-Aug-74			674,820		
NOB,maint	25-Jun-74	18-Sep-74		207,855			
D&S PIERS,maint	19-Jul-74	09-Sep-74		199,710			
			852,544	1,379,243	3,061,266	5,293,053	109,753,800
NIT,VPA,maint	08-Dec-74	24-Dec-74			199,174		
NH45,maint	29-Jan-75	16-Mar-75	1,622,300				
DEGAUS RANGE	15-Feb-75	23-Feb-75		36,825			
CARGILL GRAIN,BR	15-Feb-75	14-Mar-75			103,324		
NNSB,maint,BR	01-Mar-75	04-Mar-75			14,625		
YELLOW RIVER(LIM)	18-Mar-75	22-Mar-75			11,728		
NNSB,maint	22-Apr-75	30-May-75			263,948		
SO. BLOCK,SB	30-May-75	01-Jun-75			7,156		
US GYPSUM,SB	01-Jun-75	02-Jun-75			4,316		
NOB,maint	28-Jun-75	16-Sep-75		530,995			
RE BASIN,maint	07-Aug-75	17-Nov-75	770,254				
			2,392,554	567,820	604,271	3,564,645	113,318,445

NNSY,maint,HD	06-Oct-75	27-Oct-75		79,695			
NH40,maint,HD	03-Oct-75	30-Oct-75	476,270				
CNN,maint,HD	03-Oct-75	30-Oct-75	120,863				
NNSB,nw	10-Oct-75	14-Dec-75			433,649		
C&O COAL PIER,BR	14-Dec-75	18-Dec-75			26,532		
NH45,maint	18-Nov-75	21-Jan-76	539,132				
NOB,12,maint	08-Feb-76	13-Mar-76		386,425			
N&W,maint	07-Mar-76	06-Apr-76			102,916		
NORSHIPCO	07-Apr-76	06-Jul-76			334,220		
NOB,25,nw&m	03-Jun-76	03-Jul-76		622,180			
VDOT,W NOR.BR	29-May-76	15-Jul-76			12,924		
NH45,maint	17-Jul-76	04-Oct-76	2,455,287				
N & W,maint	25-Aug-76	24-Sep-76			384,679		
NOB,BOAT BASIN	27-Jul-76	17-Sep-76		67,200			
			3,591,552	1,155,500	1,294,920	6,041,972	119,360,417
NNSB,maint	28-Nov-76	03-Jan-77			110,307		
NNSB,WAY5&6,m	23-Nov-76	30-Nov-76			37,205		
C&O COAL PIER	14-Feb-77	20-Feb-77			20,045		
VDOT,JRB	14-Feb-77	20-Feb-77			6,071		
NNSY,maint,BR	08-Feb-77	23-Feb-77		39,645			
NOB,20,maint	12-Feb-77	04-May-77		528,325			
NNSB,nw,BR	26-Apr-77	17-Jun-77			333,900		
SPA,maint	05-May-77	20-Jun-77	743,476				
VDOT,JRB	06-May-77	21-May-77			5,528		
WILLOUGHBY BAY	18-May-77	20-May-77	2,400				
DEGAUS RANGE	21-May-77	21-Jun-77		130,480			
DEEP CR,NN,m,BR	25-Jun-77	15-Jul-77	42,862				
			788,738	698,450	513,056	2,000,244	121,360,661
NORSHIPCO	01-Oct-77	25-Jan-78			222,230		
NNSB,W EXT,nw	17-Dec-77	31-Dec-77			53,646		
NOB,2&4,maint	30-Jan-78	21-Feb-78		211,245			
RE BASIN,maint	21-Feb-78	05-Jan-79	1,231,637				
NH40&S&35,m,HD	02-Mar-78	29-Mar-78	303,786				
NIT,VPA,nw	15-Mar-78	13-Aug-78			954,180		
CNN,maint,HD	16-Mar-78	01-Apr-78	129,160				
CNG,nw,BR	21-Mar-78	14-May-78			108,389		
NOB,12,maint	04-Apr-78	01-Jun-78		345,990			
NOB,12,nw	04-Apr-78	01-Jun-78		146,090			
FUEL LINE TRENCH	12-May-78	11-Jun-78		8,458			
C & O PIER14,BR	24-May-78	10-Jun-78			59,400		
NIT,VPA,maint	03-Jun-78	07-Jul-78			457,370		
NH45,maint	06-Jun-78	01-Nov-78	2,147,368				
ERT,maint,BR	12-Jun-78	15-Jun-78			2,250		
PMT,VPA,nw	15-Jun-78	17-Nov-78			601,176		
			3,811,951	711,783	2,458,641	6,982,375	128,343,036
EXXON PIER	15-Oct-78	24-Oct-78			76,091		
NOB,PIER24,nw	12-Dec-78	14-Feb-79		475,435			
NOB,D&S PIERS	06-Jan-79	20-Mar-79		337,630			
YORKTOWN NWS,HD	02-Jan-79	06-Mar-79		400,971			
NIT,VPA,maint	15-Jul-79	29-Jul-79			111,255		
			0	1,214,036	187,346	1,401,382	129,744,418

VDOT,JRB,nw	16-Oct-79	24-Oct-79			9,068		
DEEP CR,NN,maint	25-Oct-79	18-Jan-80	296,375				
SPA,maint	15-Aug-79	18-Nov-79	1,477,626				
NH45,maint	10-Nov-79	18-Jun-80	2,016,563				
NOB,PIERS,m	21-Nov-79	22-Feb-80		204,007			
NNA,maint	12-Apr-80	29-May-80	1,087,166				
NOB,3-7,22,25m	21-Apr-80	18-Jun-80		407,375			
CONT GRAIN,nw&m	17-Jun-80	06-Aug-80			159,350		
N&W,nw&m	07-Jul-80	02-Aug-80			230,354		
NOB,12,maint	12-Aug-80	03-Sep-80		251,738			
RE BASIN,maint	20-Feb-80	14-Oct-80	1,637,381				
NOB,7,maint	04-Sep-80	06-Sep-80		25,092			
NIT,VPA,maint	19-Feb-80	22-Feb-80			14,823		
			6,515,111	888,212	413,595	7,816,918	137,561,336
NOB,AFDL,maint	12-May-81	05-Jul-81		247,155			
NOB PIERS,maint	23-Jul-81	14-Nov-81		651,882			
CI FUEL DEPOT,m	14-Sep-81	14-Oct-81		35,997			
			0	935,034	0	935,034	138,496,370
NH45,maint	14-Sep-81	22-Jan-82	2,228,076				
N&W,maint	19-Nov-81	01-Dec-81			96,024		
RE BASIN,maint	09-Jan-82	30-Sep-82	1,414,988				
CNN maint	24-Apr-82	23-Jun-82	648,722				
DOMINION TER,nw	25-Jul-82	30-Sep-82			330,000		
NOB,maint	22-Jan-82	19-Mar-82		891,629			
			4,291,786	891,629	426,024	5,609,439	144,105,809
RE BASIN,maint	01-Oct-82	08-Jun-83	1,414,988				
DOMINION TER,nw	01-Oct-82	09-Jun-83			989,925		
NH45,maint	14-Nov-82	24-May-83	2,183,692				
NOB PIERS,maint	28-Sep-82	11-Apr-83		366,479			
NOB,ADFL,maint	03-May-83	24-May-83		114,005			
NIT,VPA,maint	12-Jun-83	05-Jul-83			392,148		
			3,598,680	480,484	1,382,073	5,461,237	149,567,046
NOB PIERS,maint	19-Oct-83	26-Nov-83 N*		363,098			
RE BASIN.maint	01-Apr-84	30-Sep-84 S	869,433				
NH45,maint	06-Apr-84	30-Sep-84 N	1,752,340				
NOB PIER 11,m	22-May-84	06-Jul-84 N		469,639			
SPA,maint	04-Feb-84	29-Sep-84 N	2,451,377				
			5,073,150	832,737	0	5,905,887	155,472,933
RE BASIN,maint	01-Oct-84	16-May-85 S	1,391,094				
NH45,maint	01-Oct-84	14-Dec-84 N	876,171				
NOB PIERS,maint	16-Sep-84	28-Nov-84 N		775,448			
N & W,maint	23-Oct-84	24-Nov-84 N			121,457		
NIT,maint&nw	03-Feb-85	02-Apr-85 C			600,095		
NNA,maint,HO	02-Feb-85	07-Mar-85 N	183,546				
NOB PIERS,maint	07-Mar-85	01-May-85 N		610,386			
EXXON PIER,maint	16-May-85	22-May-85 N			77,150		
LEHIGH CEMENT,m	22-May-85	24-May-85 N			45,400		
NNA,maint	31-Jul-85	11-Aug-85 N	251,987				
			2,702,798	1,385,834	844,102	4,932,734	160,405,667

* Large existing site was subdivided in 1983 into three compartments:
N = north cell, S = south cell, and C = center cell.

VDOT,I-664,nw	07-Jan-86	19-Mar-86 C			997,142		
WB ELIZ R,maint	02-Feb-86	22-Mar-86 C	150,431				
NIT,nw	22-May-86	22-Jun-86 C			1,618,841		
NOB PIERS,maint	01-Jun-86	29-Jun-86 C		185,365			
NH40,maint	15-Jul-86	14-Aug-86 C	192,055				
NH45,maint	15-Jul-86	30-Aug-86 C	529,325				
			871,811	185,365	2,615,983	3,673,159	164,078,826
NOB PIERS,nw	09-Jun-87	01-Aug-87S		978,250			
NOB PIERS,nw	20-Jul-87	08-Aug-87S		153,474			
RE BASIN,maint	08-May-87	23-Aug-87S,C	1,681,024				
			1,681,024	1,131,724	0	2,812,748	166,891,574
			120,424,524	23,122,507	23,344,543		166,891,574

APPENDIX B: SIMULATED FILLING HISTORIES FOR INDIVIDUAL DISPOSAL CELLS - TABULATED RESULTS

Table B1

Existing Craney Island Without Expansion Projects:

Fiscal Year in Which Existing Cells Will Fill

Dredging Scenario	Cell		
	South	Center	North
S1	1993	1997*	1991*
S2	1993*	1994*	1991*
S3	1993*	1994*	1991*
S4	1993*	1994*	1991*
S5	1993*	1994*	1991*
S6	1993*	1994*	1991*

* Predicted to fill before end of listed fiscal year.

Table B2

Existing Craney Island With Expansion Projects:

Fiscal Year in Which South Cell Will Fill

Dredging Scenario	Expansion Alternative					
	1	2	3	4	5	6
S1	2005	2008	1997	1996	2000	1997
S2	2003*	2007*	1995*	1994*	2000*	1994*
S3	2002*	2005*	1995*	1994*	1996*	1994*
S4	2005*	2009*	1998*	1994*	2000*	1998*
S5	1997*	2003*	1995*	1994*	1996*	1994*
S6	1997*	1998	1995*	1994*	1996*	1994*

* Predicted to fill before end of listed fiscal year.

Table B3

Existing Craney Island With Expansion Projects:

Fiscal Year in Which Center Cell Will Fill

Dredging Scenario	Expansion Alternative 1	2	3	4	5	6
S1	2015*	2021*	2004*	2003*	2010	2004*
S2	2012	2019	2001	2000	2009	2000
S3	2011	2017	1999*	1998	2003	1998*
S4	2011*	2017	2002	1998*	2006	2002*
S5	2006*	2015*	1997*	1996*	2000	1996*
S6	2006*	2007*	1997*	1996*	2000	1996*

* Predicted to fill before end of listed fiscal year.

Table B4

Existing Craney Island With Expansion Projects:

Fiscal Year in Which North Cell Will Fill

Dredging Scenario	Expansion Alternative 1	2	3	4	5	6
S1	1991*	1991*	1991*	1991*	1991*	1991*
S2	1991*	1991*	1991*	1991*	1991*	1991*
S3	1991*	1991*	1991*	1991*	1991*	1991*
S4	1991*	1991*	1991*	1991*	1991*	1991*
S5	1991*	1991*	1991*	1991*	1991*	1991*
S6	1991*	1991*	1991*	1991*	1991*	1991*

* Predicted to fill before end of listed fiscal year.

Table B5

Expansion Projects Without Craney Island:

Fiscal Year in Which Expansion Cells Will Fill

Dredging Scenario	Expansion Alternatives									
	1		2					5		
	A	B	A	B	C	3	4	A	B	6
S1	2031	2026*	2040** (2047)	2040** (2048)	2040** (2043)	2004*	2002*	2020*	2021	2007*
S2	2021	2017*	2040*	2040** (2041*)	2037*	1996	1995*	2012	2015	2000*
S3	2018	2015*	2038*	2039*	2037*	1996	1995*	2009	2011	1997
S4	2026*	2022*	2040** (2042*)	2040** (2043*)	2040*	2000*	1997*	2015*	2017	2002*
S5	2017*	2016*	2034*	2035*	2031*	1996*	1995*	2006	2009	1997*
S6	2013	2015*	2033*	2030	2028*	1996*	1995*	2005*	2005	1997*

* Predicted to fill before end of listed fiscal year.

** Fiscal Year 2040 was the last year for which disposal operations were simulated. Thus, the cell is predicted to fill sometime after the end of FY 2040; the projected year of filling is shown below in parentheses.

Table B6

Expansion Projects With Craney Island:

Fiscal Year in Which Expansion Cells Will Fill

Dredging Scenario	Expansion Alternatives									
	1		2					5		
	A	B	A	B	C	3	4	A	B	6
S1	2038	2033	2040** (2053)	2040** (2054)	2040** (2050)	2011	2008*	2025*	2028	2012
S2	2033*	2028	2040** (2050)	2040** (2047)	2040** (2043)	2005	2003	2020*	2023*	2009*
S3	2028*	2023	2040** (2044)	2040** (2045)	2040** (2043)	2002	1999*	2016	2019*	2005
S4	2032	2027	2040** (2047)	2040** (2048)	2040** (2045*)	2006	2003	2021	2024*	2009*
S5	2025	2020	2040** (2041)	2040** (2042)	2040** (2038)	1998	1997*	2016	2019	2004
S6	2023*	2016*	2036	2037	2035	1998	1997*	2014	2015	2001

* Predicted to fill before end of listed fiscal year.

** Fiscal Year 2040 was the last year for which disposal operations were simulated. Thus, the cell is predicted to fill sometime after the end of FY 2040; the projected year of filling is shown below in parentheses.

APPENDIX C: SIMULATED FILLING HISTORIES FOR INDIVIDUAL DISPOSAL CELLS - GRAPHICAL PRESENTATION

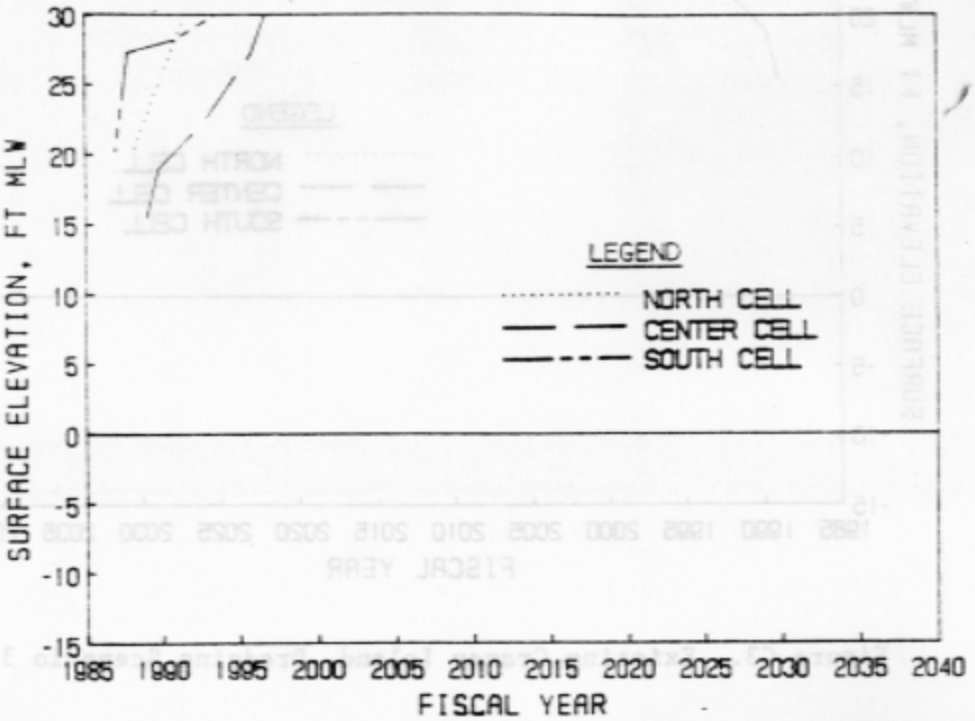

Figure C1. Existing Craney Island, Dredging Scenario 1

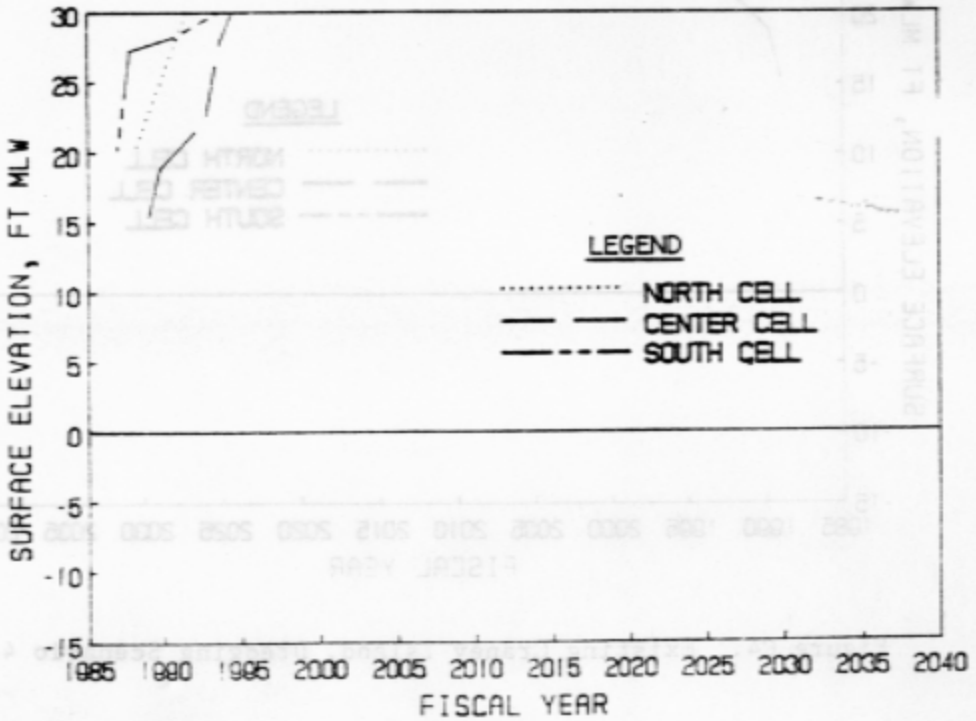

Figure C2. Existing Craney Island, Dredging Scenario 2

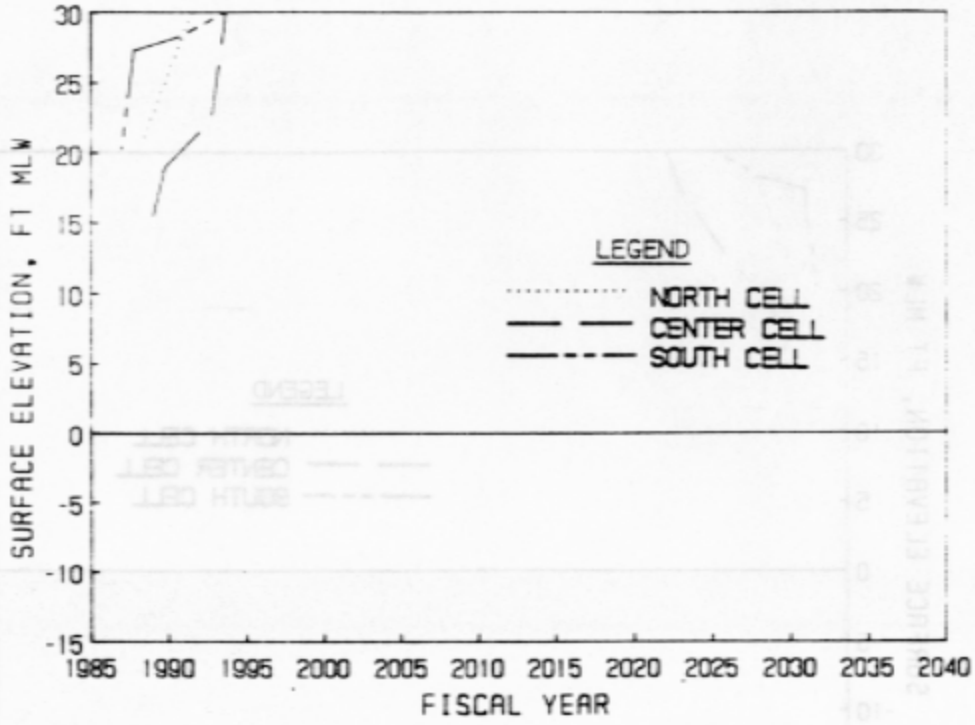

Figure C3. Existing Craney Island, Dredging Scenario 3

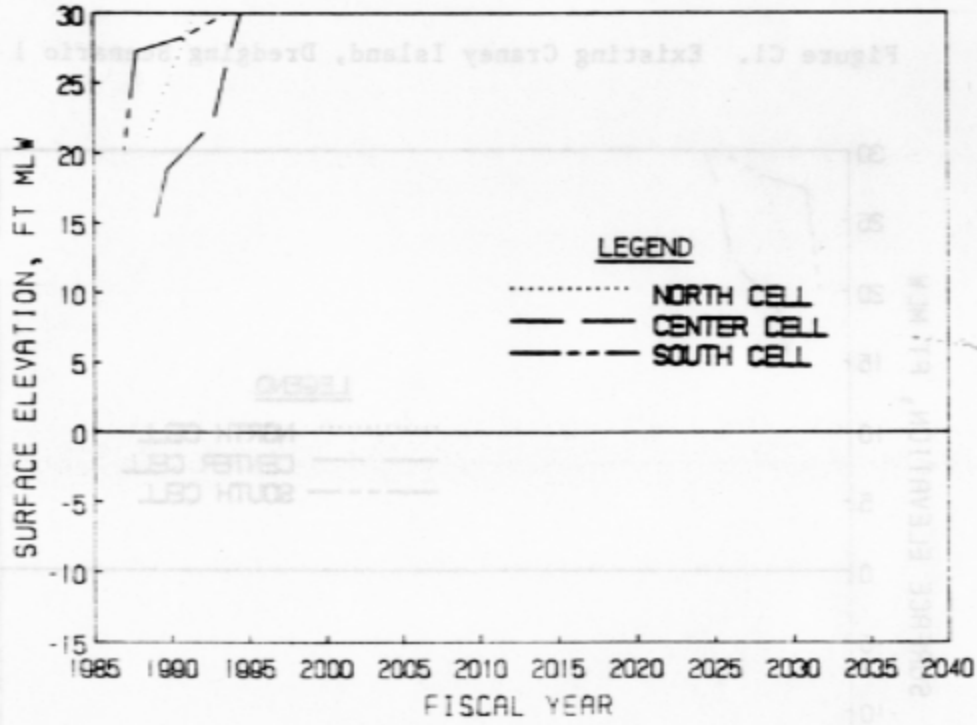

Figure C4. Existing Craney Island, Dredging Scenario 4

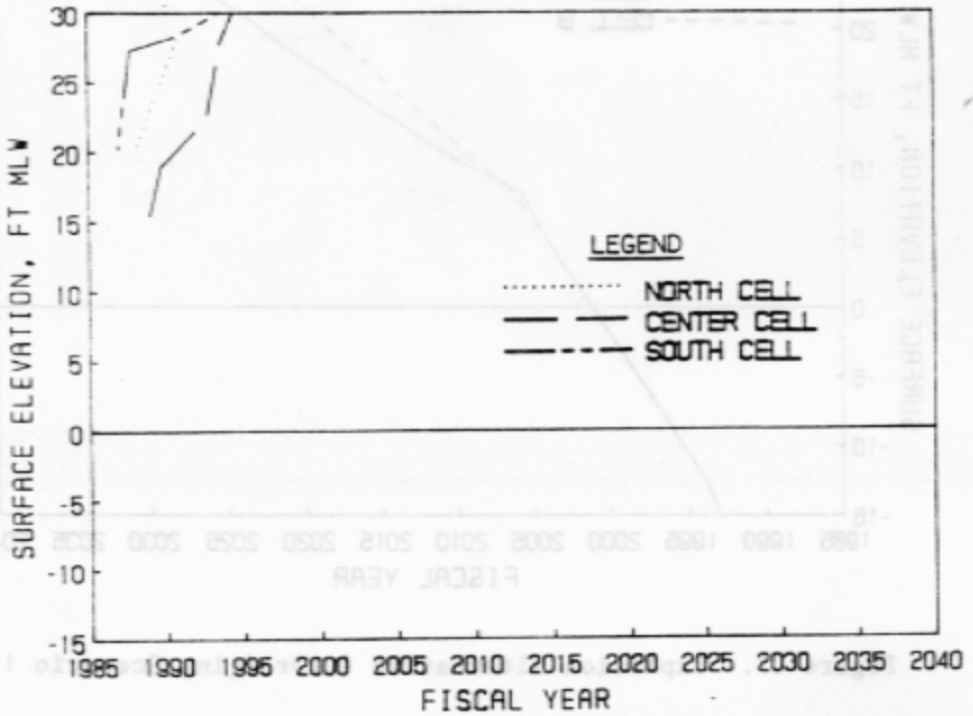

Figure C5. Existing Craney Island, Dredging Scenario 5

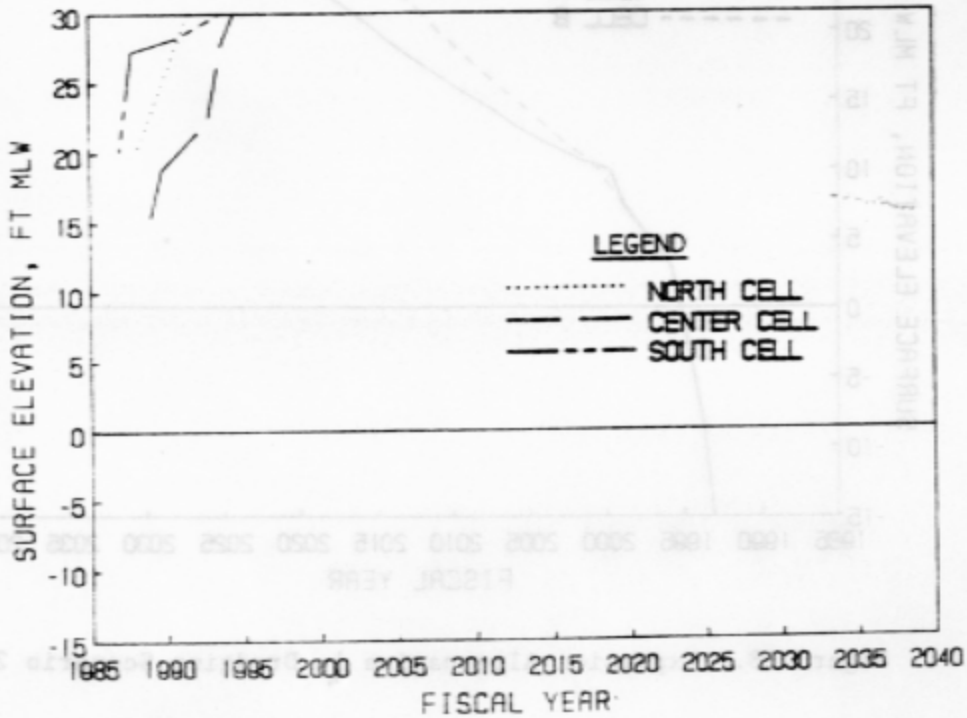

Figure C6. Existing Craney Island, Dredging Scenario 6

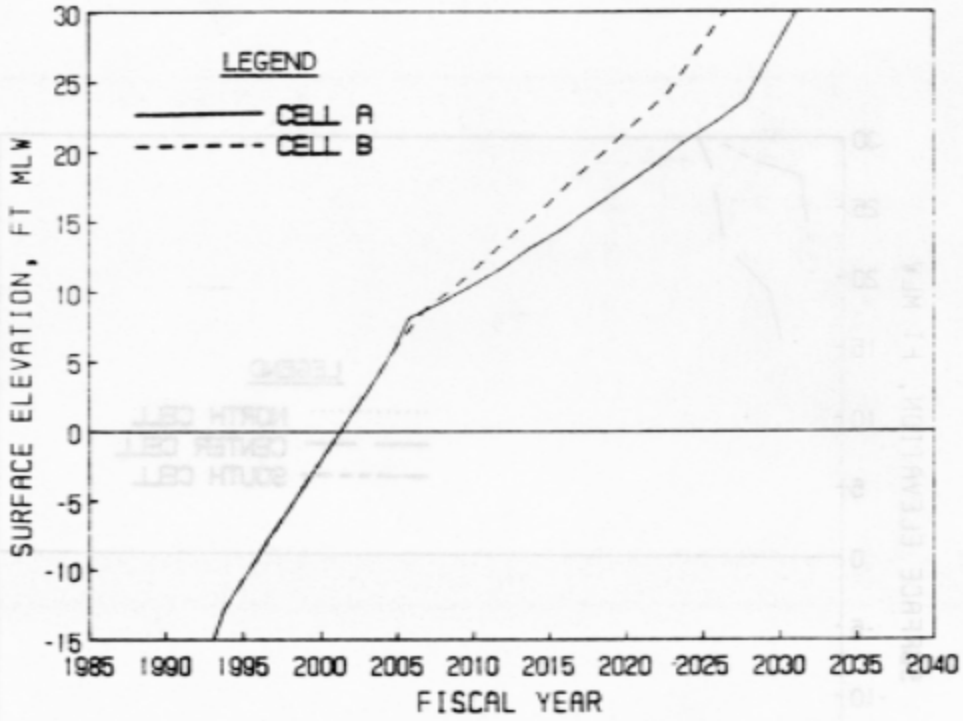

Figure C7. Expansion Alternative 1, Dredging Scenario 1

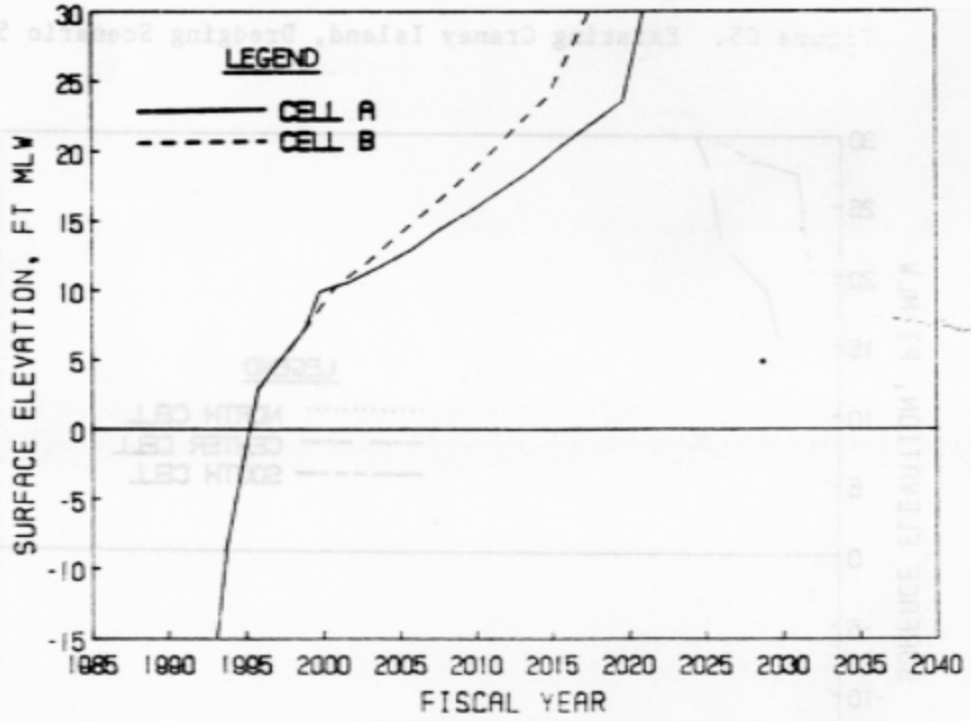

Figure C8. Expansion Alternative 1, Dredging Scenario 2

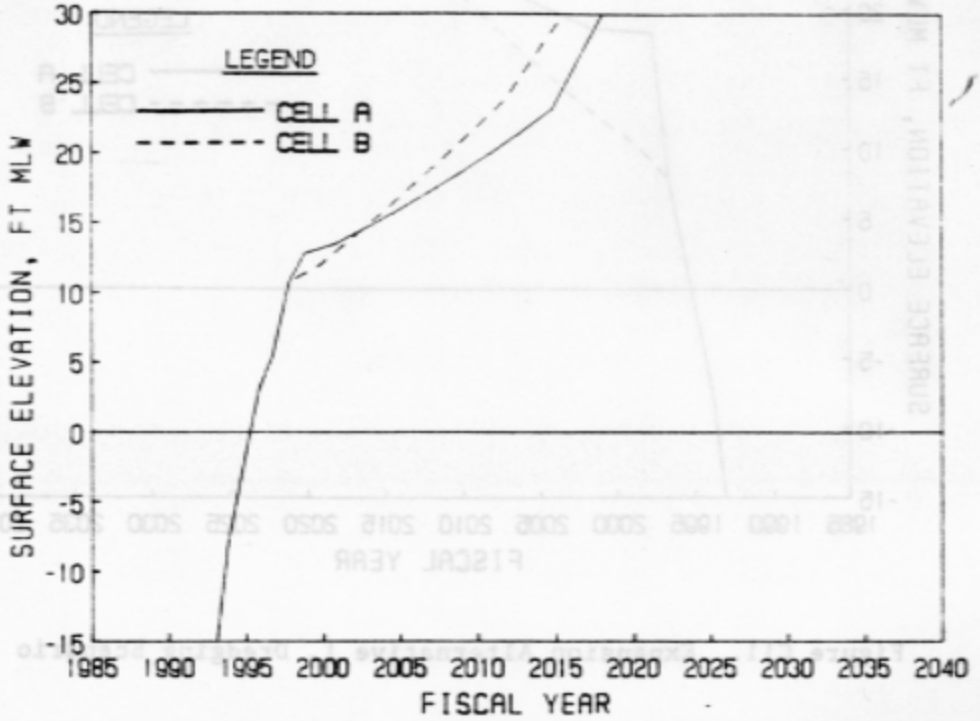

Figure C9. Expansion Alternative 1, Dredging Scenario 3

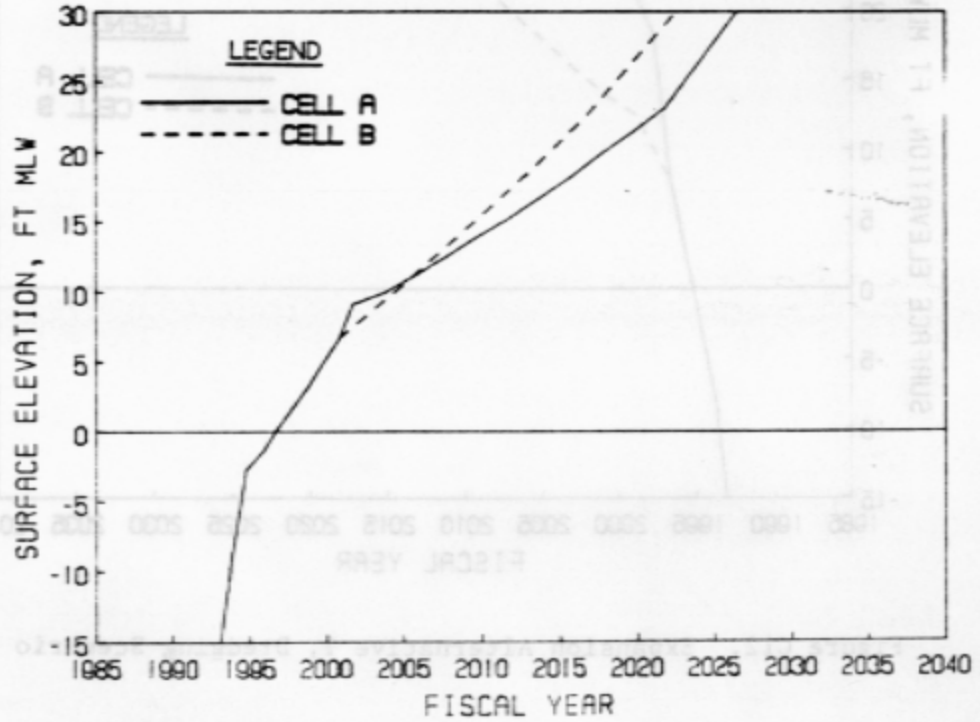

Figure C10. Expansion Alternative 1, Dredging Scenario 4

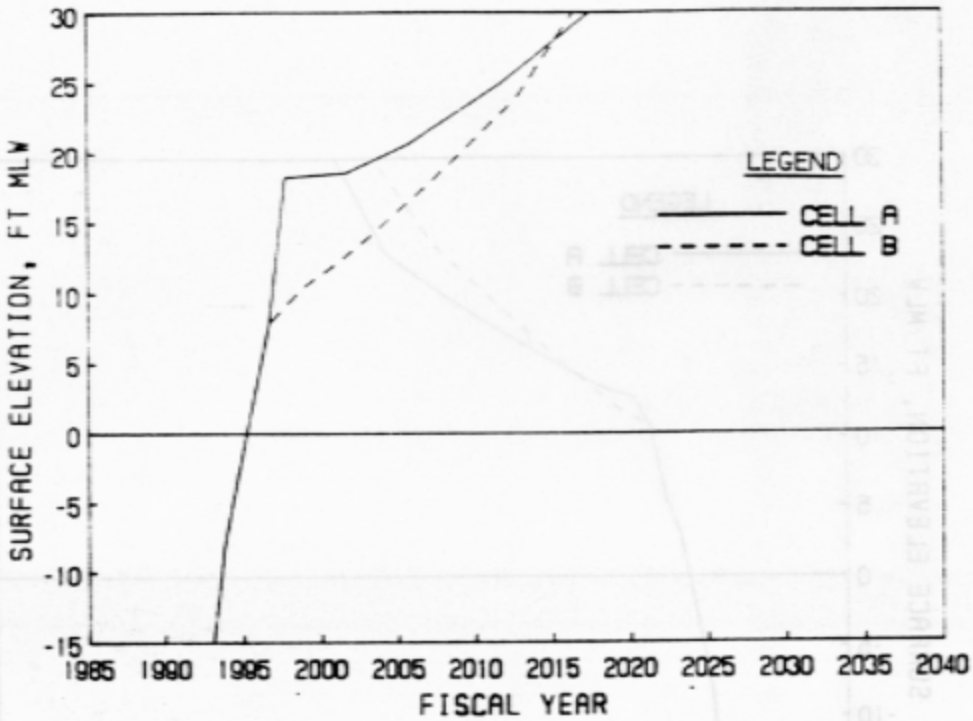

Figure C11. Expansion Alternative 1, Dredging Scenario 5

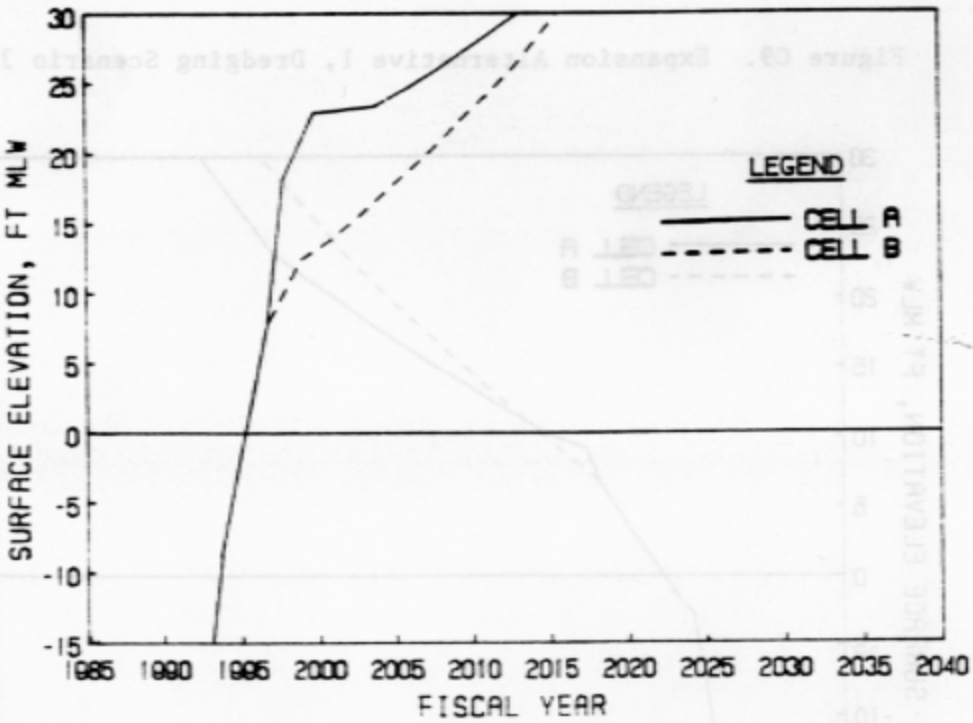

Figure C12. Expansion Alternative 1, Dredging Scenario 6

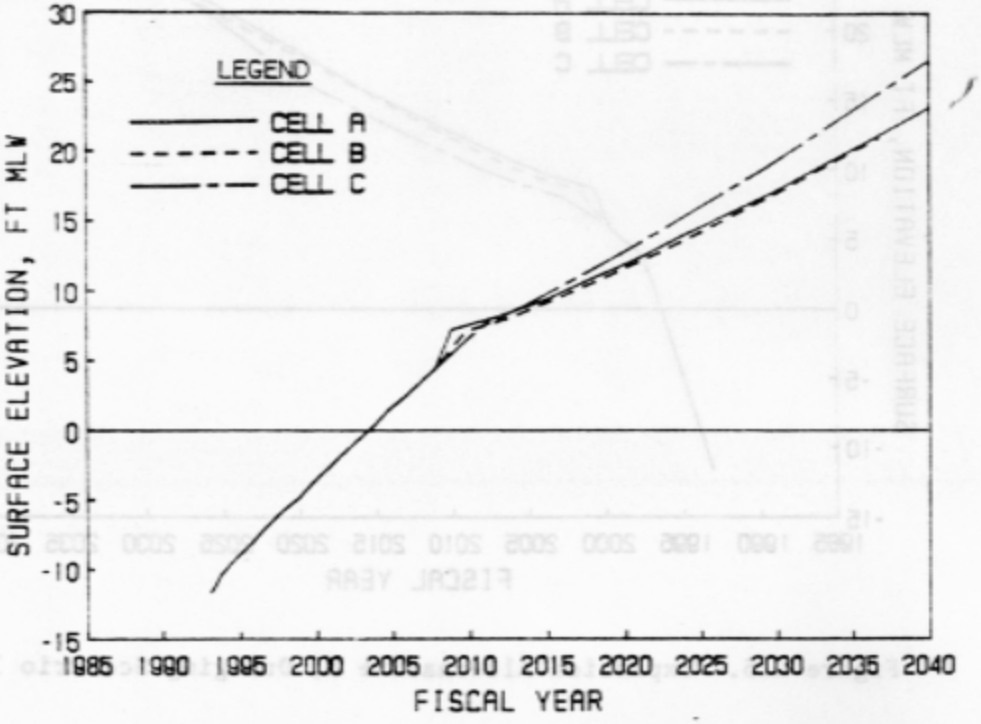

Figure C13. Expansion Alternative 2, Dredging Scenario 1

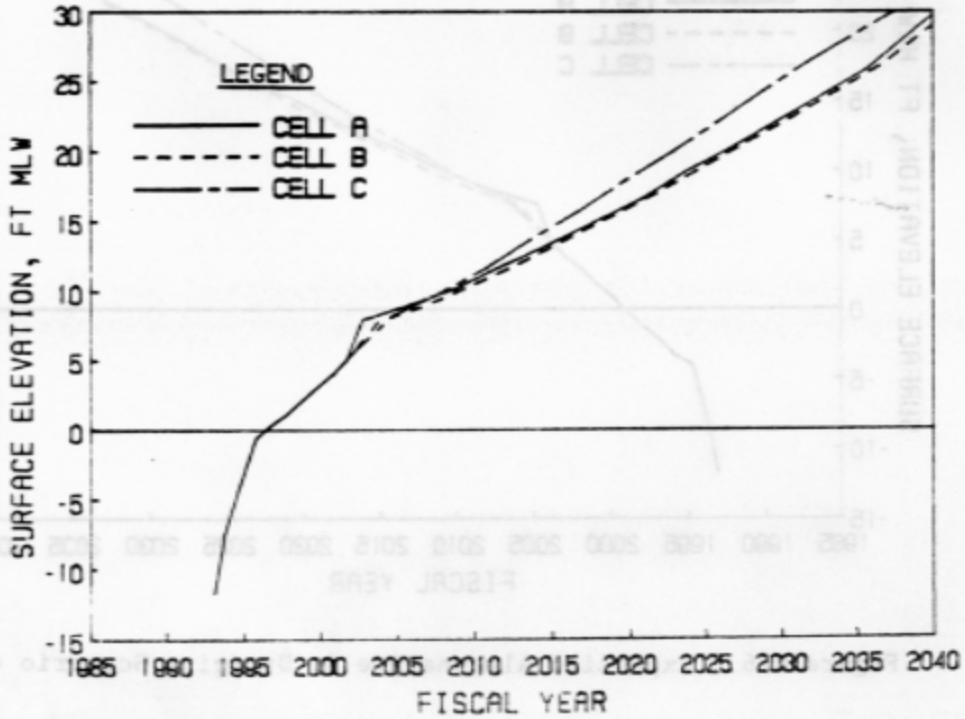

Figure C14. Expansion Alternative 2, Dredging Scenario 2

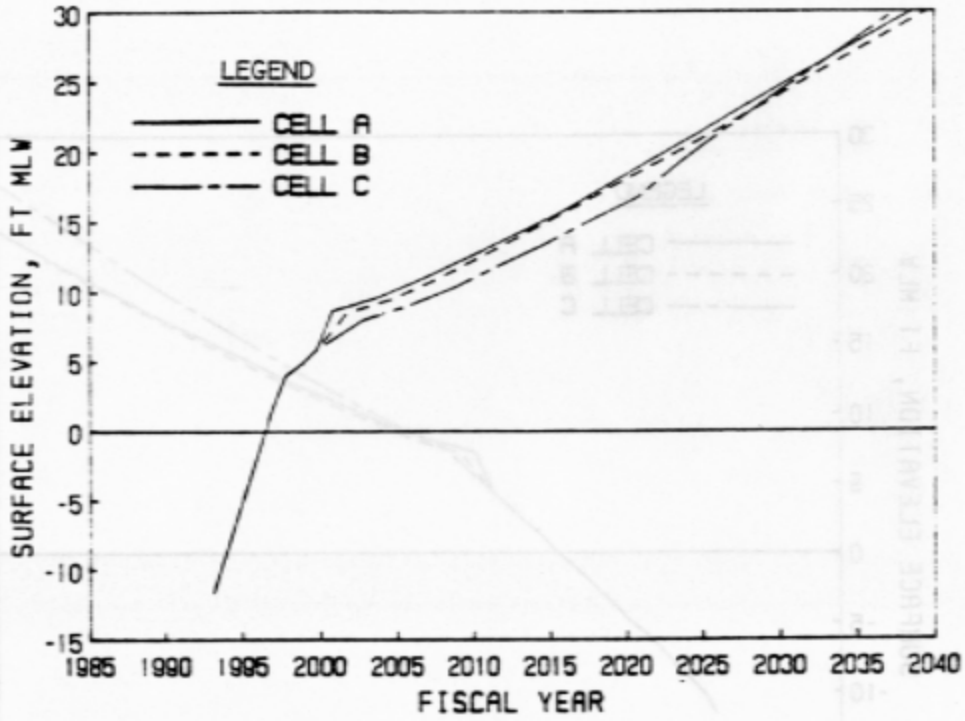

Figure C15. Expansion Alternative 2, Dredging Scenario 3

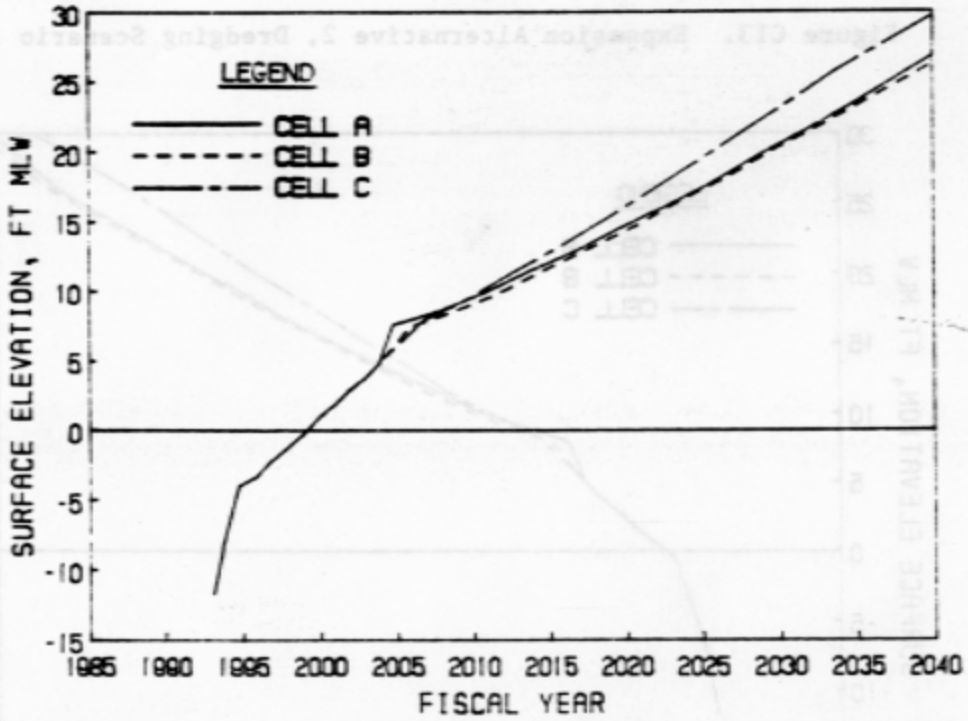

Figure C16. Expansion Alternative 2, Dredging Scenario 4

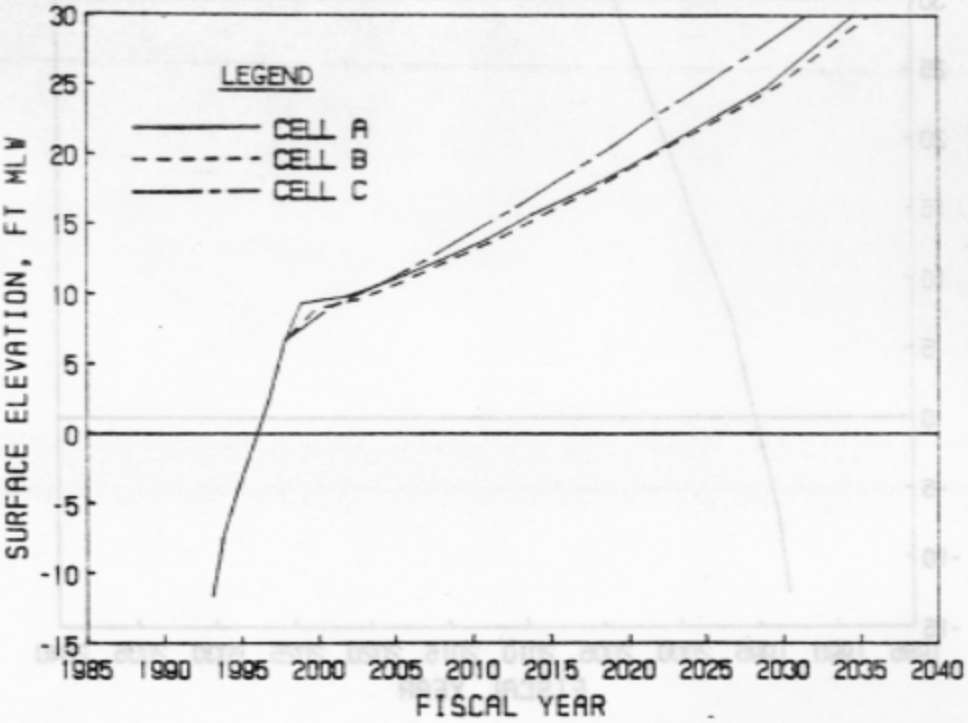

Figure C17. Expansion Alternative 2, Dredging Scenario 5

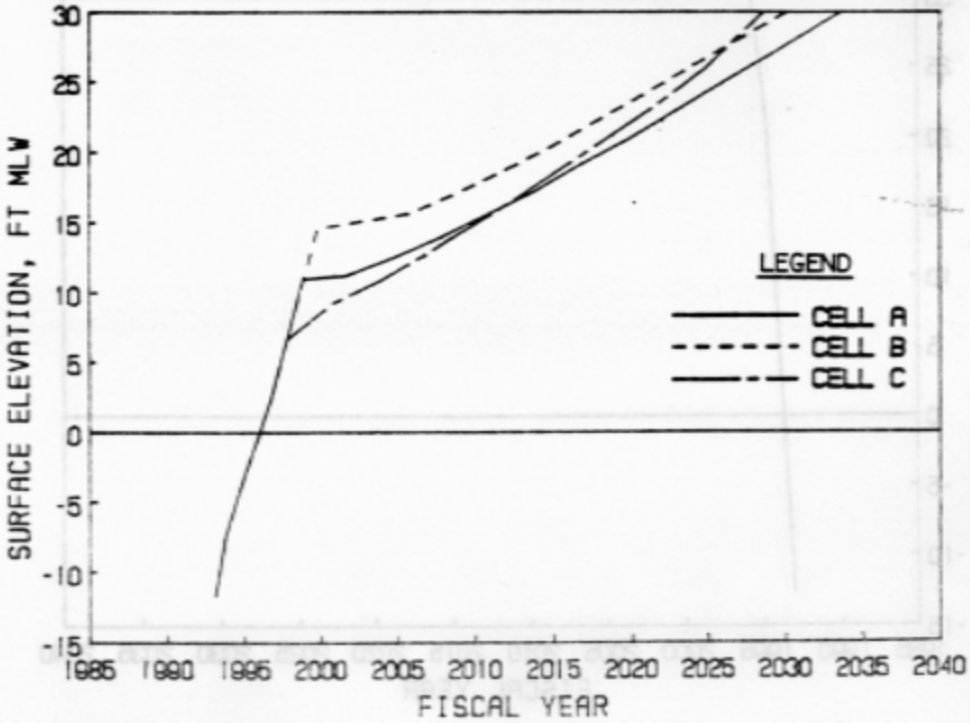

Figure C18. Expansion Alternative 2, Dredging Scenario 6

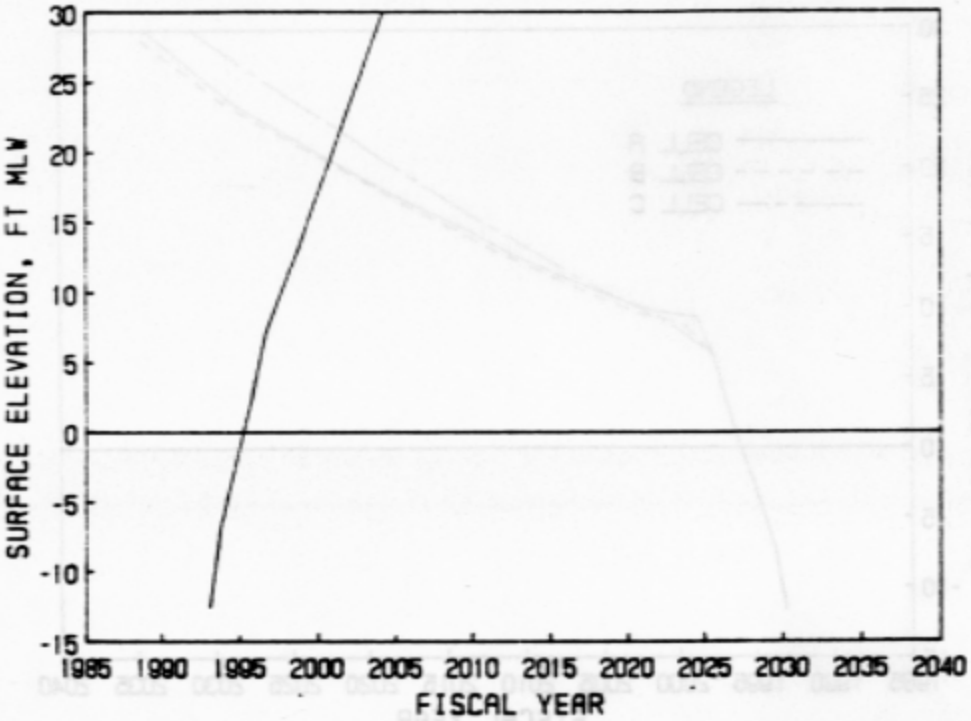

Figure C19. Expansion Alternative 3, Dredging Scenario 1

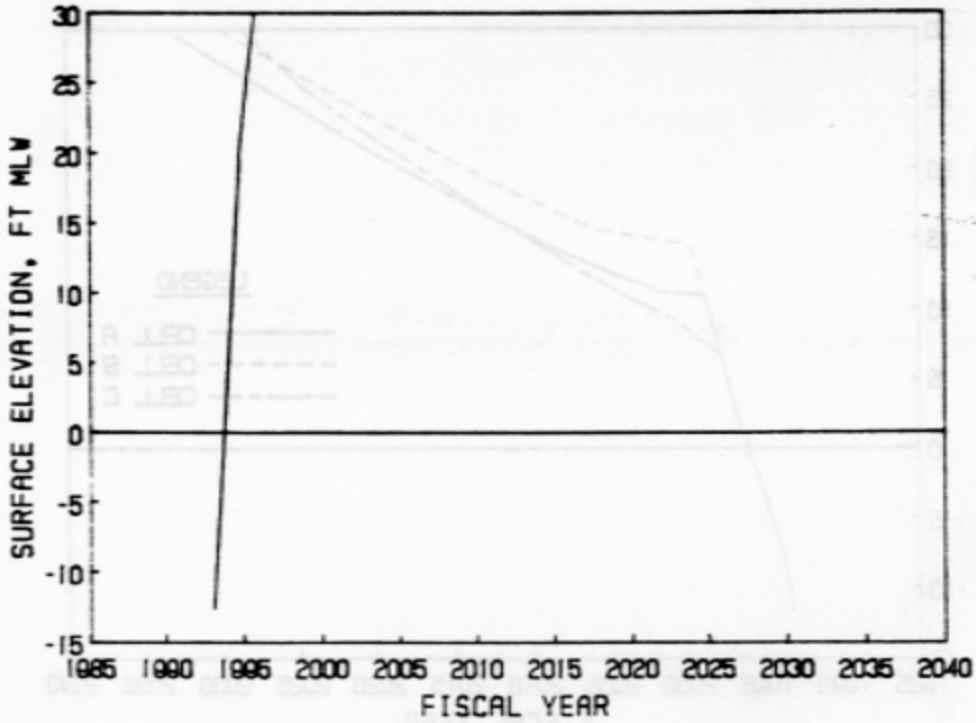

Figure C20. Expansion Alternative 3, Dredging Scenario 2

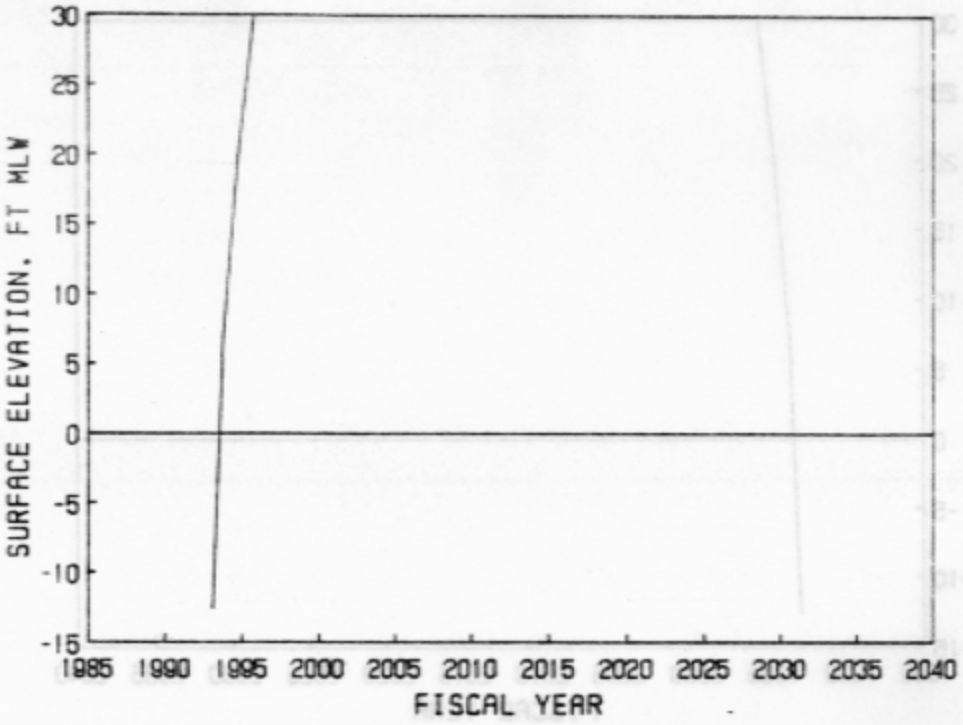

Figure C21. Expansion Alternative 3, Dredging Scenario 3

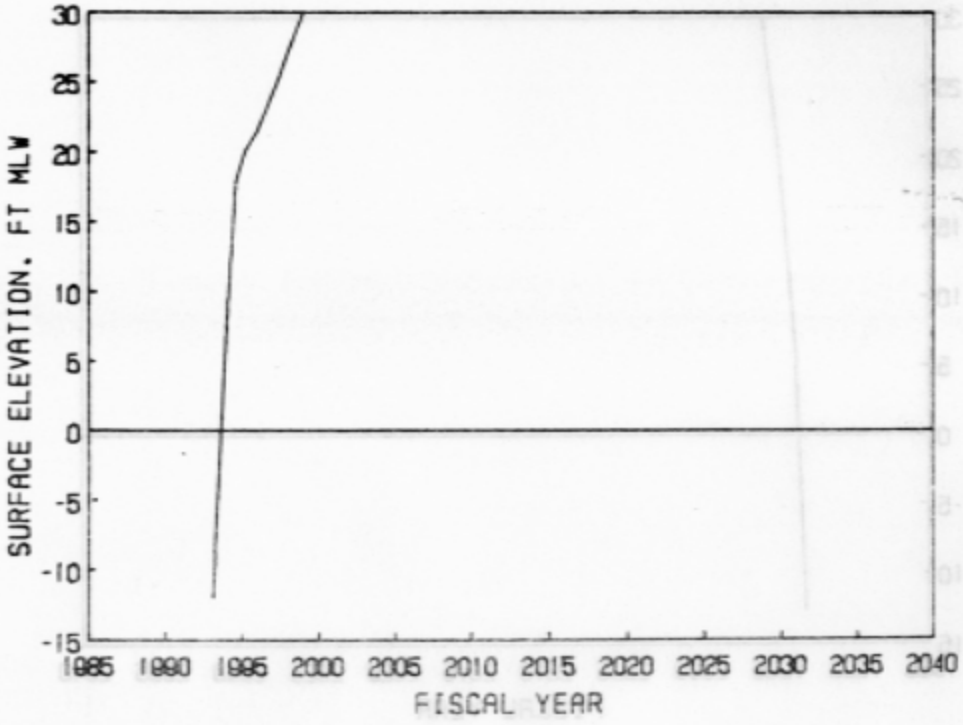

Figure C22. Expansion Alternative 3, Dredging Scenario 4

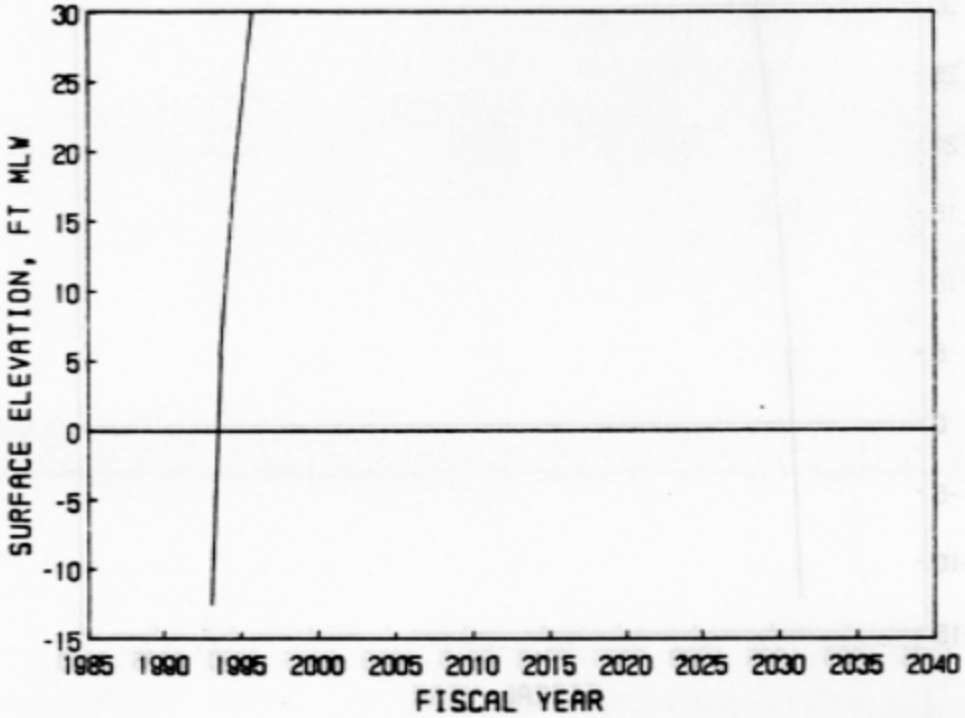

Figure C23. Expansion Alternative 3, Dredging Scenario 5

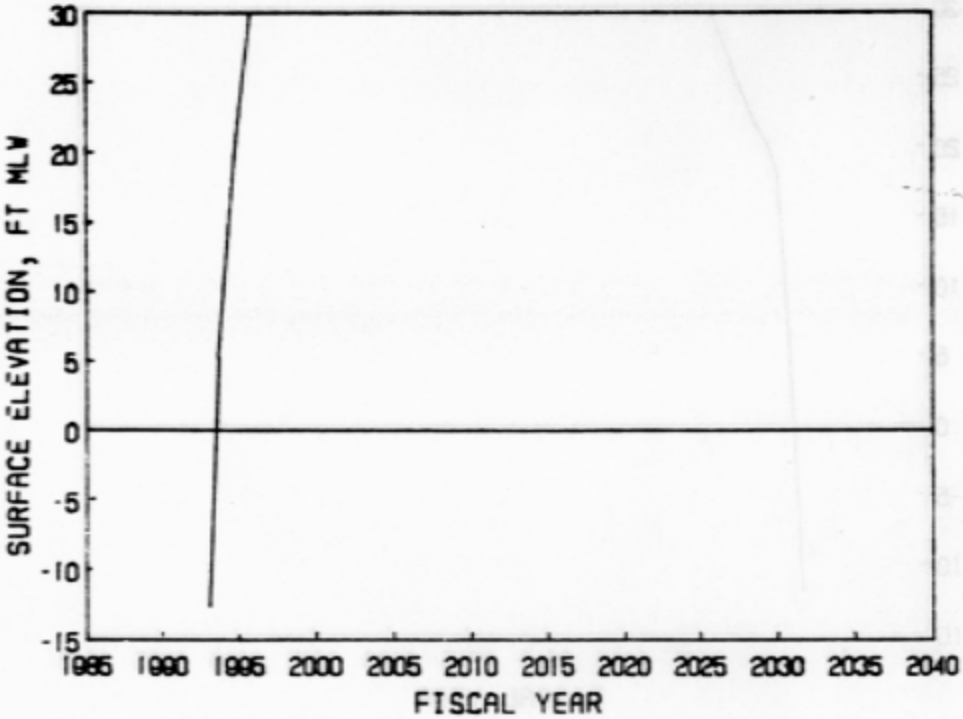

Figure C24. Expansion Alternative 3, Dredging Scenario 6

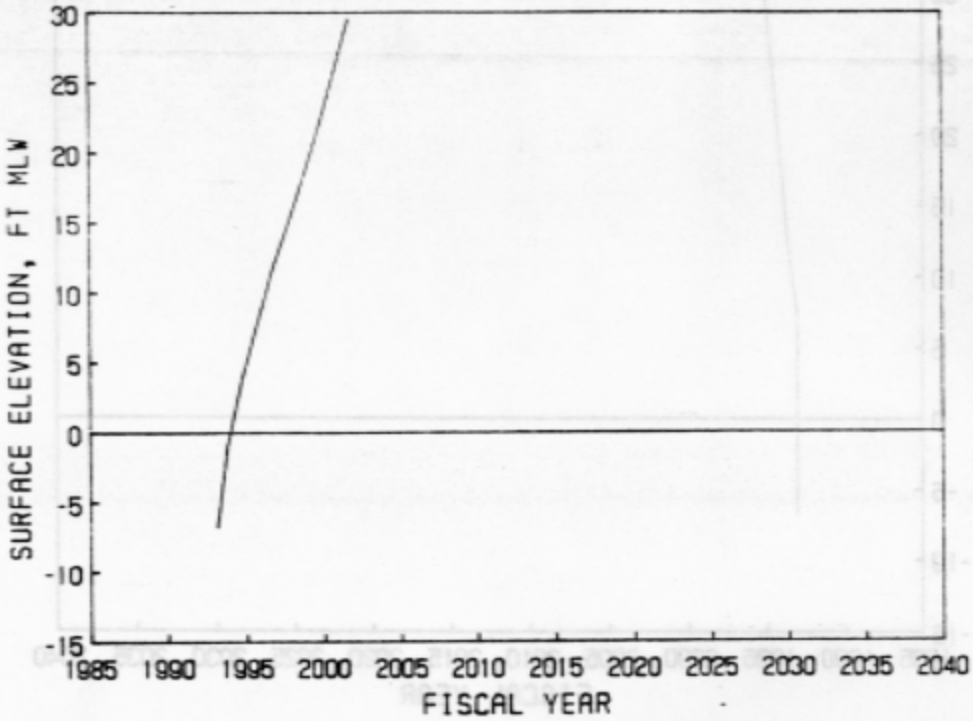

Figure C25. Expansion Alternative 4, Dredging Scenario 1

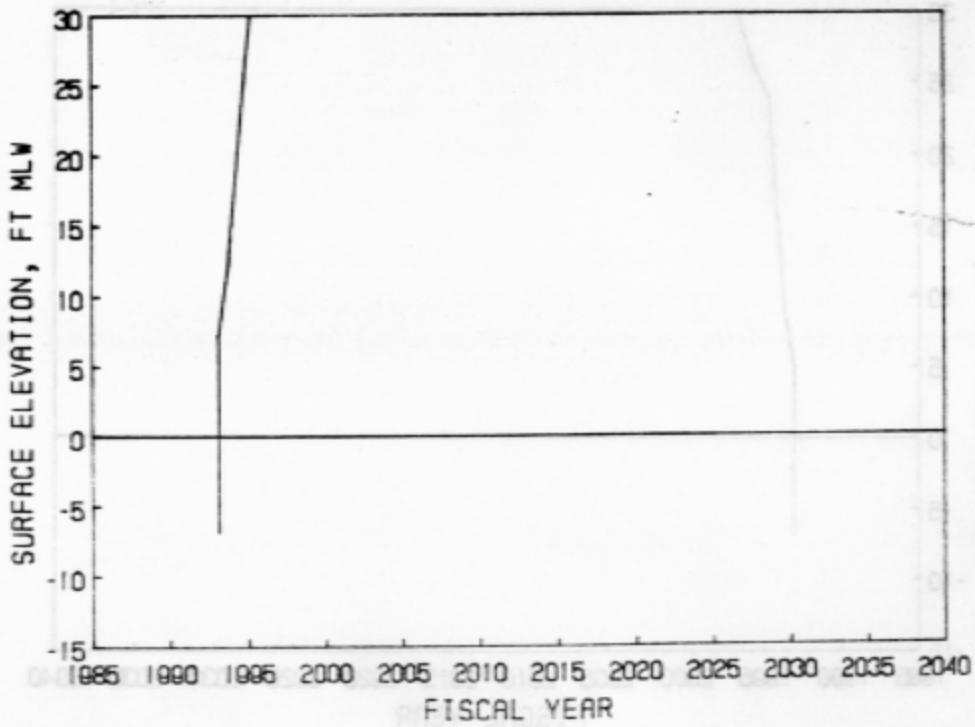

Figure C26. Expansion Alternative 4, Dredging Scenario 2

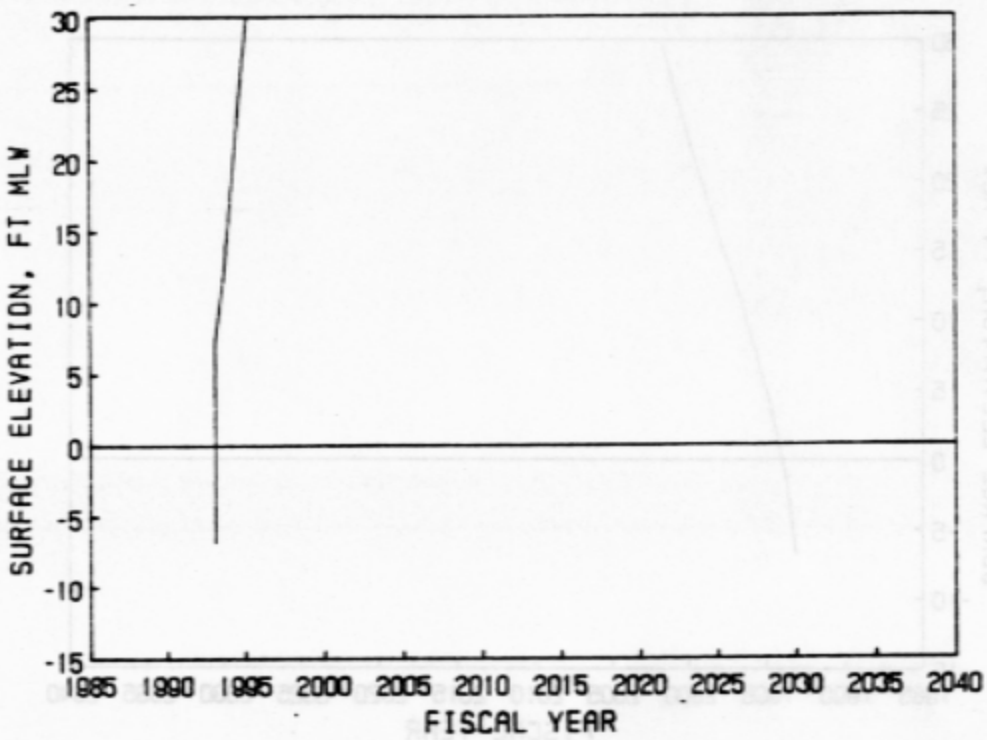

Figure C27. Expansion Alternative 4, Dredging Scenario 3

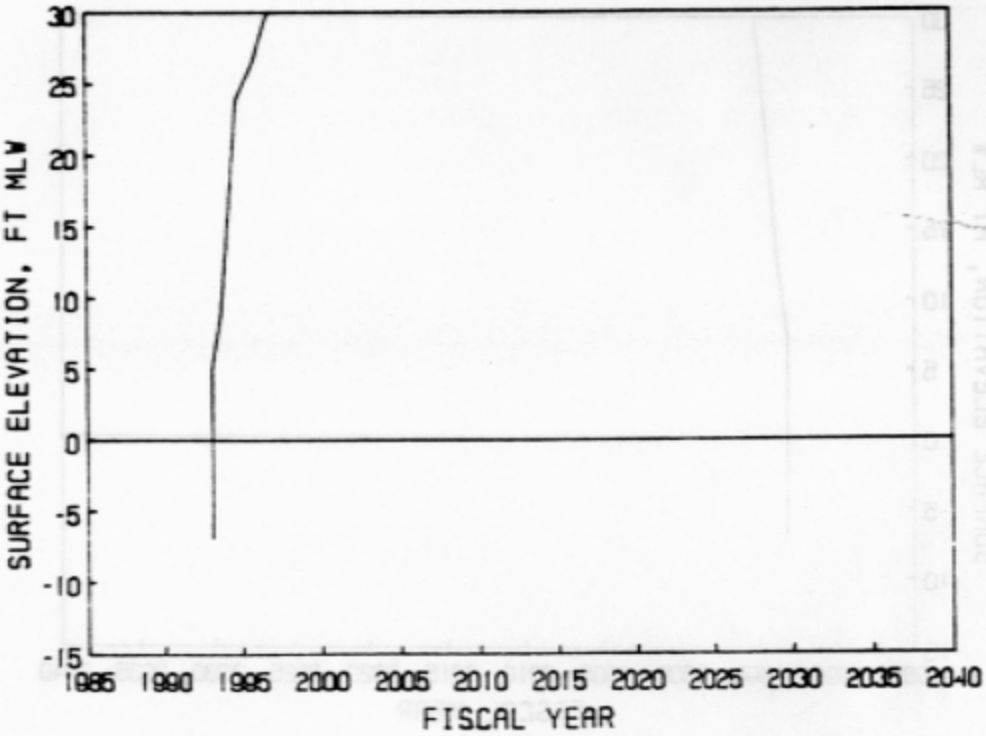

Figure C28. Expansion Alternative 4, Dredging Scenario 4

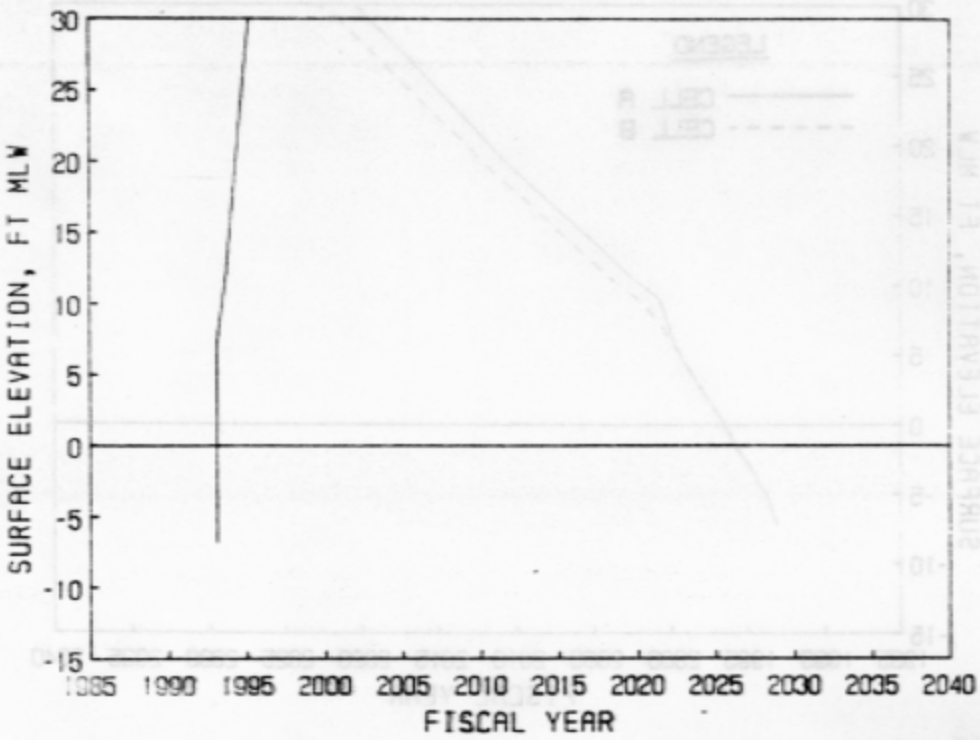

Figure C29. Expansion Alternative 4, Dredging Scenario 5

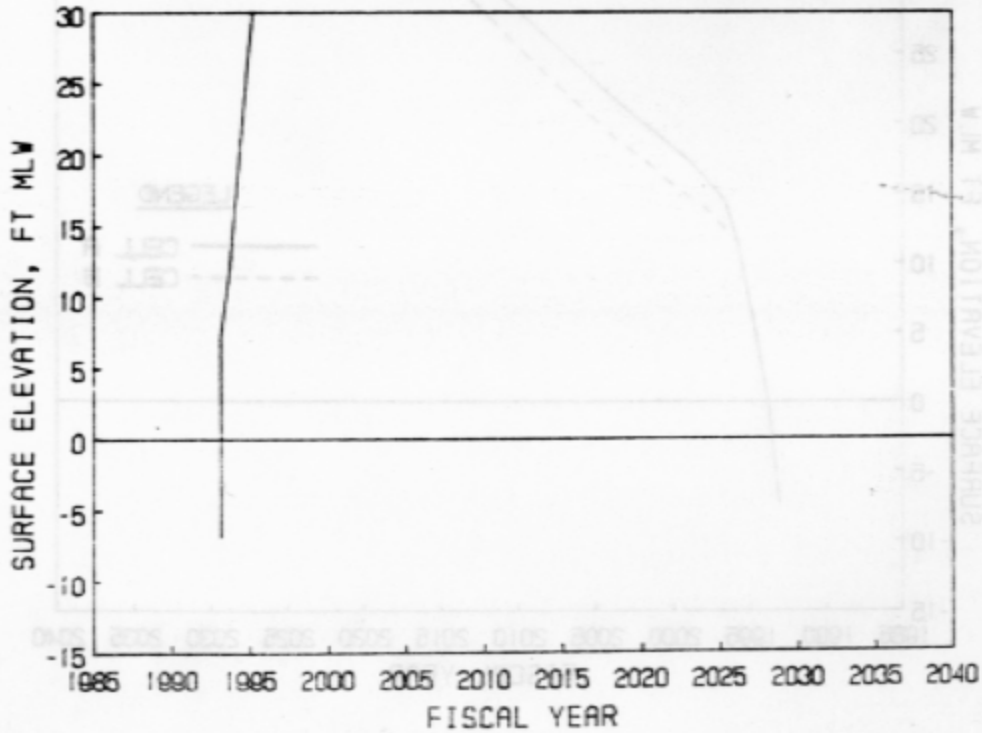

Figure C30. Expansion Alternative 4, Dredging Scenario 6

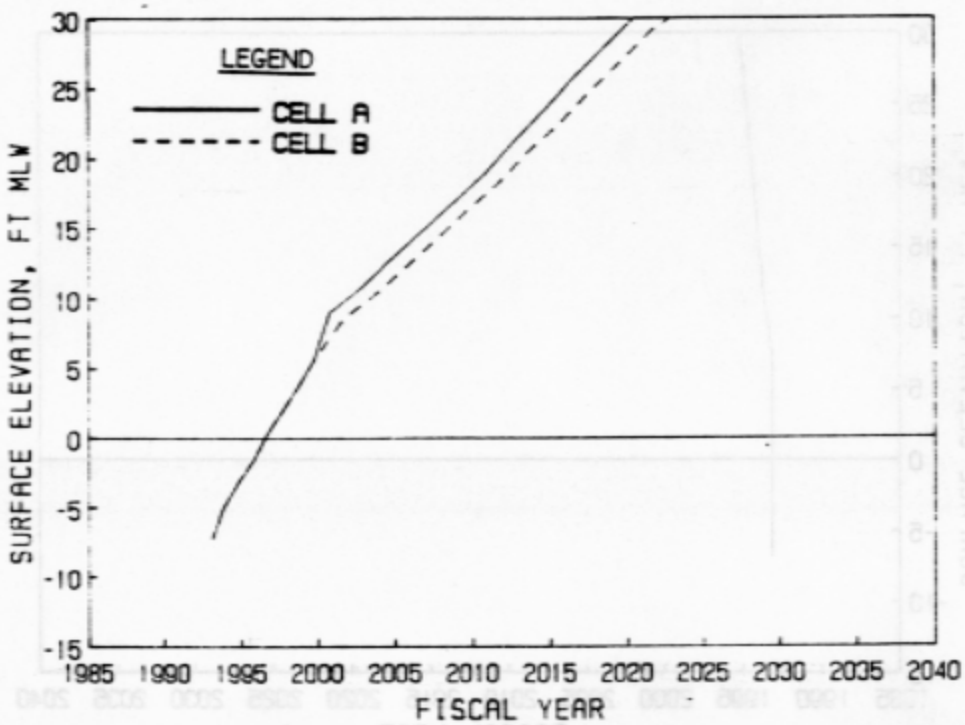

Figure C31. Expansion Alternative 5, Dredging Scenario 1

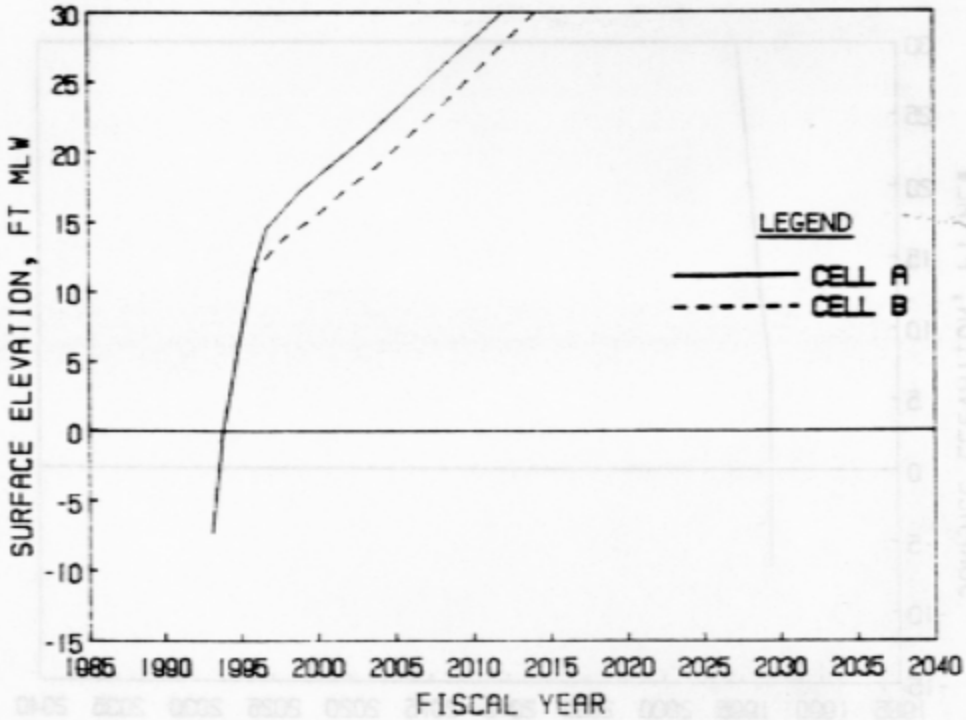

Figure C32. Expansion Alternative 5, Dredging Scenario 2

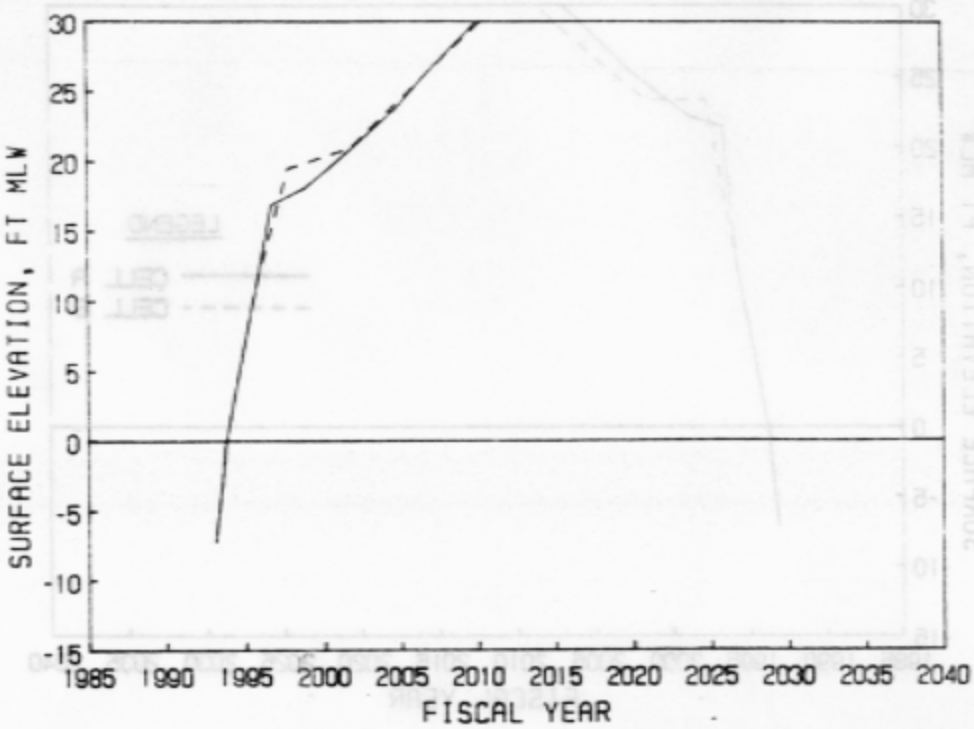

Figure C33. Expansion Alternative 5, Dredging Scenario 3

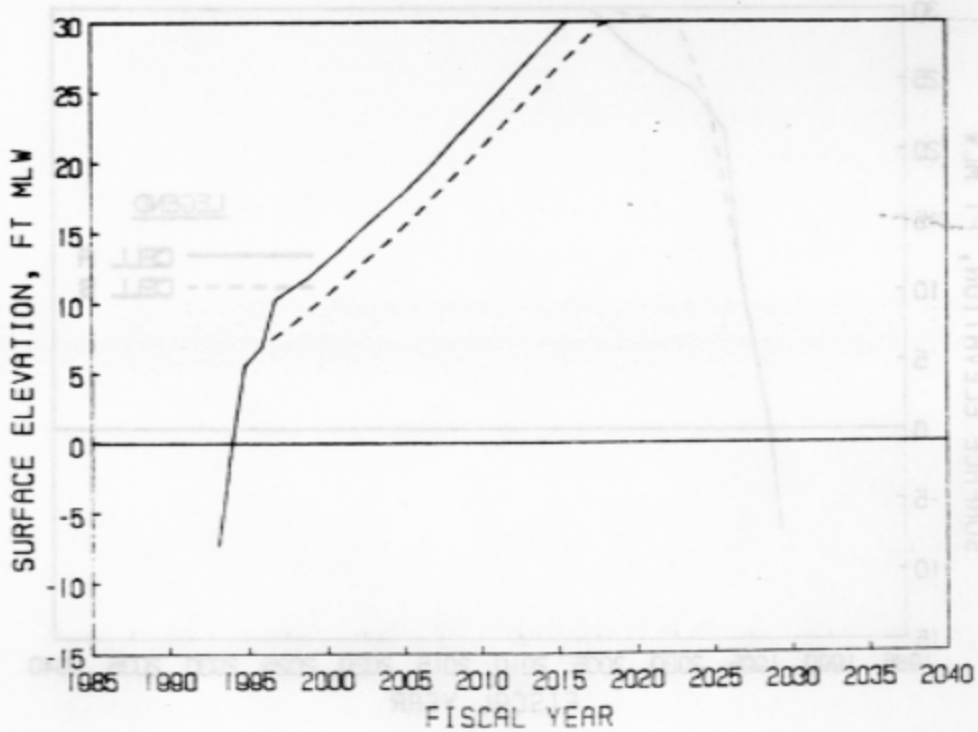

Figure C34. Expansion Alternative 5, Dredging Scenario 4

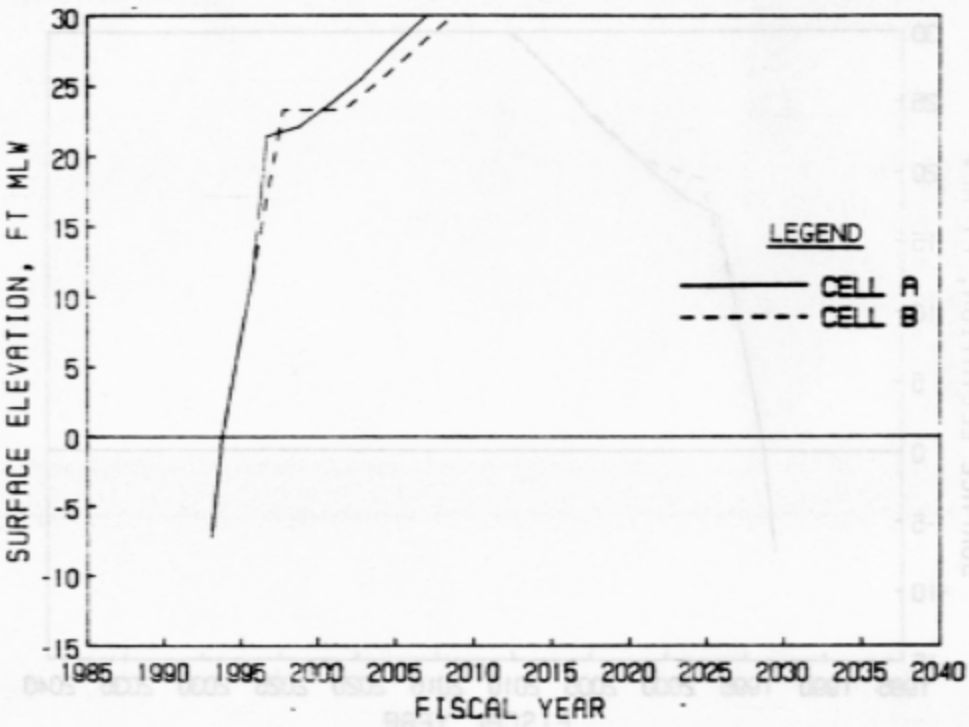

Figure C35. Expansion Alternative 5, Dredging Scenario 5

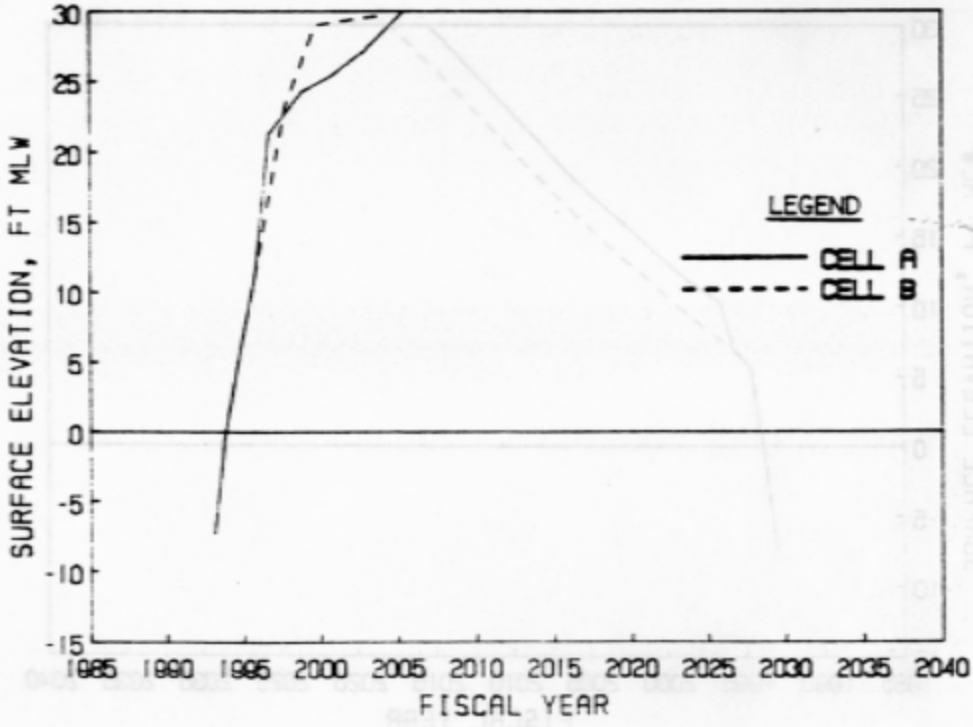

Figure C36. Expansion Alternative 5, Dredging Scenario 6

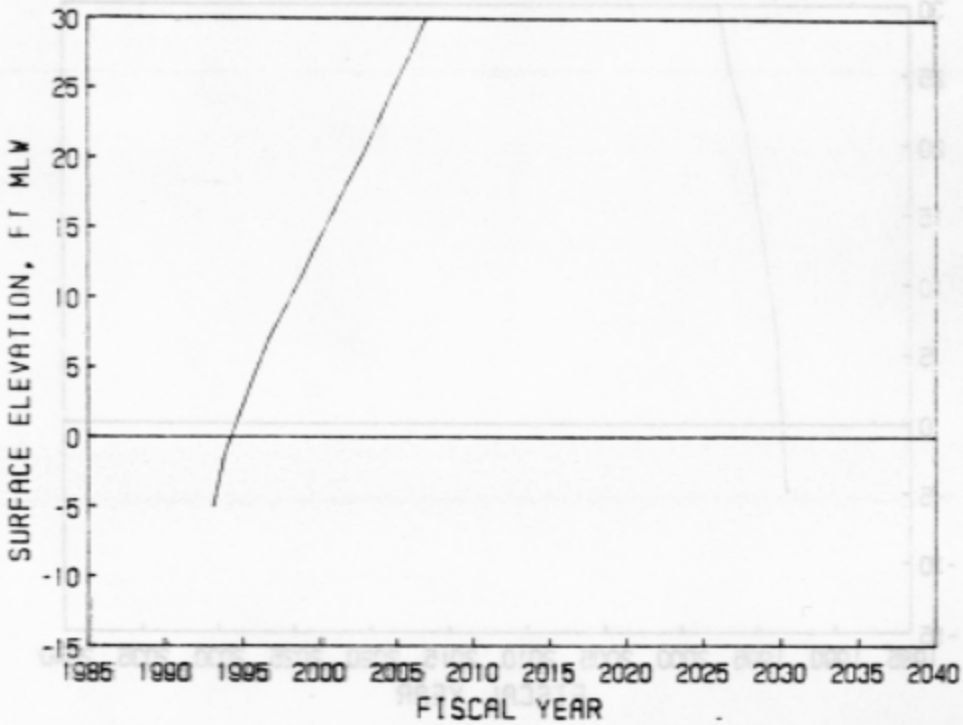

Figure C37. Expansion Alternative 6, Dredging Scenario 1

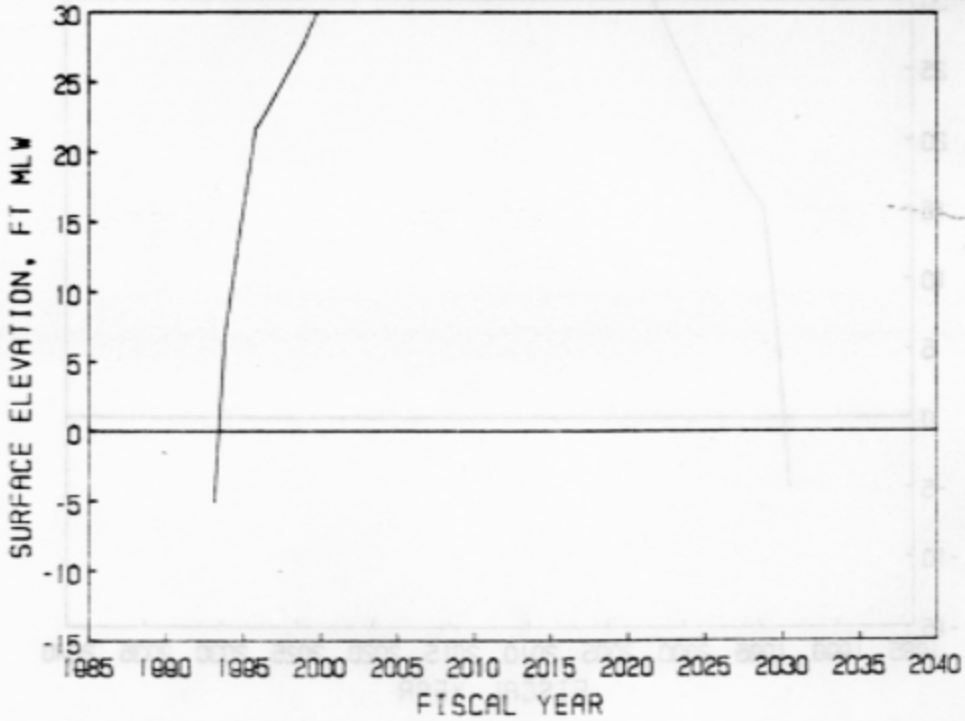

Figure C38. Expansion Alternative 6, Dredging Scenario 2

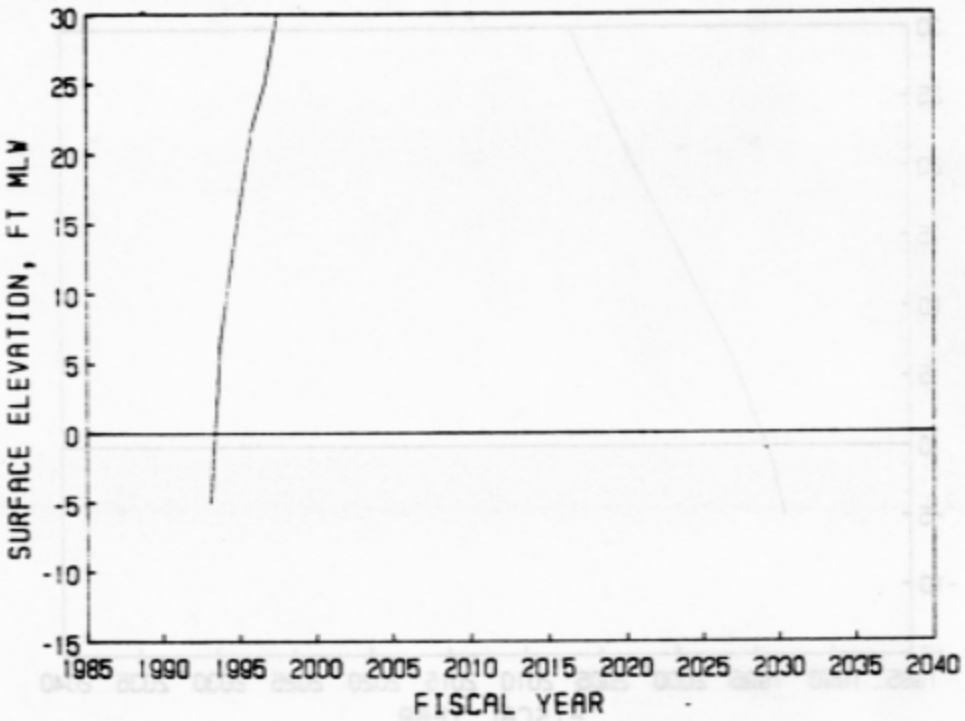

Figure C39. Expansion Alternative 6, Dredging Scenario 3

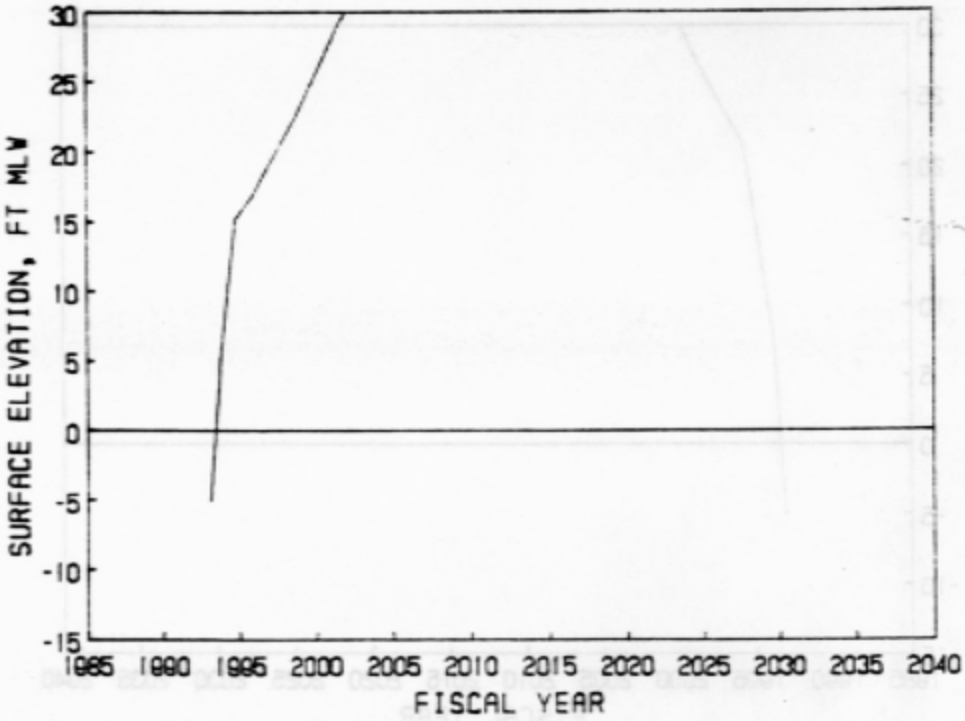

Figure C40. Expansion Alternative 6, Dredging Scenario 4

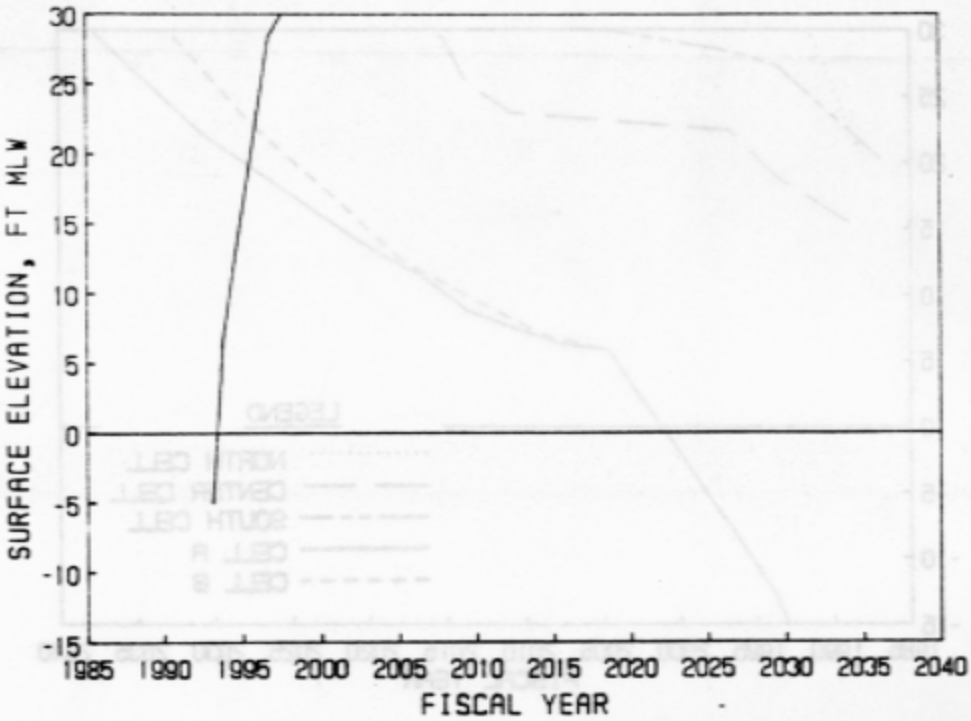

Figure C41. Expansion Alternative 6, Dredging Scenario 5

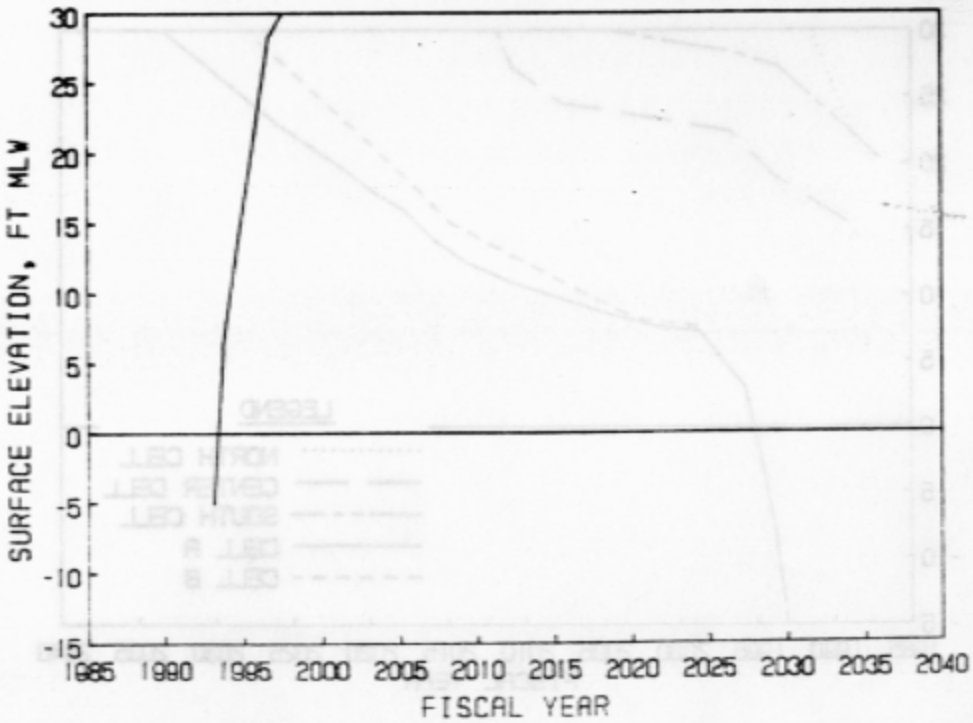

Figure C42. Expansion Alternative 6, Dredging Scenario 6

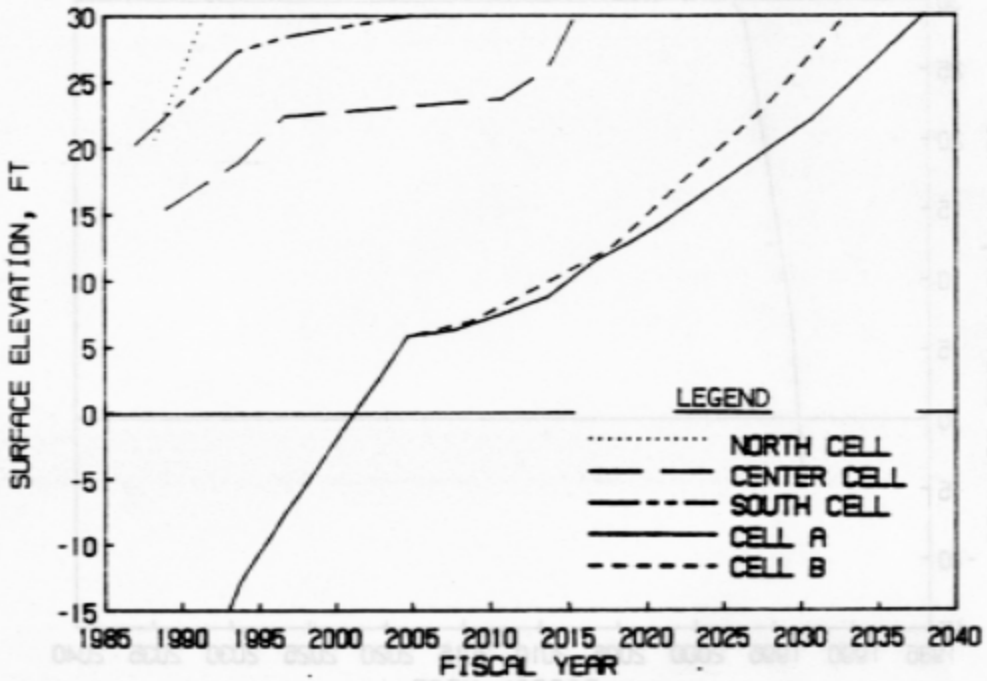

Figure C43. Expansion Alternative 1 with Craney Island, Dredging Scenario 1

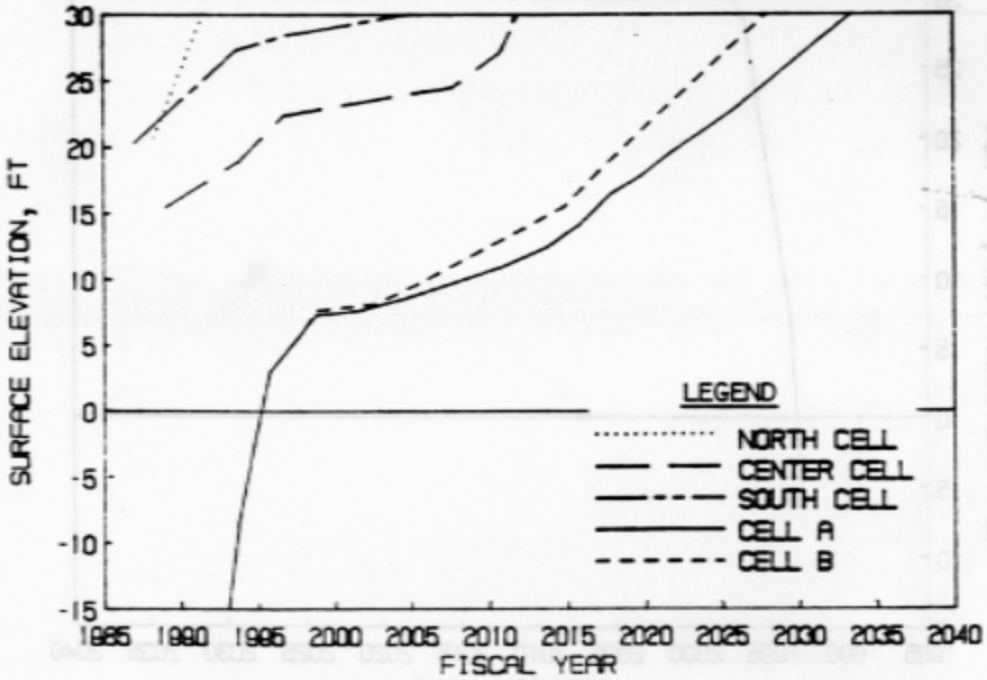

Figure C44. Expansion Alternative 1 with Craney Island, Dredging Scenario 2

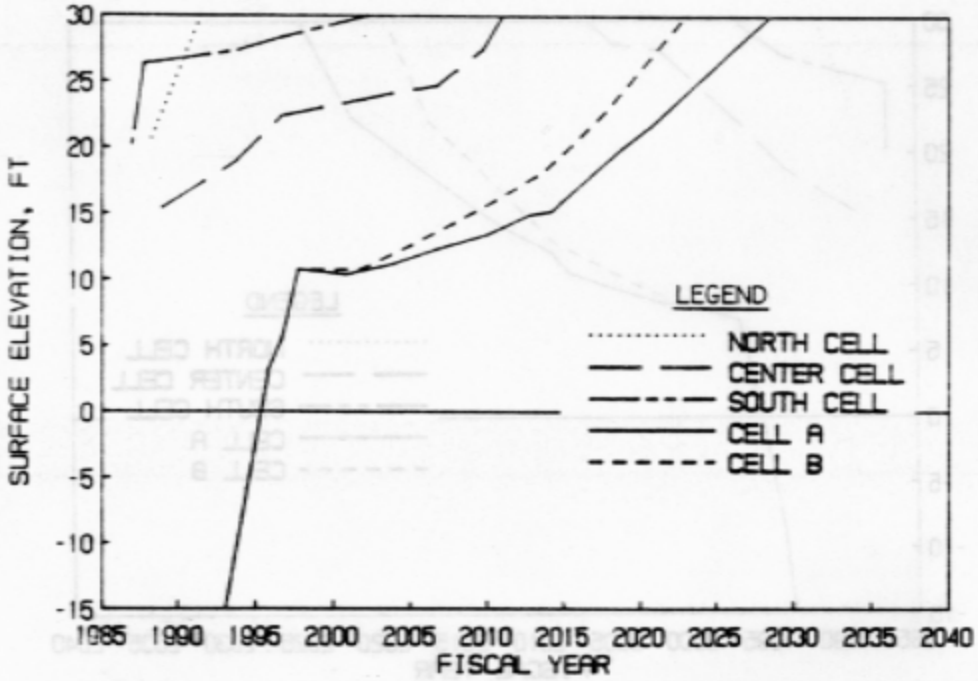

Figure C45. Expansion Alternative 1 with Craney Island, Dredging Scenario 3

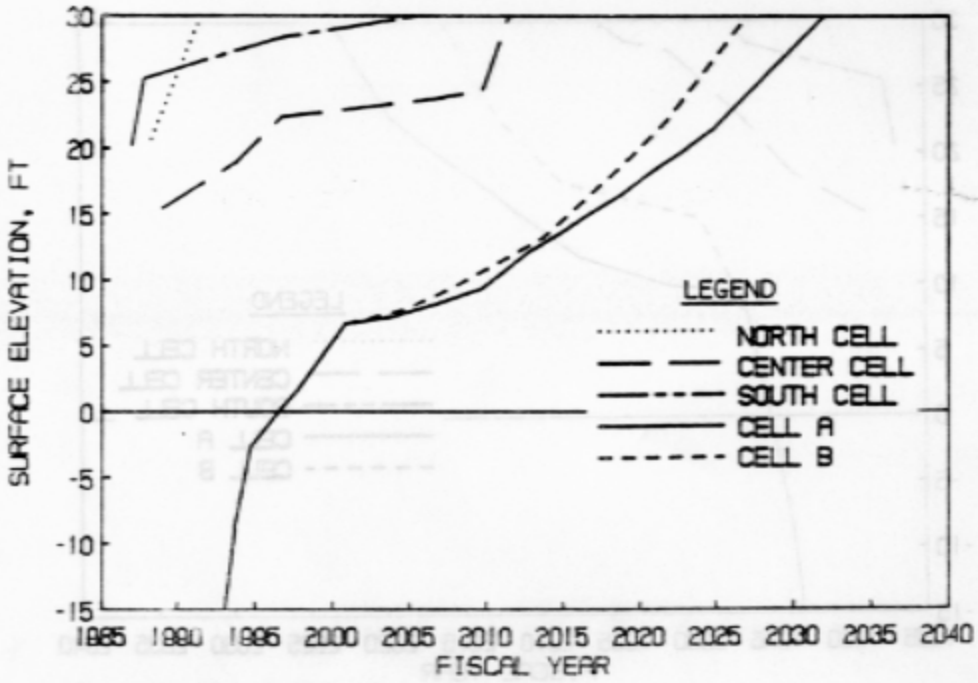

Figure C46. Expansion Alternative 1 with Craney Island, Dredging Scenario 4

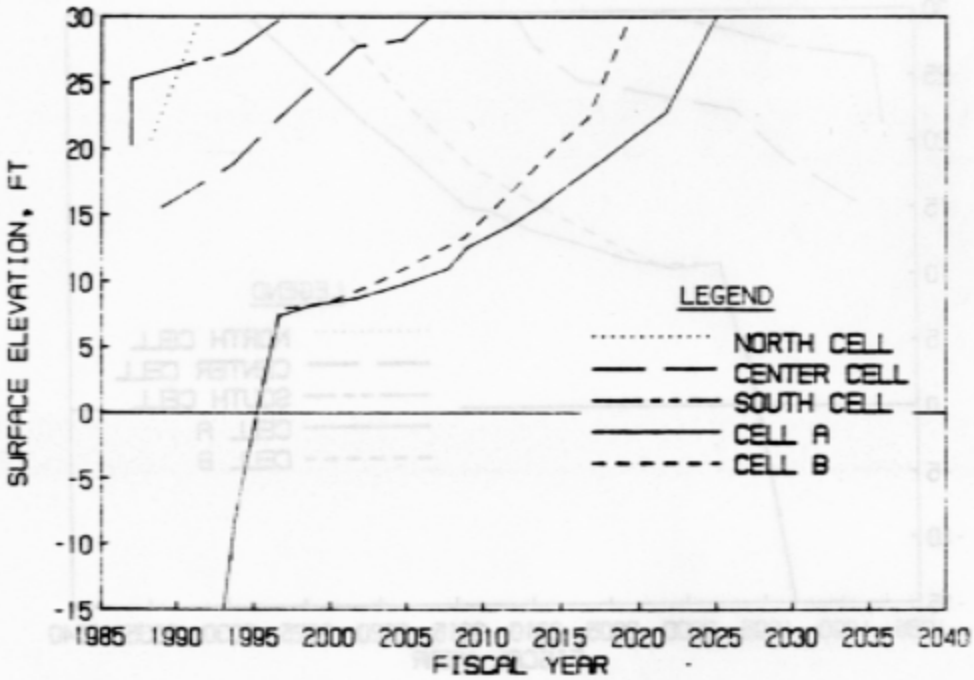

Figure C47. Expansion Alternative 1 with Craney Island, Dredging Scenario 5

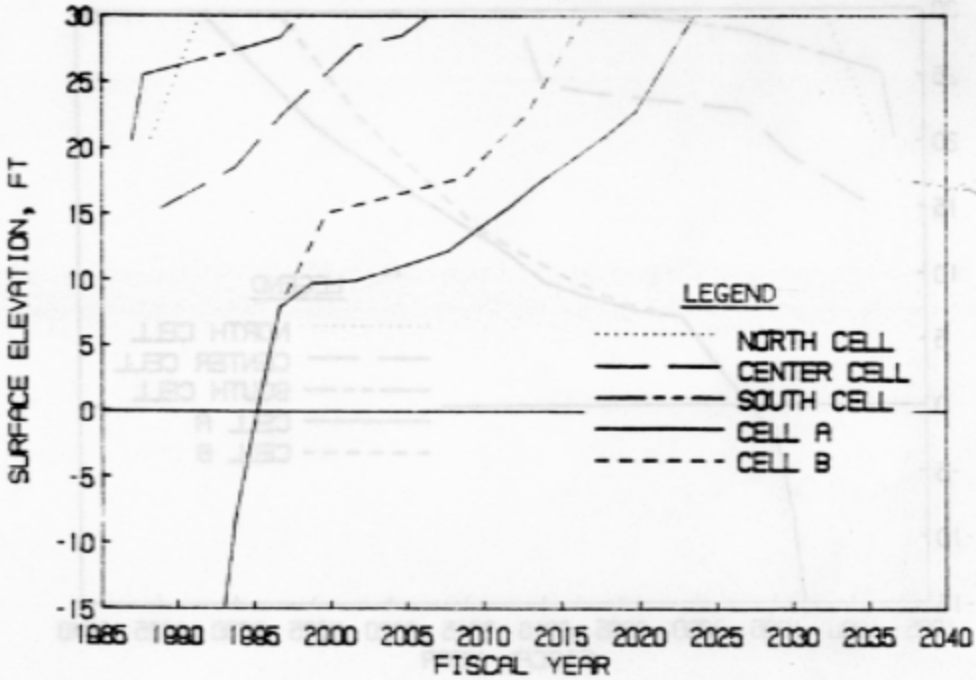

Figure C48. Expansion Alternative 1 with Craney Island, Dredging Scenario 6

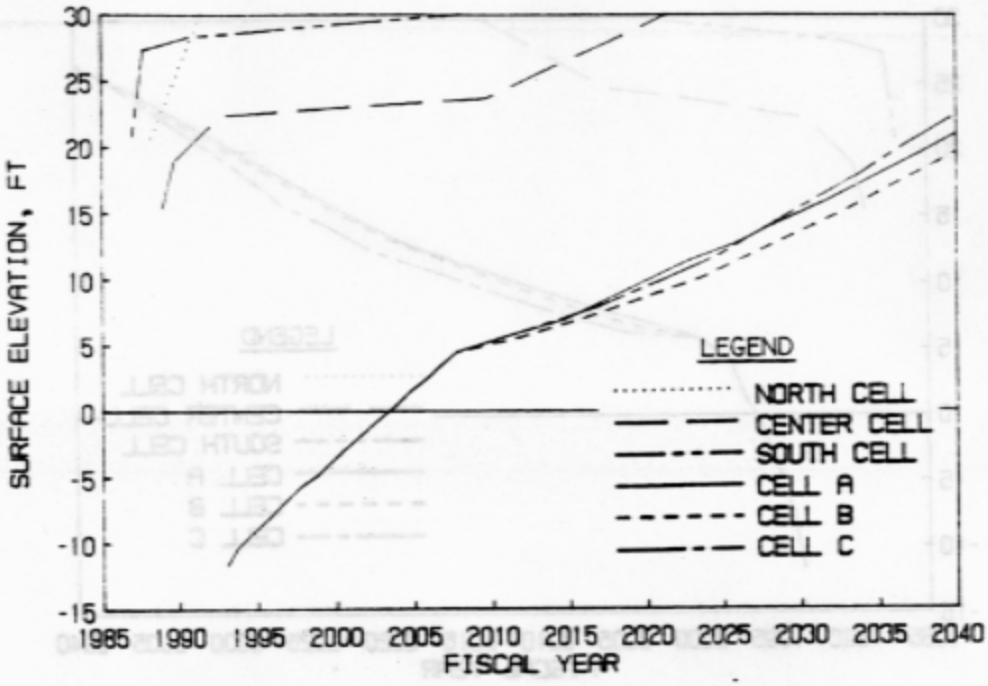

Figure C49. Expansion Alternative 2 with Craney Island, Dredging Scenario 1

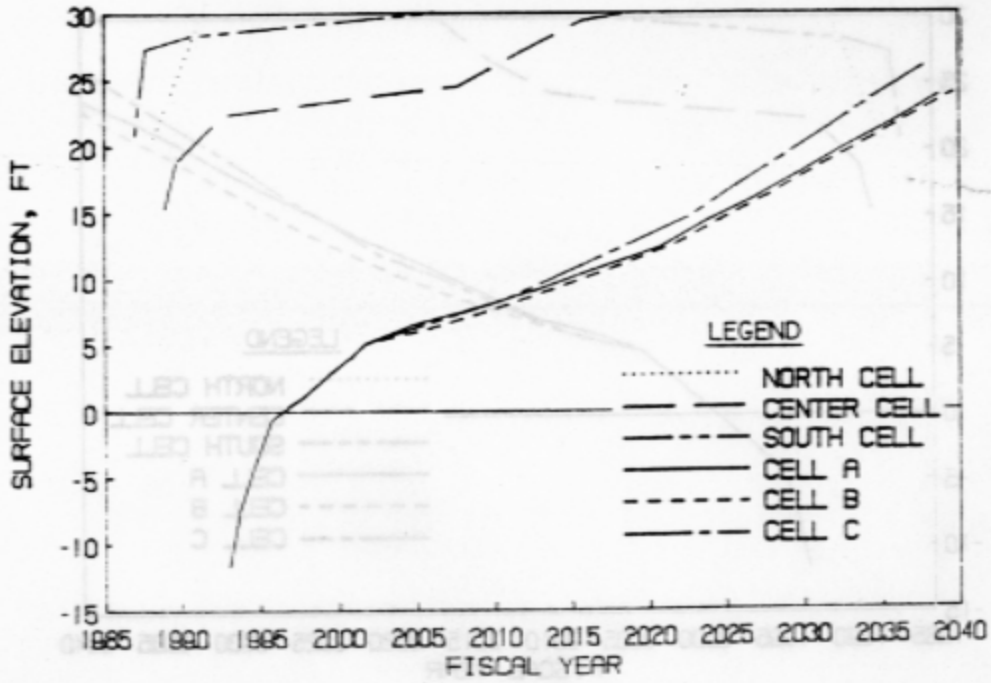

Figure C50. Expansion Alternative 2 with Craney Island, Dredging Scenario 2

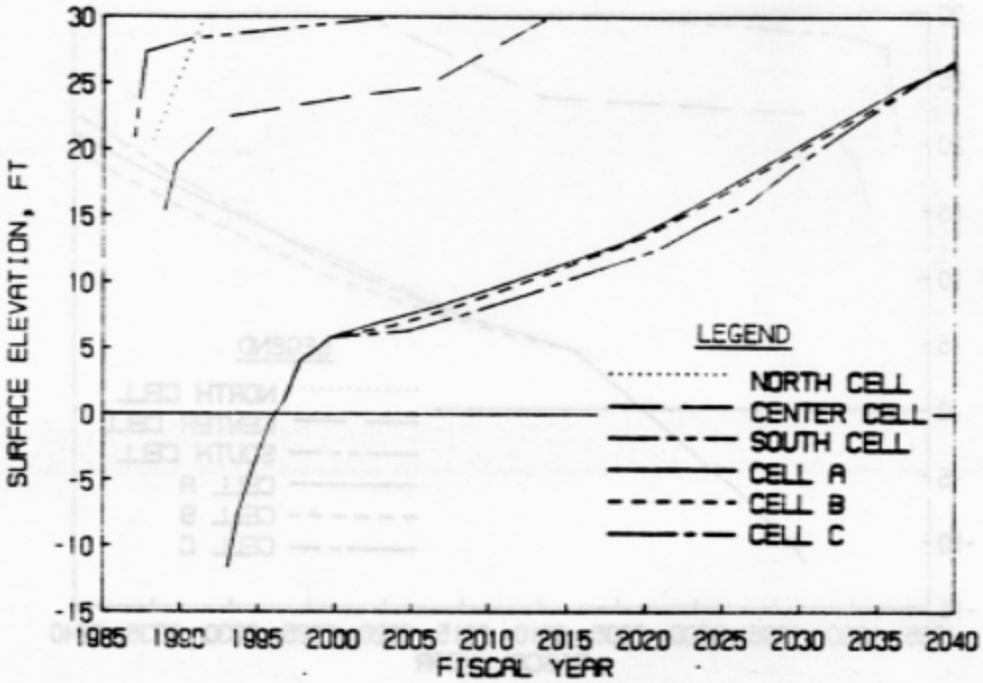

Figure C51. Expansion Alternative 2 with Craney Island, Dredging Scenario 3

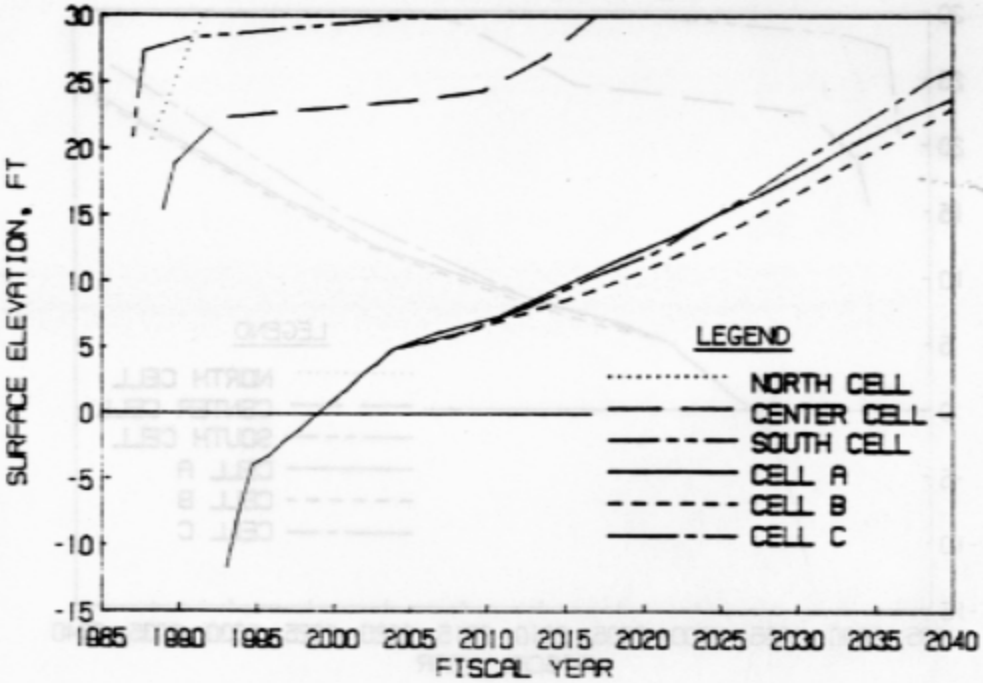

Figure C52. Expansion Alternative 2 with Craney Island, Dredging Scenario 4

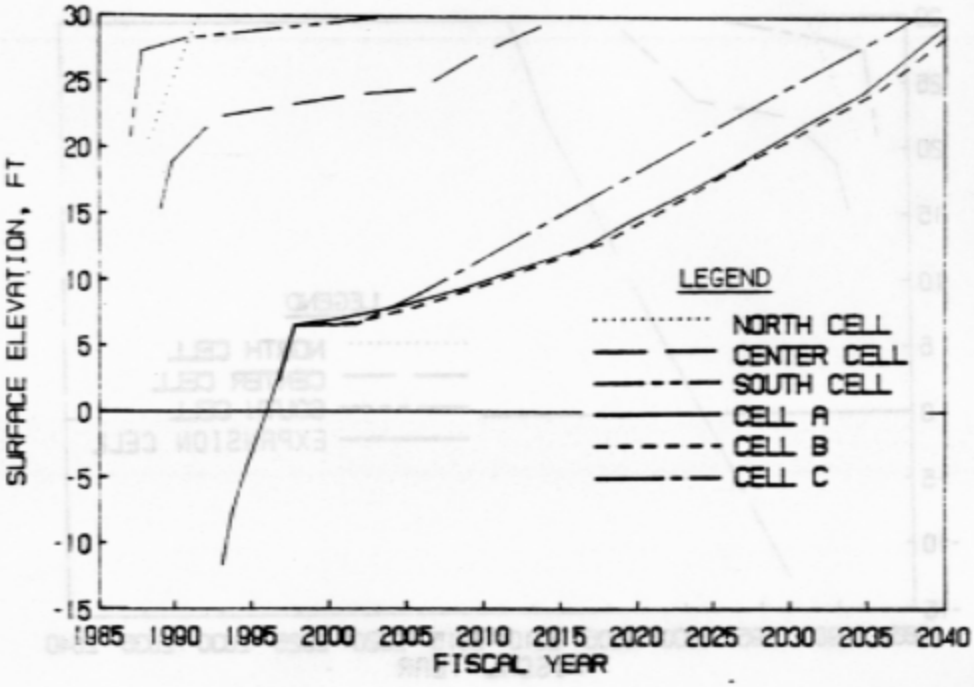

Figure C53. Expansion Alternative 2 with Craney Island, Dredging Scenario 5

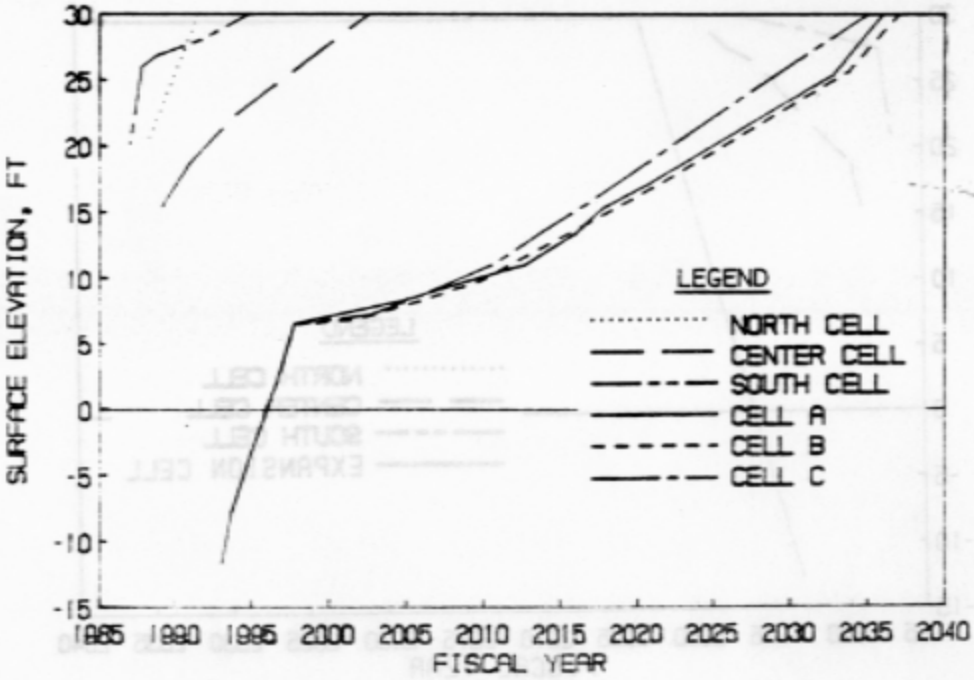

Figure C54. Expansion Alternative 2 with Craney Island, Dredging Scenario 6

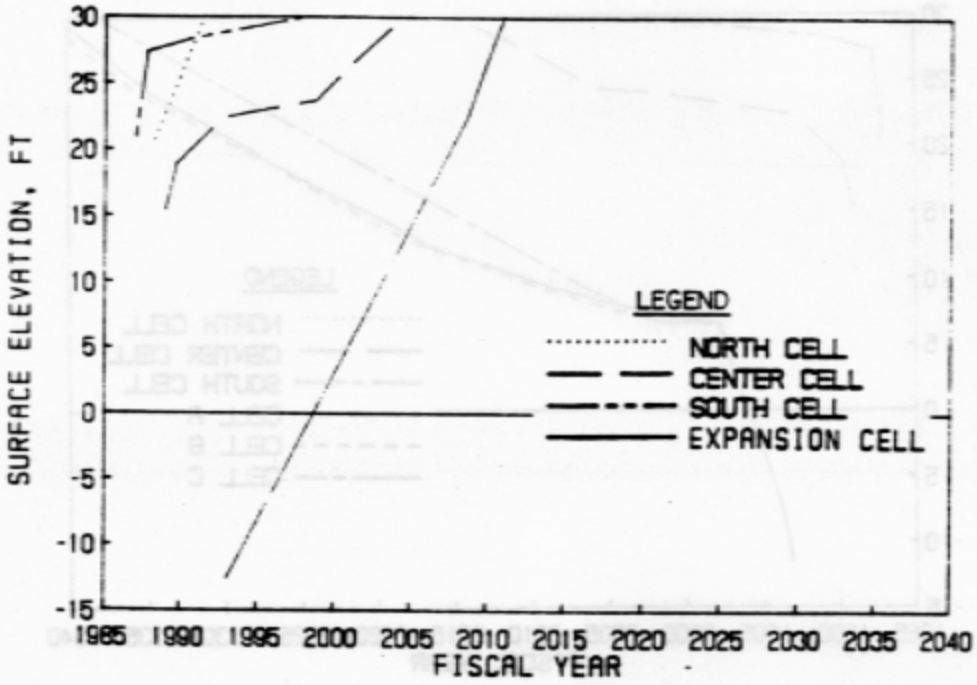

Figure C55. Expansion Alternative 3 with Craney Island, Dredging Scenario 1

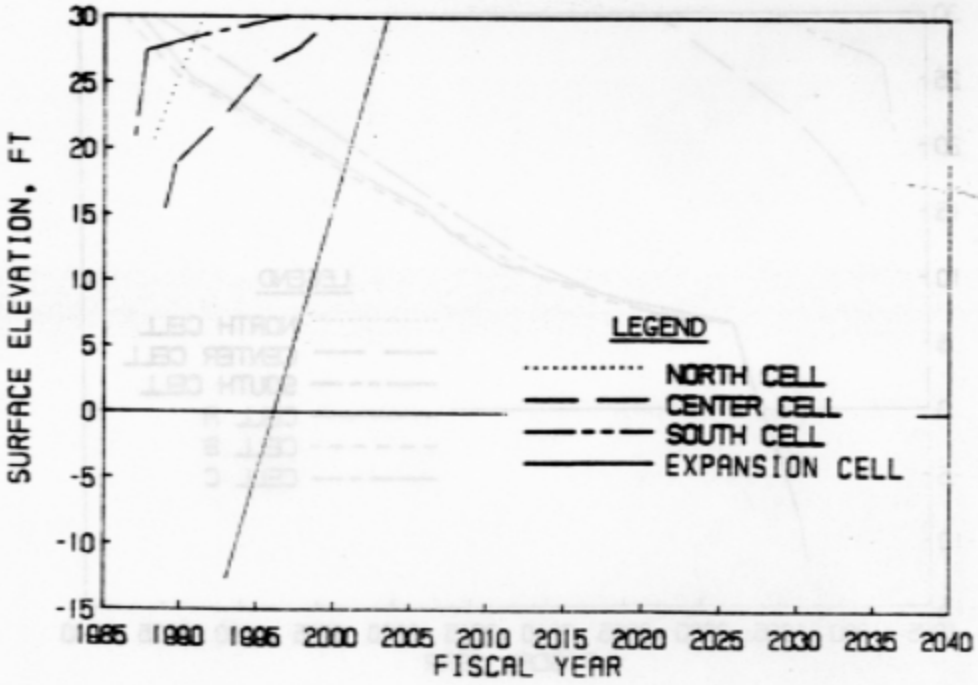

Figure C56. Expansion Alternative 3 with Craney Island, Dredging Scenario 2

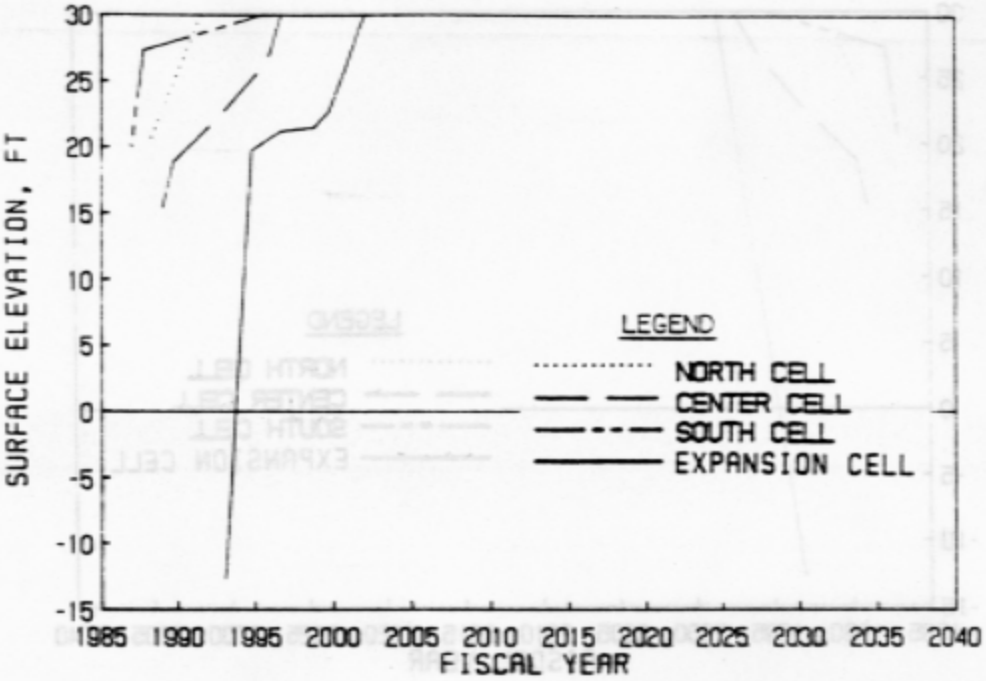

Figure C57. Expansion Alternative 3 with Craney Island, Dredging Scenario 3

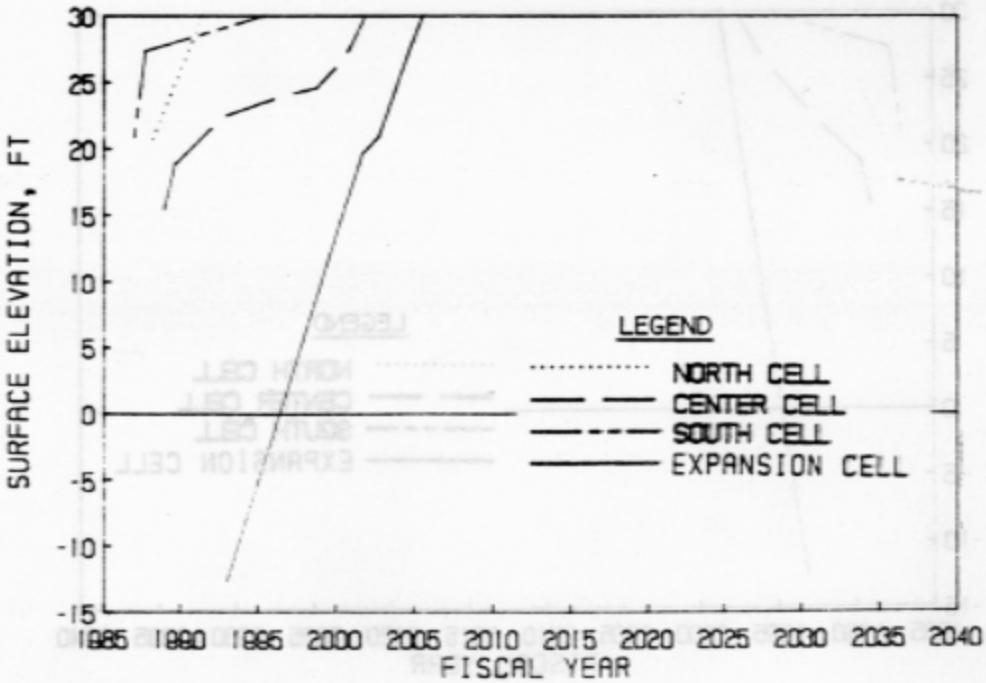

Figure C58. Expansion Alternative 3 with Craney Island, Dredging Scenario 4

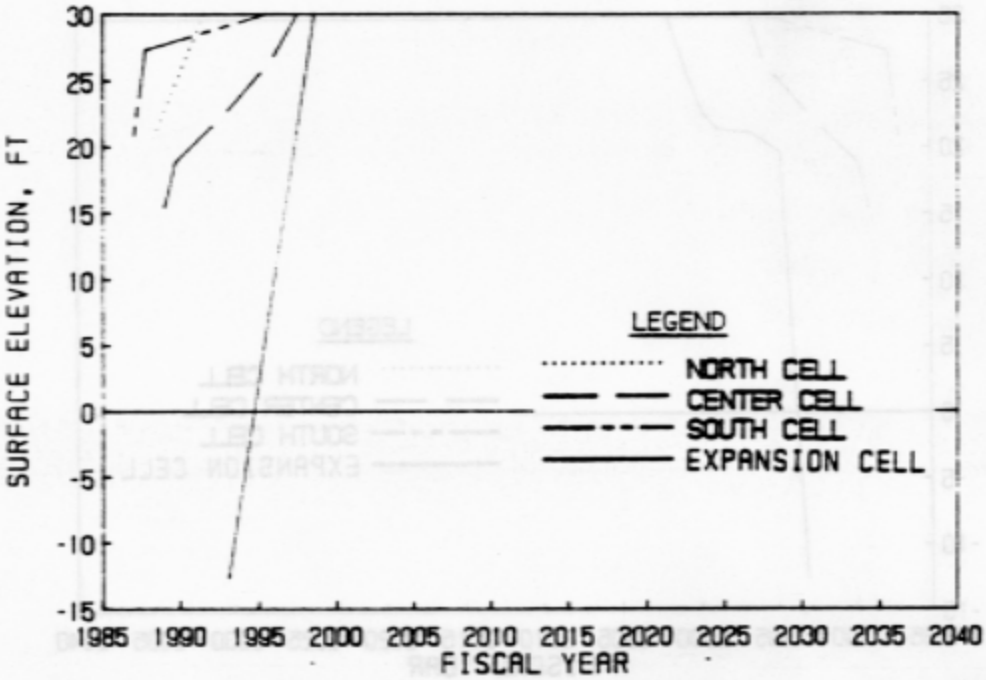

Figure C59. Expansion Alternative 3 with Craney Island, Dredging Scenario 5

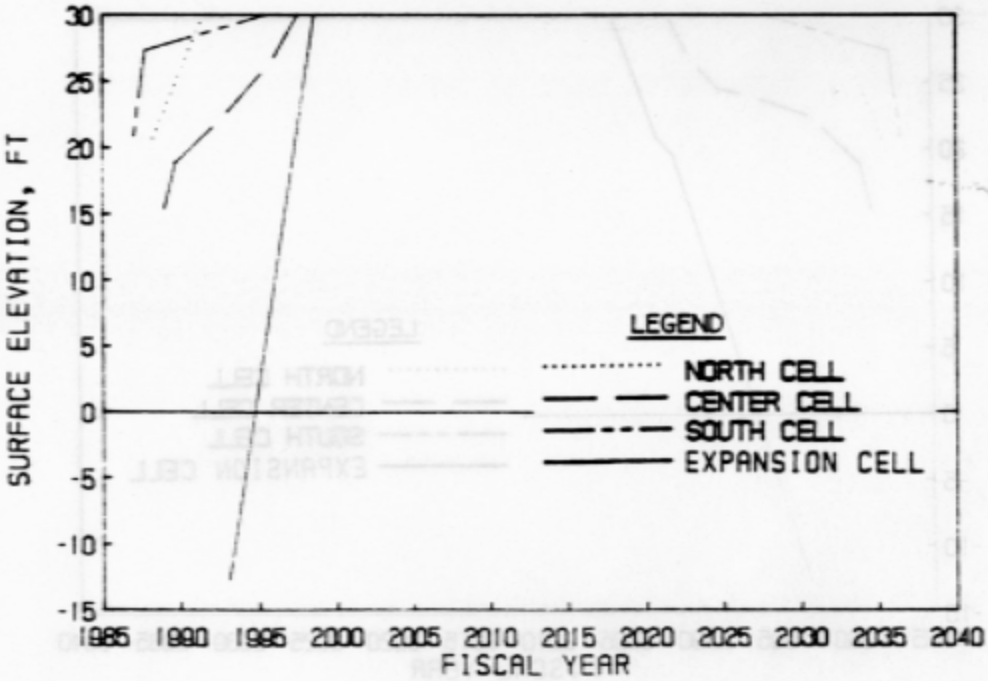

Figure C60. Expansion Alternative 3 with Craney Island, Dredging Scenario 6

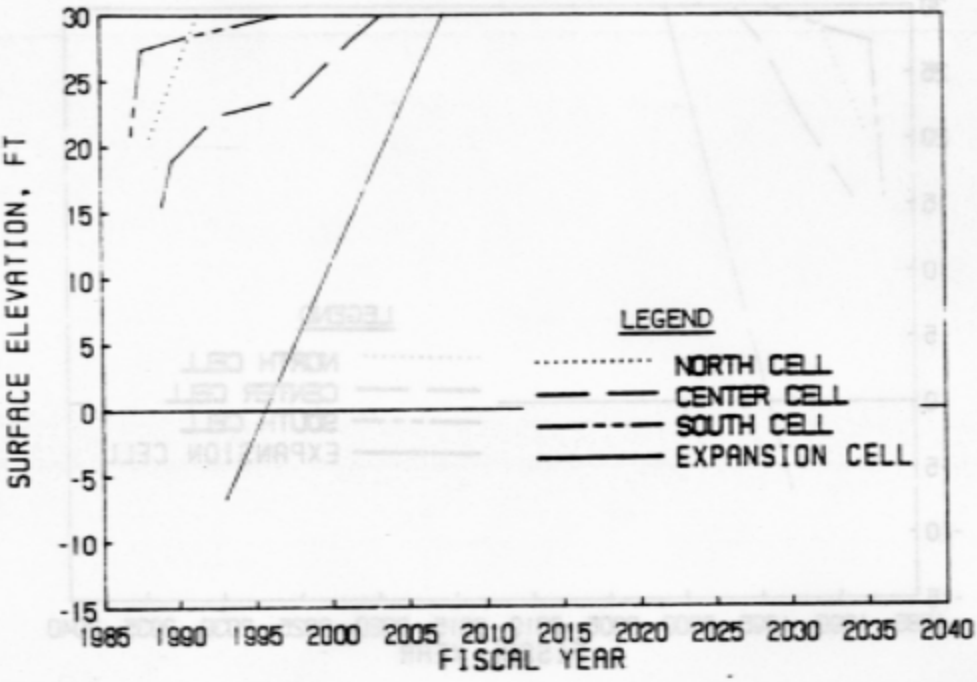

Figure C61. Expansion Alternative 4 with Craney Island, Dredging Scenario 1

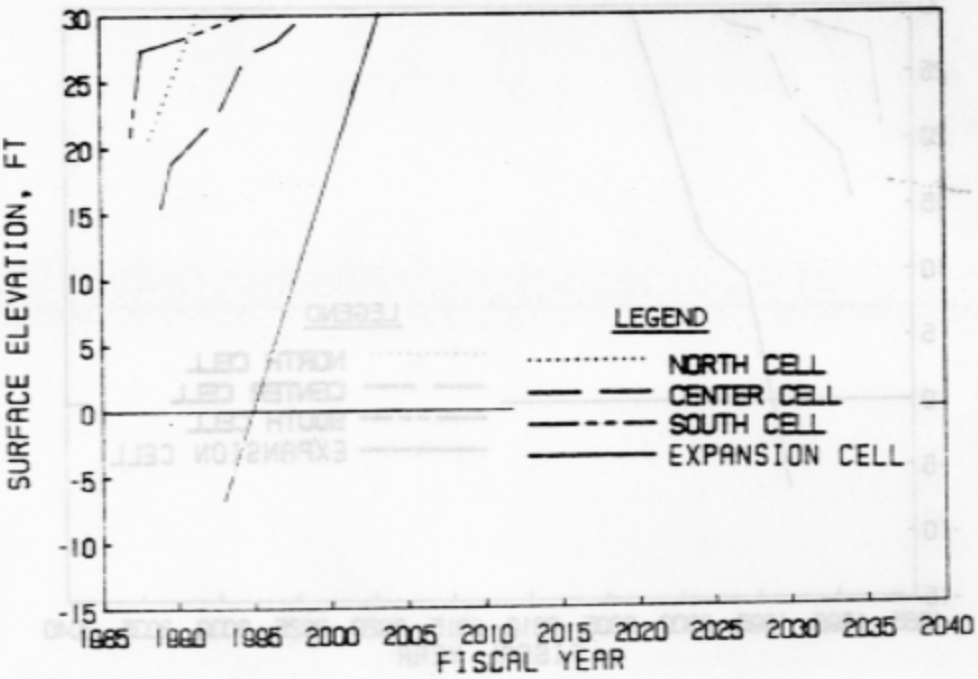

Figure C62. Expansion Alternative 4 with Craney Island, Dredging Scenario 2

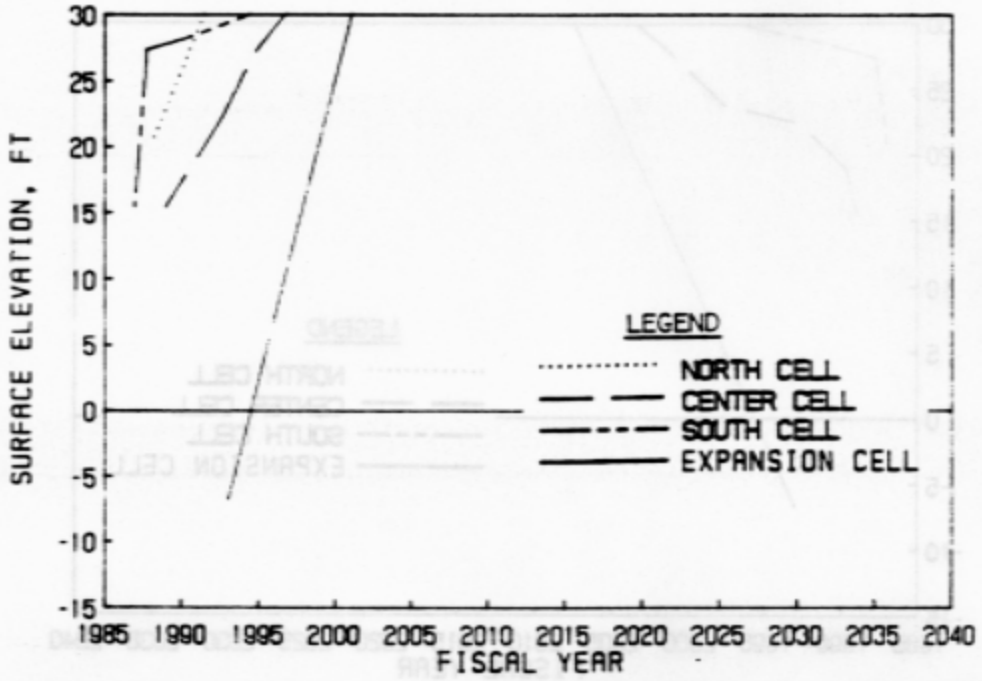

Figure C63. Expansion Alternative 4 with Craney Island, Dredging Scenario 3

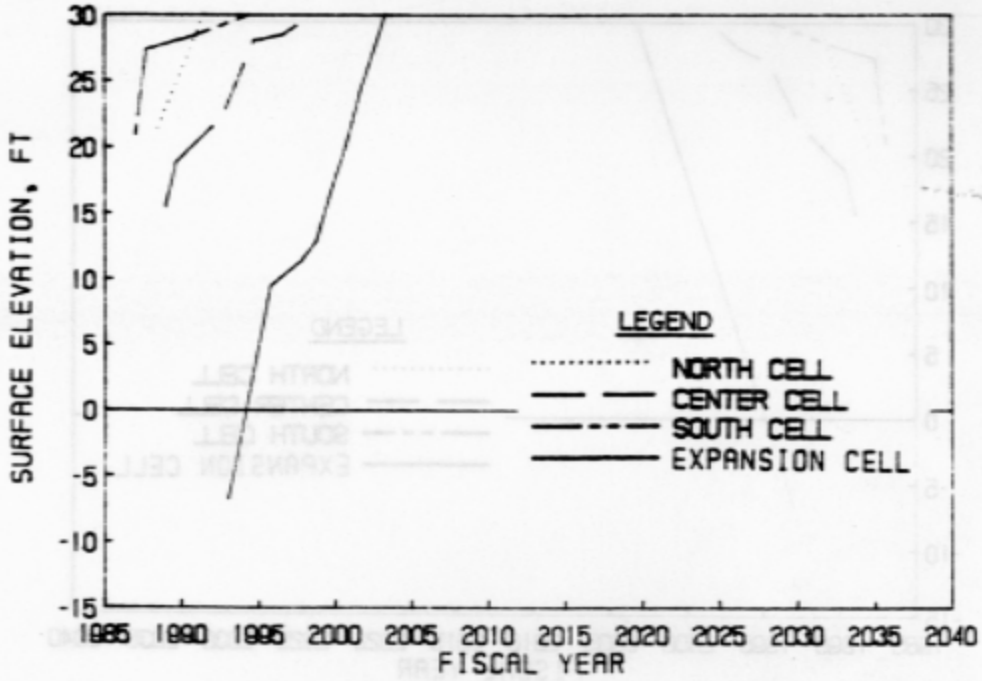

Figure C64. Expansion Alternative 4 with Craney Island, Dredging Scenario 4

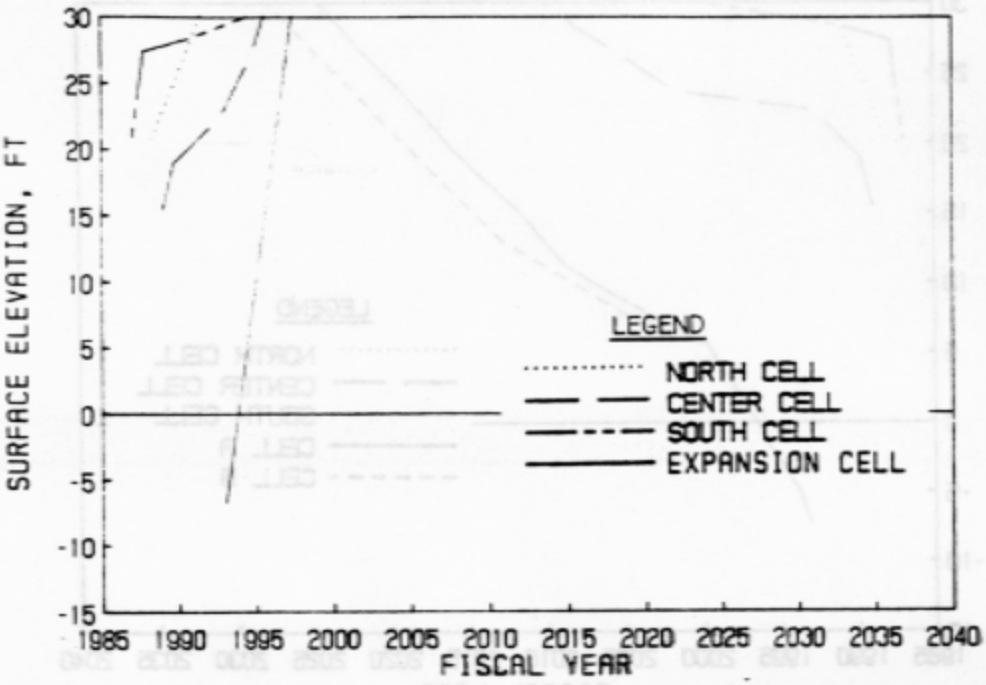

Figure C65. Expansion Alternative 4 with Craney Island, Dredging Scenario 5

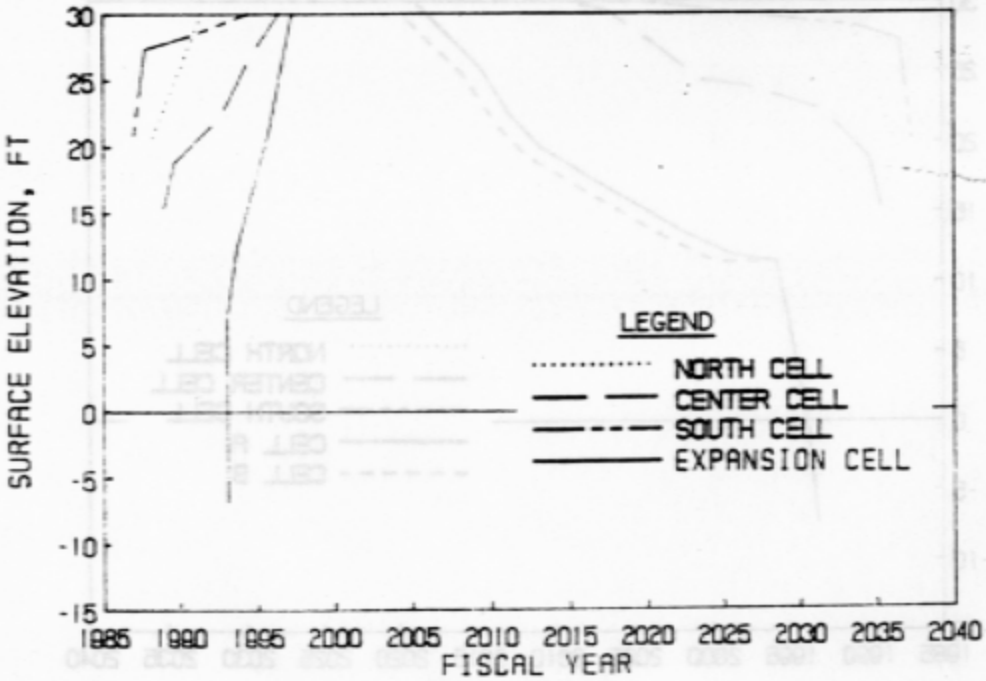

Figure C66. Expansion Alternative 4 with Craney Island, Dredging Scenario 6

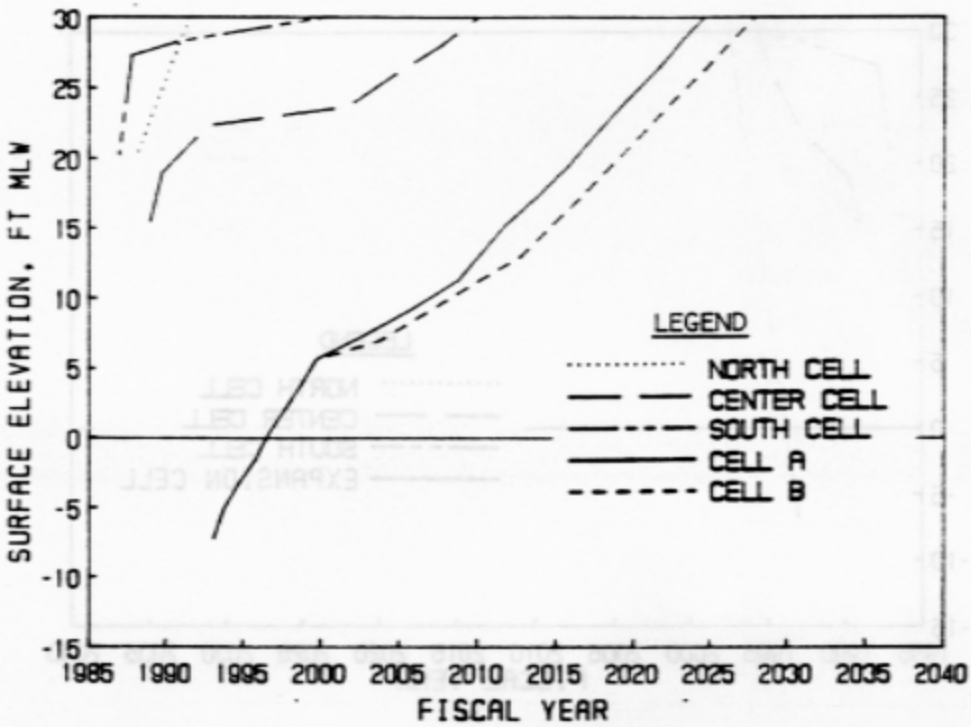

Figure C67. Expansion Alternative 5 with Craney Island, Dredging Scenario 1

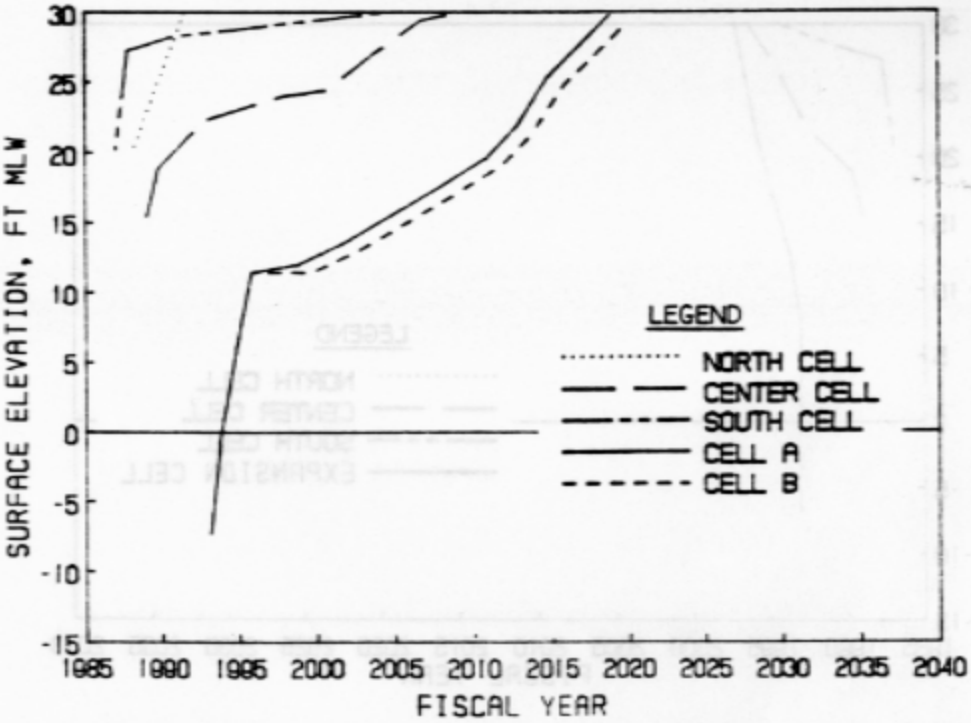

Figure C68. Expansion Alternative 5 with Craney Island, Dredging Scenario 2

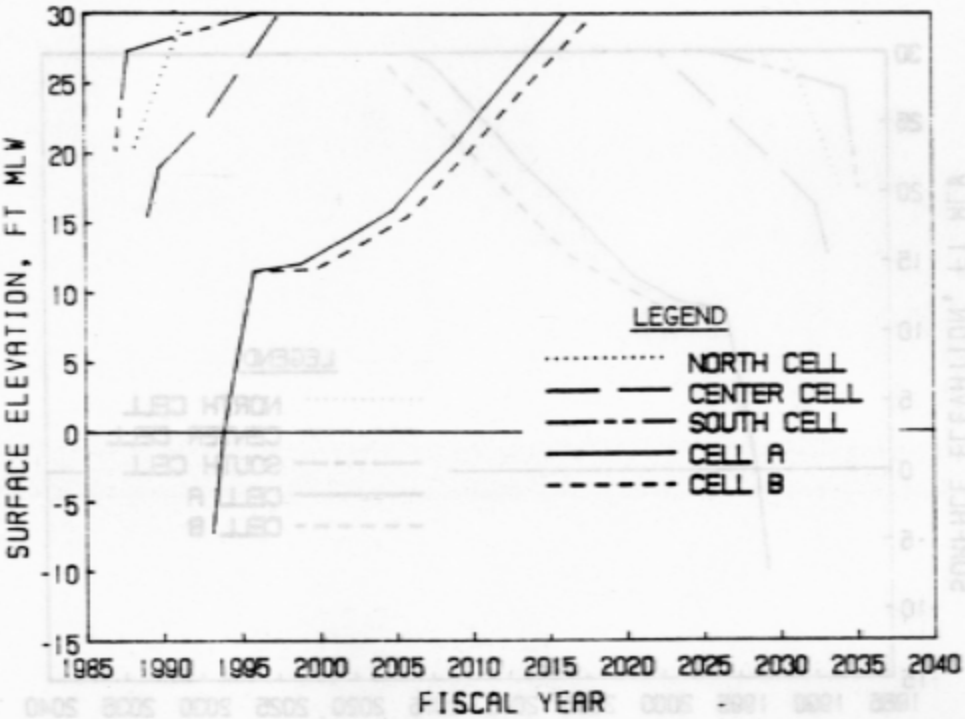

Figure C69. Expansion Alternative 5 with Craney Island, Dredging Scenario 3

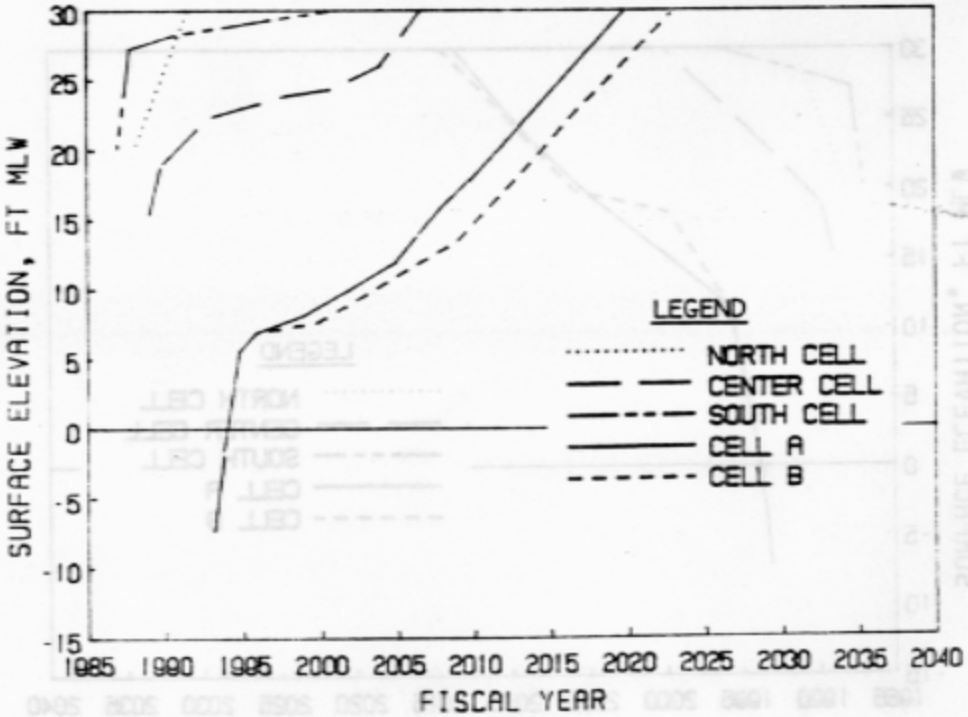

Figure C70. Expansion Alternative 5 with Craney Island, Dredging Scenario 4

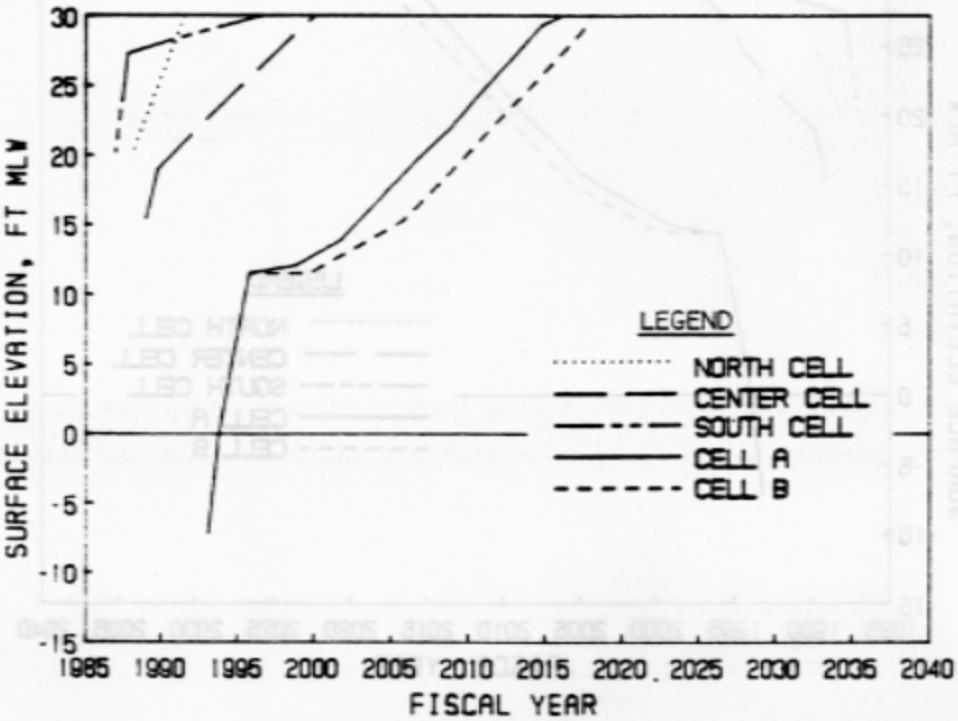

Figure C71. Expansion Alternative 5 with Craney Island, Dredging Scenario 5

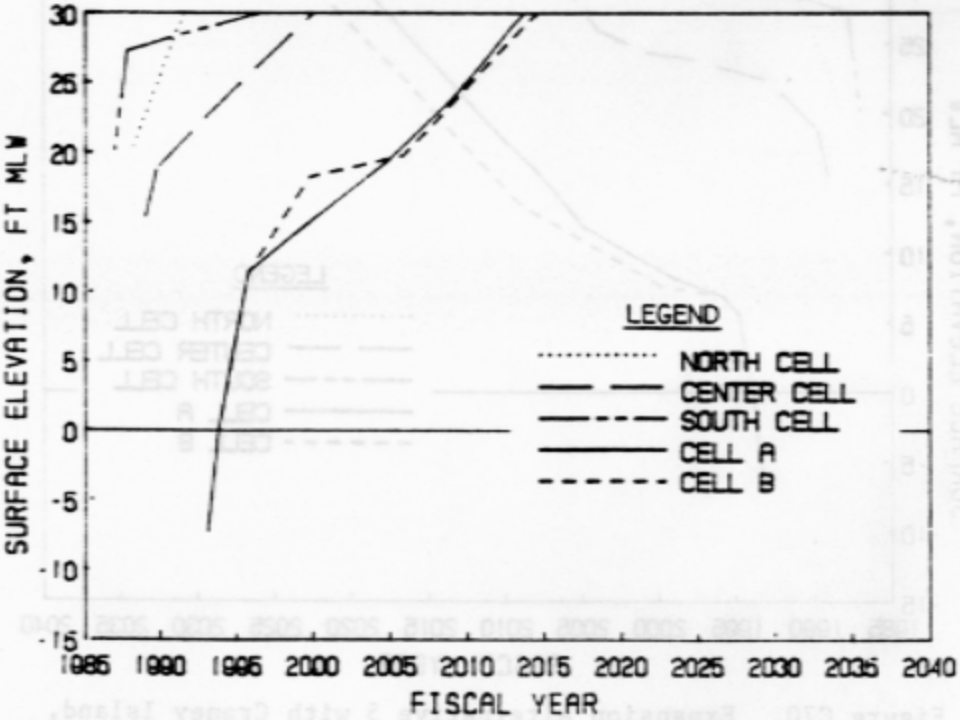

Figure C72. Expansion Alternative 5 with Craney Island, Dredging Scenario 6

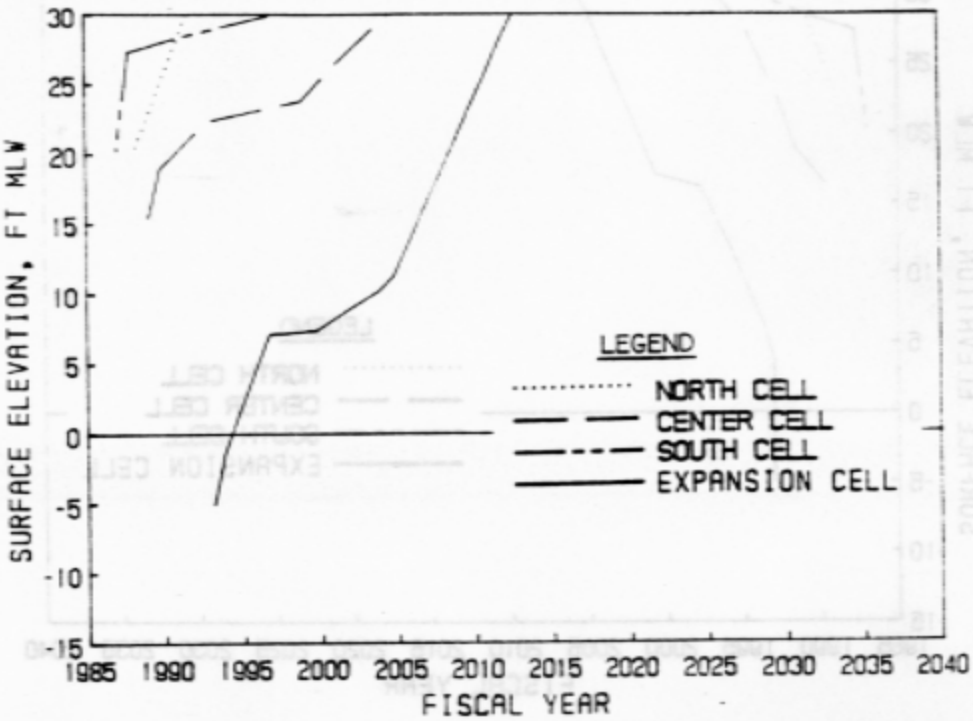

Figure C73. Expansion Alternative 6 with Craney Island, Dredging Scenario 1

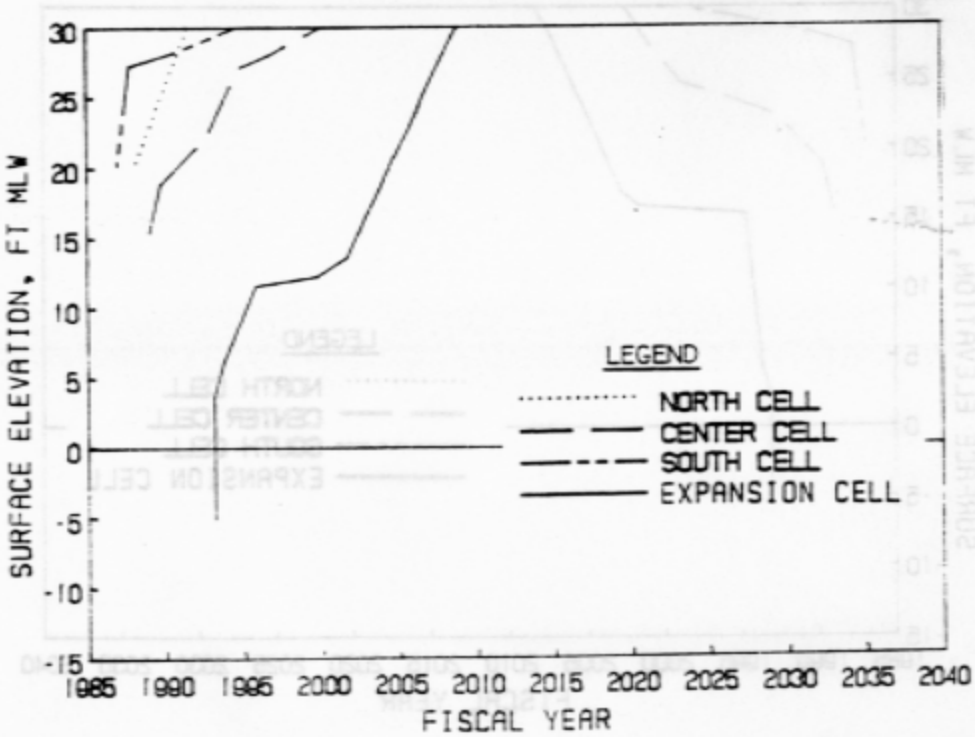

Figure C74. Expansion Alternative 6 with Craney Island, Dredging Scenario 2

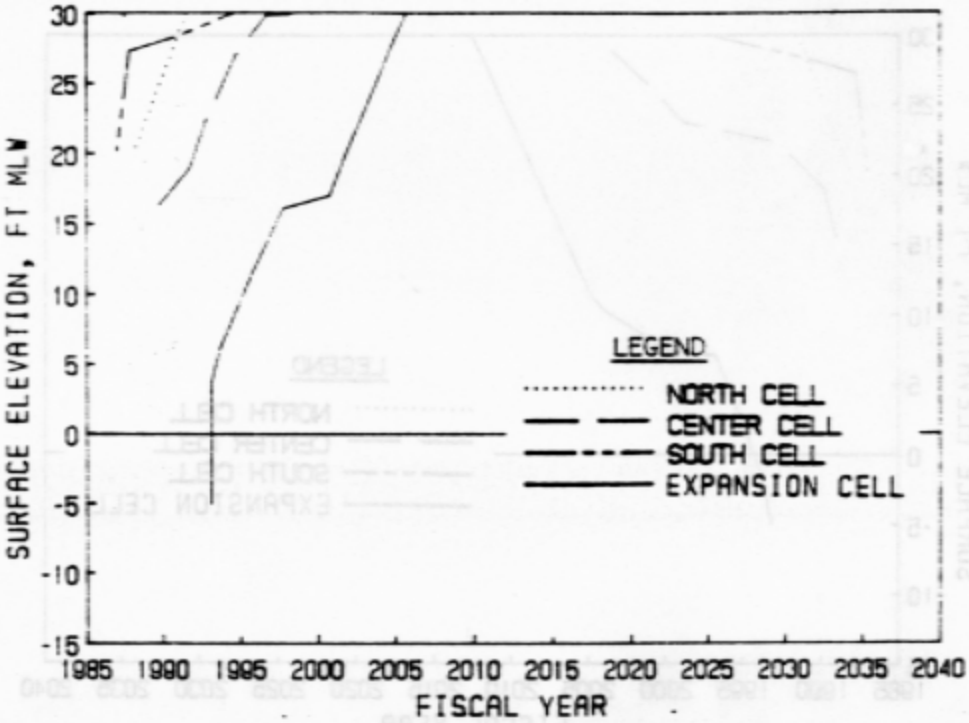

Figure C75. Expansion Alternative 6 with Craney Island, Dredging Scenario 3

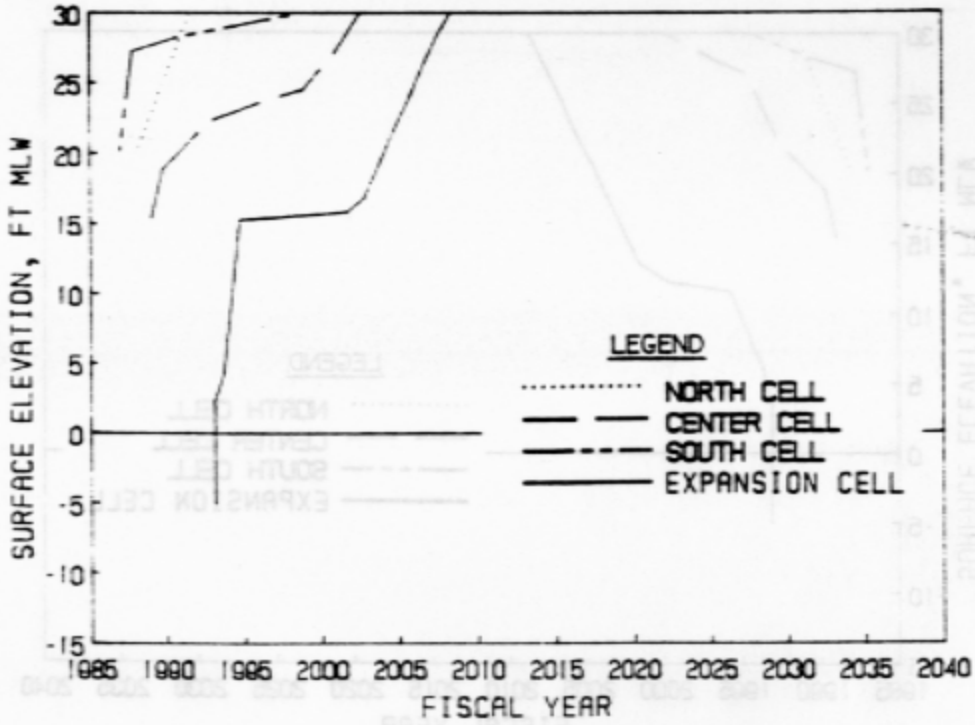

Figure C76. Expansion Alternative 6 with Craney Island, Dredging Scenario 4

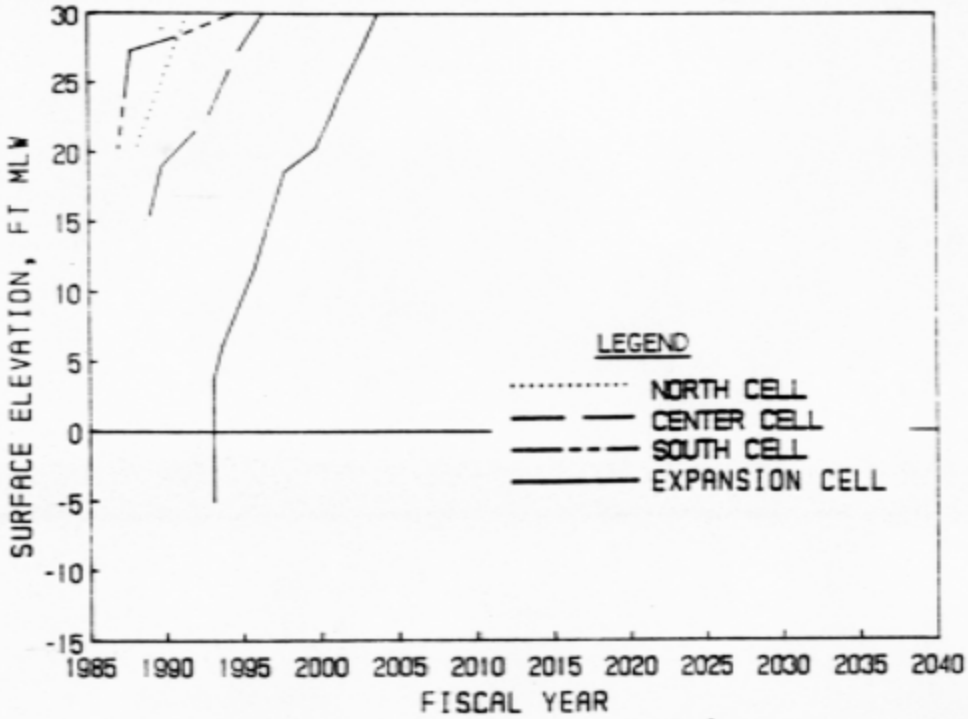

Figure C77. Expansion Alternative 6 with Craney Island, Dredging Scenario 5

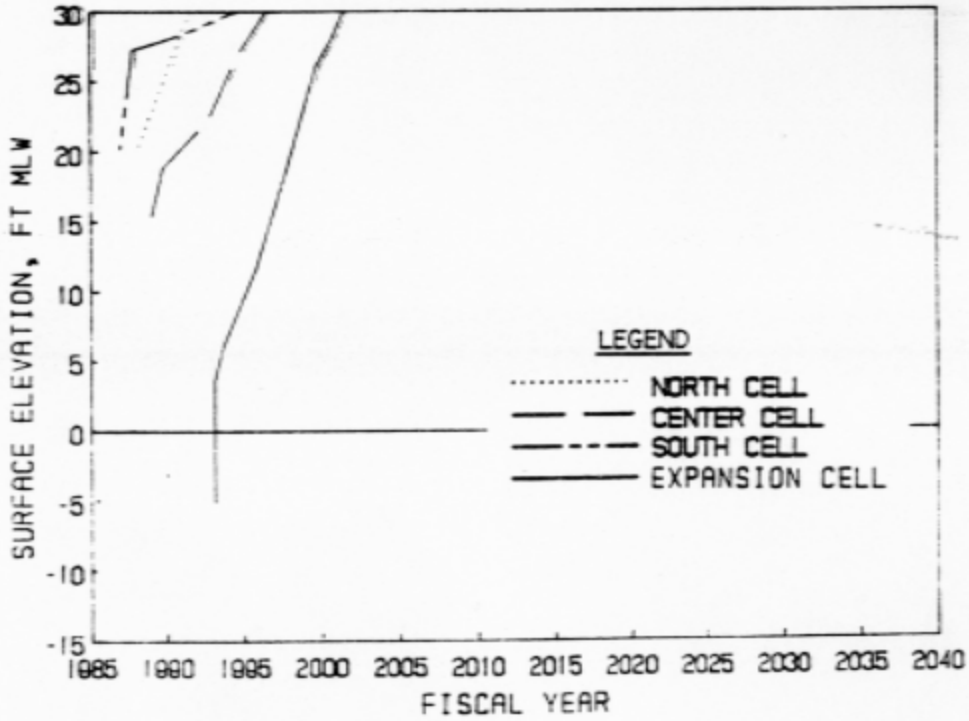

Figure C78. Expansion Alternative 6 with Craney Island, Dredging Scenario 6

ATTACHMENT 2

DRAFT

GEOTECHNICAL FEASIBILITY STUDY
REPLACEMENT OR EXTENSION OF THE
CRANEY ISLAND DISPOSAL AREA
NORFOLK, VIRGINIA

by

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Washington, DC 20314-1000

and

U. S. Army Engineer District, Norfolk
Norfolk, Virginia 23510-1096

PREFACE

This report presents the results of preliminary geotechnical engineering studies and gives estimated costs for embankment construction for five alternate disposal areas for the extension and/or replacement of the Craney Island Disposal Area located in Norfolk, Virginia.

This project was conducted for the US Army Engineer District, Norfolk (NAO), Norfolk, Virginia, and the US Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi, during the period January, 1986 to October, 1986. WES's work was authorized by IAO No. AD-86-3011 dated 10 December 1985.

Concept formulation and general supervision of the study were carried out by by Mr. T. J. Szelest, NAO, and Dr. Jack Fowler, WES, under the guidance of Mr. Ronn G. Vann, Chief, Dredging Management Branch, and Mr. Jack G. Starr, Chief, Engineering Division, NAO. Onsite technical investigations were conducted by Mr. M. T. Byrne and by Mr. D. A. Pezza, Chief, Geotechnical Branch, NAO.

This report was written by Dr. S. J. Spigolon and Dr. Jack Fowler under the general supervision of Mr. G. B. Mitchell, Chief, Engineering Group, Soil Mechanics Division (SMD), Mr. C. L. McAnear, Chief, SMD, and Dr. W. F. Marcuson III, Chief, GL.

COL Allen F. Crum, USA, was the previous Director of WES. COL Dwayne G. Lee, CE, is the present Commander and Director. Dr. Robert W. Whalin is Technical Director.

This report should be cited as follows:

> Spigolon, S. J. and Fowler, J. 1987. "Geotechnical Feasibility Study, Replacement or Extension of the Craney Island Disposal Area, Norfolk, Virginia." Miscellaneous Paper D-87-9, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.

CONTENTS

	Page
PREFACE	1
LIST OF TABLES	3
LIST OF FIGURES	4
PART I: INTRODUCTION	5
Background	5
Objective	8
Scope of Work	8
PART II: PRIOR AND CONCURRENT STUDIES	9
Long-Term Disposal Work Plan, 1985	9
Hydrodynamic Evaluation	9
Disposal Volume Study	10
Raising of Existing Dikes	11
1986 Subsurface Investigation	11
PART III: GEOTECHNICAL ENGINEERING STUDIES	12
Design and Construction Considerations	12
Foundation Soil Conditions	13
Embankment Stability	24
Construction Materials and Methods	32
Slope Erosion Protection	33
Instrumentation and Monitoring	33
PART IV: COST ESTIMATE	36
Estimates of Dike Subsidence	36
Estimates of Dike Material Volumes	36
Cost Estimates	38
PART V: CONCLUSIONS AND RECOMMENDATIONS	40
Conclusions	40
Recommendations for Further Studies	40
REFERENCES	41
APPENDIX A: TYPICAL INPUT FOR UTEXAS2 SLOPE STABILITY ANALYSIS PROGRAM	A1

LIST OF TABLES

Table		Page
1	Percentage Increase in Ebb/Flood Velocities.....	10
2	Comparison of Soil Unit Weight from 1948 and 1971 Test Boring Samples.....	20
3	Material Properties Used in Slope Stability Analyses.....	26
4	Results of Slope Stability Analyses.....	29
5	Estimated Total Dike Subsidence.....	37
6	Estimated Dike Material Volumes for Various Proposed Line Segments.....	37
7	Cost Estimate for the Alternative Configurations....	39

LIST OF FIGURES

Figure		Page
1	Project location	6
2	Alternative configurations, expansion/replacement of Craney Island Disposal Facility	7
3	Generalized subsurface profile	14
4	Boring location plan, 1971-1986 investigations	15
5	Shear strength profile, existing east dike	16
6	Shear strength profile, existing north dike	17
7	Shear strength profile, existing west dike	18
8	Shear strength profile, 1949 and 1972 borings	21
9	Shear strength profile, 1986 borings	23
10	Typical dike cross section used for slope stability studies	25
11	Assumed failure surface used in wedge analyses	28
12	Slope stability factor of safety related to cohesion at profile line (CPROFL)	31

GEOTECHNICAL FEASIBILITY STUDY
REPLACEMENT OR EXTENSION OF THE CRANEY ISLAND DISPOSAL AREA, NORFOLK, VIRGINIA

PART I: INTRODUCTION

Background

1. The Craney Island Disposal Area is a 2500 acre confined dredged fill disposal facility operated by the US Army Engineer District, Norfolk (NAO). The facility is located adjacent to and north of Portsmouth, near Norfolk, Virginia, shown in Figure 1.

2. Craney Island is the major maintenance dredged material disposal area for the Norfolk harbor and channels. It was completed in 1957 and has been used almost continuously since then. The level of the perimeter dikes has been raised several times, reaching the present elevation +26 ft MLW. The original design was for an estimated 96 million cubic yard capacity and a 20-year life for the facility.

3. Due to new plans for greatly increased harbor dredging, including both maintenance and channel deepening, the estimated life of the existing facility has been greatly reduced. Studies of the disposal problem (Norfolk District, 1985) have recommended extension of the Craney Island Disposal Area to the west and/or north. Proposals for extension have resulted in five alternative configurations, shown in Figure 2, having different estimated storage volumes.

4. The Norfolk District, with the assistance of the US Army Engineer Waterways Experiment Station (WES), is studying the replacement and/or extension of the Craney Island Disposal Area. WES is conducting four studies for NAO. The three studies other than the one reported herein are:

   a. Raising of the perimeter dikes at the existing Craney Island facility to el. +34 ft MLW raises the question of stability of the foundation of that dike system. A report is being prepared on that subject (Fowler et al, 1986).

   b. The expected storage volumes for five alternative configurations of the extension of Craney Island to the west and/or north is the subject of another WES study (Goforth, 1986). Estimated volumes from that study were used in this report.

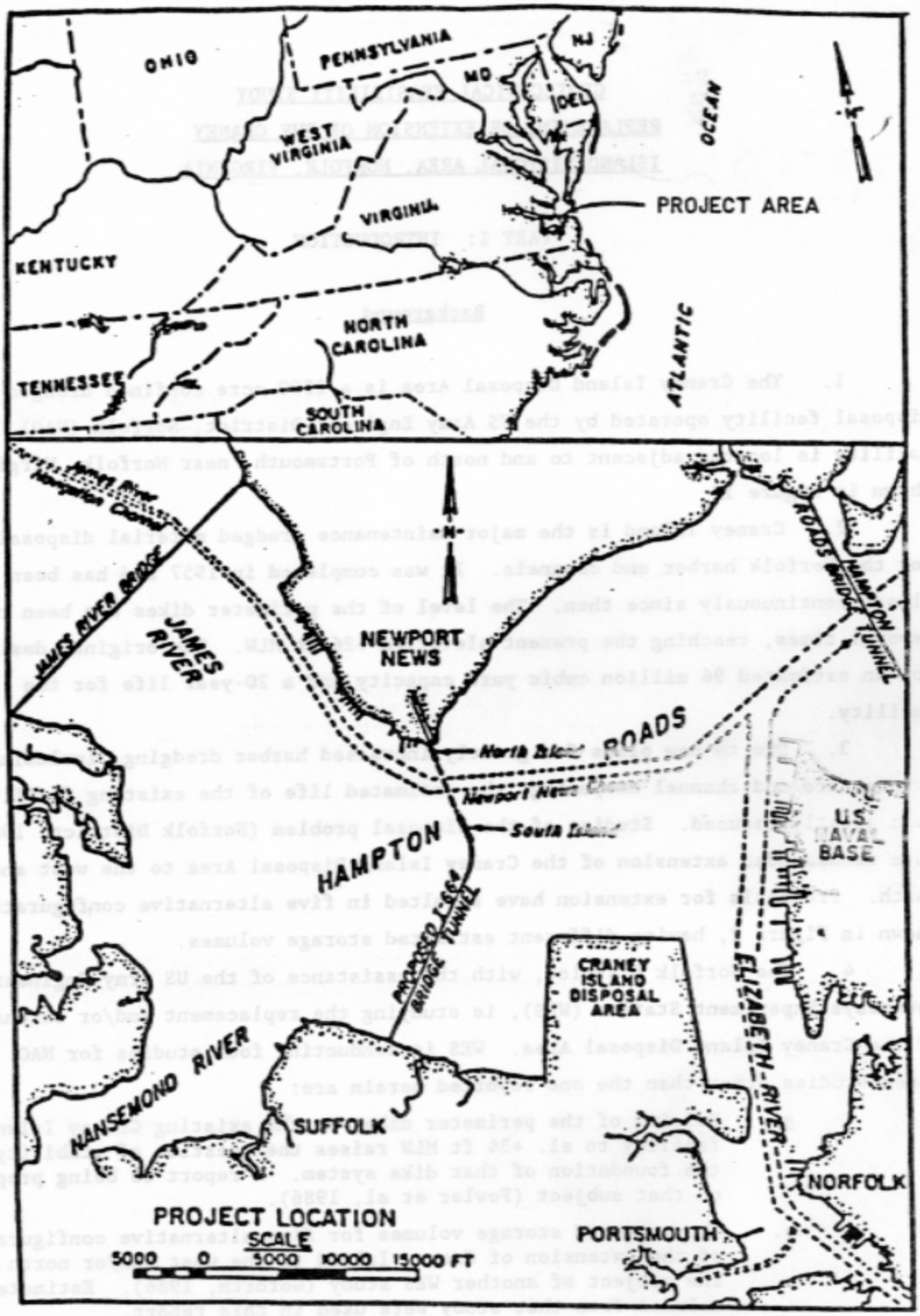


Figure 1. Project location

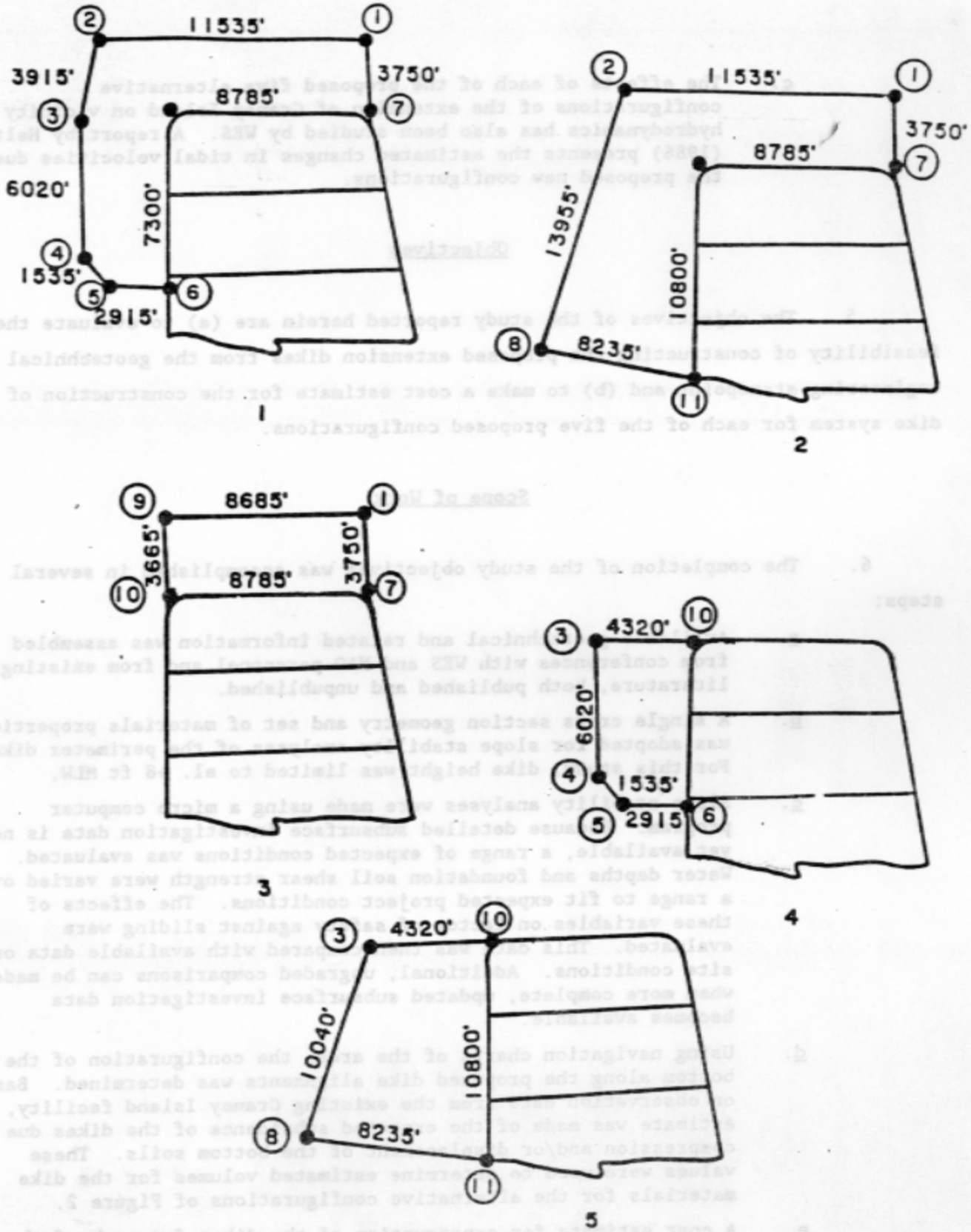


Figure 2. Alternative configurations for expansion replacement of Craney Island

c. The effects of each of the proposed five alternative configurations of the extension of Craney Island on vicinity hydrodynamics has also been studied by WES. A report by Heltzel (1986) presents the estimated changes in tidal velocities due to the proposed new configurations.

Objectives

5. The objectives of the study reported herein are (a) to evaluate the feasibility of constructing the proposed extension dikes from the geotechnical engineering standpoint and (b) to make a cost estimate for the construction of the dike system for each of the five proposed configurations.

Scope of Work

6. The completion of the study objectives was accomplished in several steps:

a. Available geotechnical and related information was assembled from conferences with WES and NAO personnel and from existing literature, both published and unpublished.

b. A single cross section geometry and set of materials properties was adopted for slope stability analyses of the perimeter dikes. For this study, dike height was limited to el. +8 ft MLW.

c. Slope stability analyses were made using a micro computer program. Because detailed subsurface investigation data is not yet available, a range of expected conditions was evaluated. Water depths and foundation soil shear strength were varied over a range to fit expected project conditions. The effects of these variables on factor of safety against sliding were evaluated. This data was then compared with available data on site conditions. Additional, upgraded comparisons can be made when more complete, updated subsurface investigation data becomes available.

d. Using navigation charts of the area, the configuration of the bottom along the proposed dike alignments was determined. Based on observation data from the existing Craney Island facility, an estimate was made of the expected subsidence of the dikes due to compression and/or displacement of the bottom soils. These values were used to determine estimated volumes for the dike materials for the alternative configurations of Figure 2.

e. A cost estimate for construction of the dikes for each of the alternative configurations was made from estimated unit costs for placement of the total volume of dike and riprap materials.

PART II: PRIOR AND CONCURRENT STUDIES

Long-Term Disposal Work Plan, 1985

7. An unpublished study entitled "Work Plan, Norfolk Harbor and Channels, Virginia, Long-Term Disposal" (Norfolk District, 1985) was prepared by NAO as part of its program of Continuation of Planning and Engineering. That report presents, in its section on Prior Studies and Reports, a discussion of two reports of importance to the project: (1) WES Technical Report EL-81-11, "Development of a Management Plan for Craney Island Disposal" (Palermo et al, 1981), which discussed the filling of the existing Craney Island facility to elevation +30 MLW and (2) a draft report by WES entitled "Effects of Norfolk Harbor Deepening on Management of Craney Island Disposal Area" (WES, 1983) which recommended extension of the facility to the west to provide for the disposal of materials from the proposed deepening project.

8. The 1985 Work Plan discussed the long term disposal problem. The channel deepening project combined with continued maintenance dredging have resulted in a two fold proposed solution: (1) raise the existing dikes to permit a fill elevation to +30 ft MLW and (2) extend the disposal area to the west. The 1985 Work Plan states... "the need for expanding and/or replacing the Craney Island Disposal Area is now critical."

9. The 1985 Work Plan recommended that several studies be made to help resolve the long term disposal problems facing Hampton Roads. Within the study area of "Engineering and Design Studies", the 1985 Work Plan report recommended "Preliminary Engineering Studies of Construction Techniques and a Construction Cost Estimate", which is the subject of the present report.

Hydrodynamic Evaluation

10. A study titled "Norfolk Harbor Long Term Disposal Study, Virginia, Evaluation of Craney Island Enlargement Alternatives" (Heltzel, 1986) was made by the Hydraulics Laboratory, WES, of the effects of four of the proposed alternative configurations of Craney Island on the vicinity hydrodynamics in the lower James River (Hampton Roads). The four configurations used were numbers 1, 2, 3, and 4 shown in Figure 2.

11. Each of the four proposed configurations was considered with and without the presence of the proposed Newport News Island. Newport News Island is a proposed new disposal facility just east of North Island and north of Newport News Channel. Each configuration was analyzed theoretically for its effect on maximum ebb/flood velocities at three selected locations in the Newport News Channel north of Craney Island just east of the proposed I-664 Bridge Tunnel. Location No. 1 is just east of North Island. Location No. 2 is due north of the west leg of Craney Island. Location No. 3 is due north of the east leg of Craney Island. The percentage increases in ebb/flood velocities are shown in Table 1.

Table 1

Percentage Increase in Ebb/Flood Velocities

(Heltzel, 1986)

Alternative	Location No. 1		Location No. 2		Location No. 3	
	Ebb	Flood	Ebb	Flood	Ebb	Flood
1	10%	14%	19%	17%	8%	4%
1-N*	10%	33%	30%	19%	9%	1%
2	11%	13%	21%	11%	9%	0
2-N	11%	28%	36%	13%	11%	0
3	4%	7%	12%	11%	11%	4%
3-N	4%	22%	23%	12%	12%	1%
4	2%	2%	3%	0	1%	0
4-N	1%	14%	11%	1%	0	0

* Alternative with Newport News Island.

12. The report concludes that Alternative No. 4, which has no northern protrusion, will cause the least impact on general circulation in the lower James River. However, none of the other configurations, especially without Newport News Island, is estimated to cause detrimental change.

Disposal Volume Study

13. Another study by WES that is currently in the draft stage presents calculations of the storage volumes to be expected for each of the five alternative configurations. The working draft is entitled "Disposal Life

Evaluation of Alternative Expansion Configurations for Craney Island Disposal Facility" (Goforth, 1986).

14. The study assumed two exterior dike elevations, +8.0 ft MLW for the first filling, followed by extended filling at +34.0 ft MLW. The higher elevation assumes the dredged material has consolidated to +1.5 ft MLW and that the secondary dikes will be placed about 364 ft inboard from the centerline of the primary dikes. The report also presents suggested management guidelines. The volume estimates contained in the Goforth (1986) report are included in Table 7 of this report.

Raising of Existing Dikes

15. A study has been made by the Geotechnical Laboratory, WES, of the foundation stability of the proposed final perimeter dikes to be used to raise the existing Craney Island facility to +34 ft MLW. The study report is in working draft form and is titled "Perimeter Dike Stability Analysis, Craney Island, Norfolk District." (Fowler et al, 1986).

16. It was concluded that it is technically feasible to raise the west perimeter dike from +26 ft MLW to +34 ft MLW with a factor of safety of at least 1.20 provided sand berms are placed outboard of the higher dikes, i.e., the berms would be placed on the existing roadway, and that additional sand berms would be placed in the water adjacent to the west perimeter dike.

17. It was also concluded that it is technically feasible to raise the east and north perimeter dikes to elevation +40 ft MLW with a factor of safety in excess of 1.30 provided the dike crests are set back 420 to 450 ft, respectively.

1986 Subsurface Investigation

18. Seven test borings were made by NAO in late 1986 along the proposed north alignment of the expansion of Craney Island, alternative 3, Figure 2. Preliminary logs of the borings have been made available to the authors by NAO (Personal Communication, November, 1986, M. T. Byrne, Geotechnical Branch, US Army Engineer District, Norfolk). The investigation included the procurement of tube samples and laboratory unconfined compression or Q-triaxial compression tests of the marine clays.

PART III: GEOTECHNICAL ENGINEERING STUDIES

Design and Construction Considerations

19. Embankment design considerations for the perimeter dikes, as given in Chapter 6 of Engineer Manual EM 1110-2-5027, "Confined Dredged Material Disposal" (Office, Chief of Engineers, 1987), include: project constraints; foundation conditions; dike stability and settlement; construction materials and methods, and erosion control.

20. Discussion of project constraints, such as time, funding, location, height, available space, environmental safety, and aesthetics, is beyond the scope of this report.

21. The major design and construction concern of this study, from the geotechnical engineering standpoint, is the structural stability of the perimeter dike. The stability is, in turn, directly dependent on the shear strength of the soft harbor bottom marine clays and the rate at which strength will increase under the load of the gradually placed fill. Foundation conditions must be established regarding soil stratification and the lateral and vertical distribution of shear strength, compressibility, and permeability, both horizontal & vertical.

22. Embankment stability and settlement are functions of foundation soil conditions, embankment geometry, and the embankment fill soils and their method of placement. Stability analyses must consider the amount and rate of change in foundation soil strength due to compression of the soil during placement of the embankment.

23. Because filling operations for the extension of Craney Island will take place in water having a depth of 0 to over 30 ft, the type of fill materials used in embankment construction, and the method of placement, will have a great effect on dike stability.

24. These topics: foundation soil conditions, embankment stability, construction materials and methods, as well as slope erosion protection and suggested instrumentation and monitoring, are discussed in the following sections.

Foundation Soil Conditions

25. A generalized north-south soil profile through the existing Craney Island Disposal Area (Palermo et al, 1981) is shown in Figure 3. The soil profile indicates a firm bottom at elevation -90 ft MLW consisting of dense sands and silty sands. Above the sands is a layer of marine clay. Harbor bottom in the study area for the present report is at about zero ft MLW to -32 ft MLW. Therefore, the marine clays are about 90 to 58 ft thick. For purposes of this study, the dense sand and underlying materials are considered a hard, incompressible layer.

26. Fowler (1986) presented a summary of the results of geotechnical subsurface investigations made in the area of the Craney Island Disposal Area during the period from 1944 to 1983. Additional subsurface investigations, for the proposed expansion area, have only been partially completed by NAO. These new investigations, made in late 1986, have verified that the marine clay deposits are very soft, nearly liquid, at the mud line and increase in shear strength with depth.

27. For clarity and continuity of presentation, several figures from the Fowler (1986) report are included in the present report. These are:

a. Figure 4, Boring Location Plan, showing the locations of test borings made during the 1971, 1981, and 1983 subsurface investigations of the existing Craney Island. The locations of the 1986 series of preliminary borings has been added.

b. Figures 5, 6, and 7, Shear Strength Profile, Existing East, North, and West Dike, respectively, displaying the combined results of field vane shear tests and laboratory triaxial compression tests of tube samples from the 1971, 1981, and 1983 subsurface investigations of Figure 4.

28. The marine clay layer is a continuous stratum of recent marine sediments which are presumed to be normally consolidated, i.e., they have never experienced a greater load than that imposed by their own weight. Therefore, it would be expected that soil unit weight would be lowest (void ratio highest) at the present harbor bottom (profile line) and increase (void ratio decrease) with depth. Concomitantly, shear strength should increase with depth. Assuming a relatively constant type of clay mineral, the actual shear strength may vary from point to point as a result of natural variations in sand and/or silt content

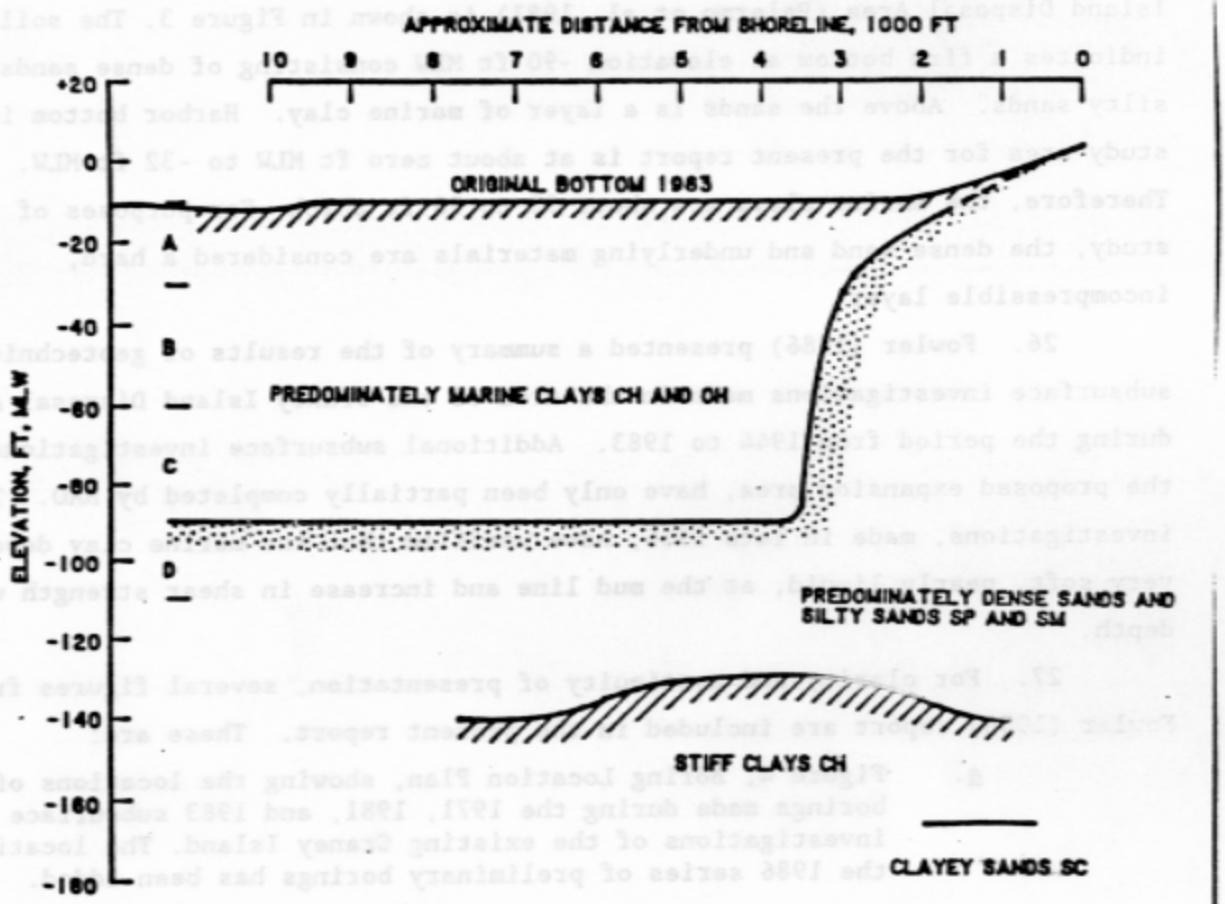


Figure 3. Generalized subsurface profile within the matrix

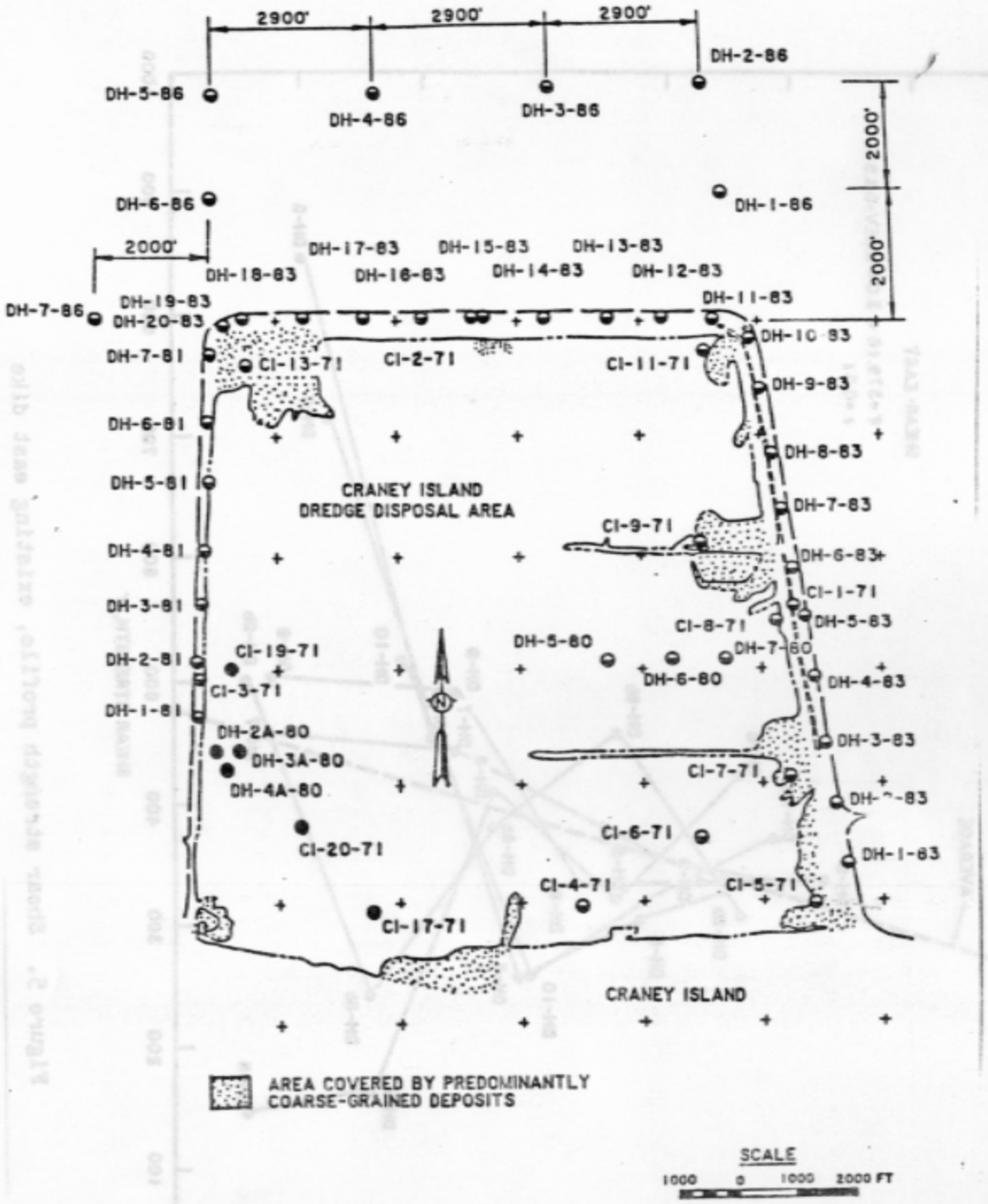


Figure 4. Boring location plan, 1971-1986 investigations

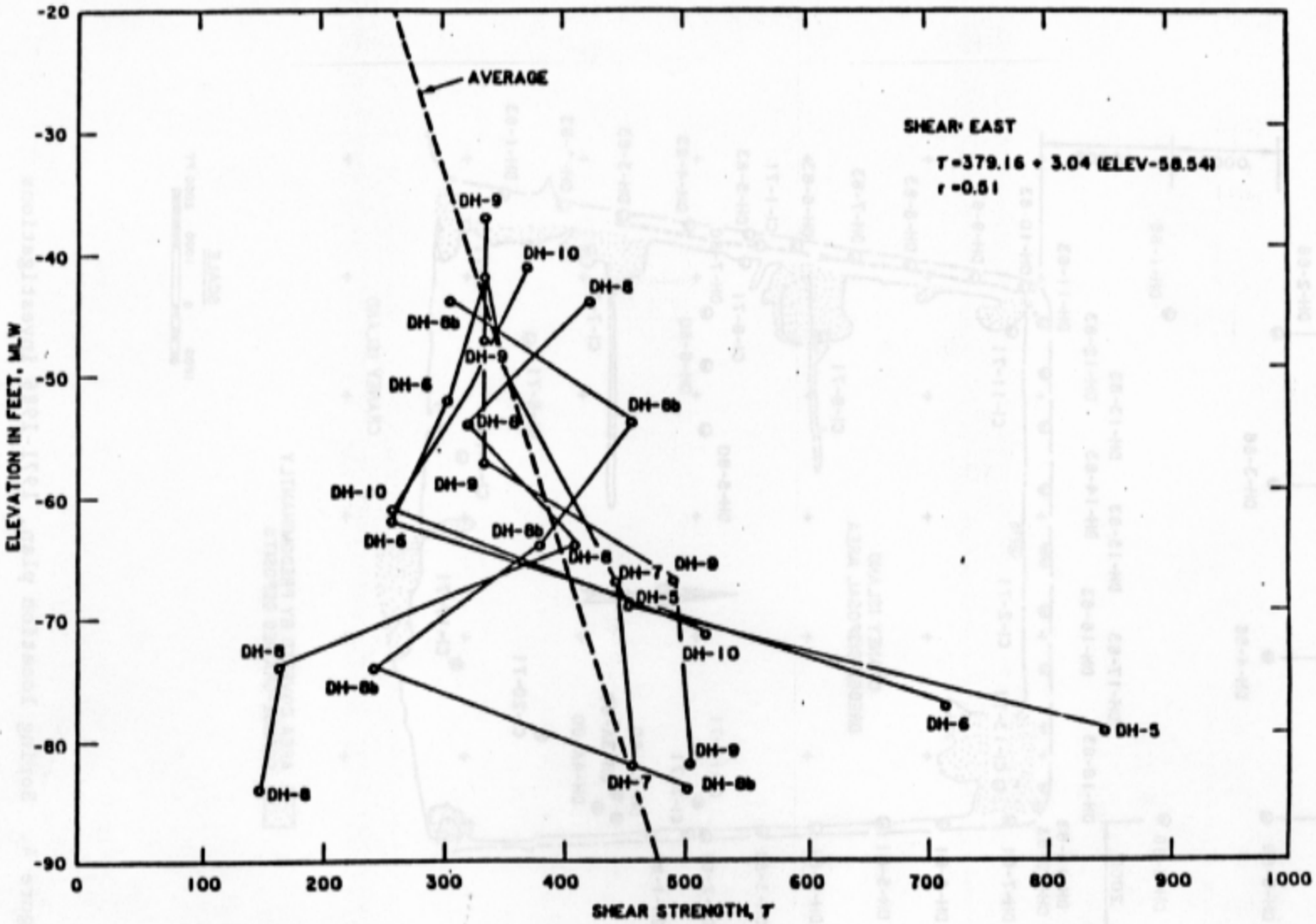


Figure 5. Shear strength profile, existing east dike

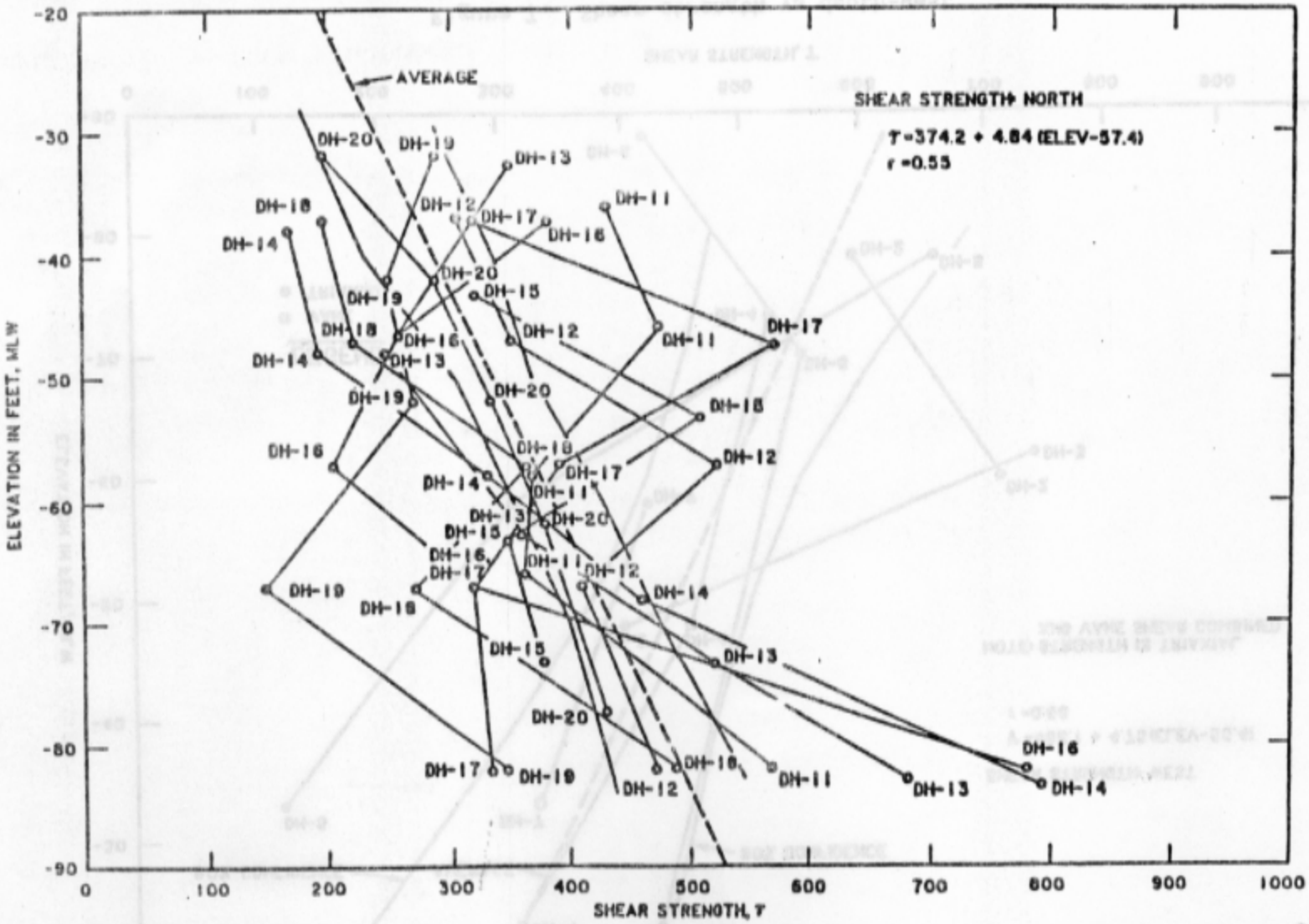


Figure 6. Shear strength vs depth-north

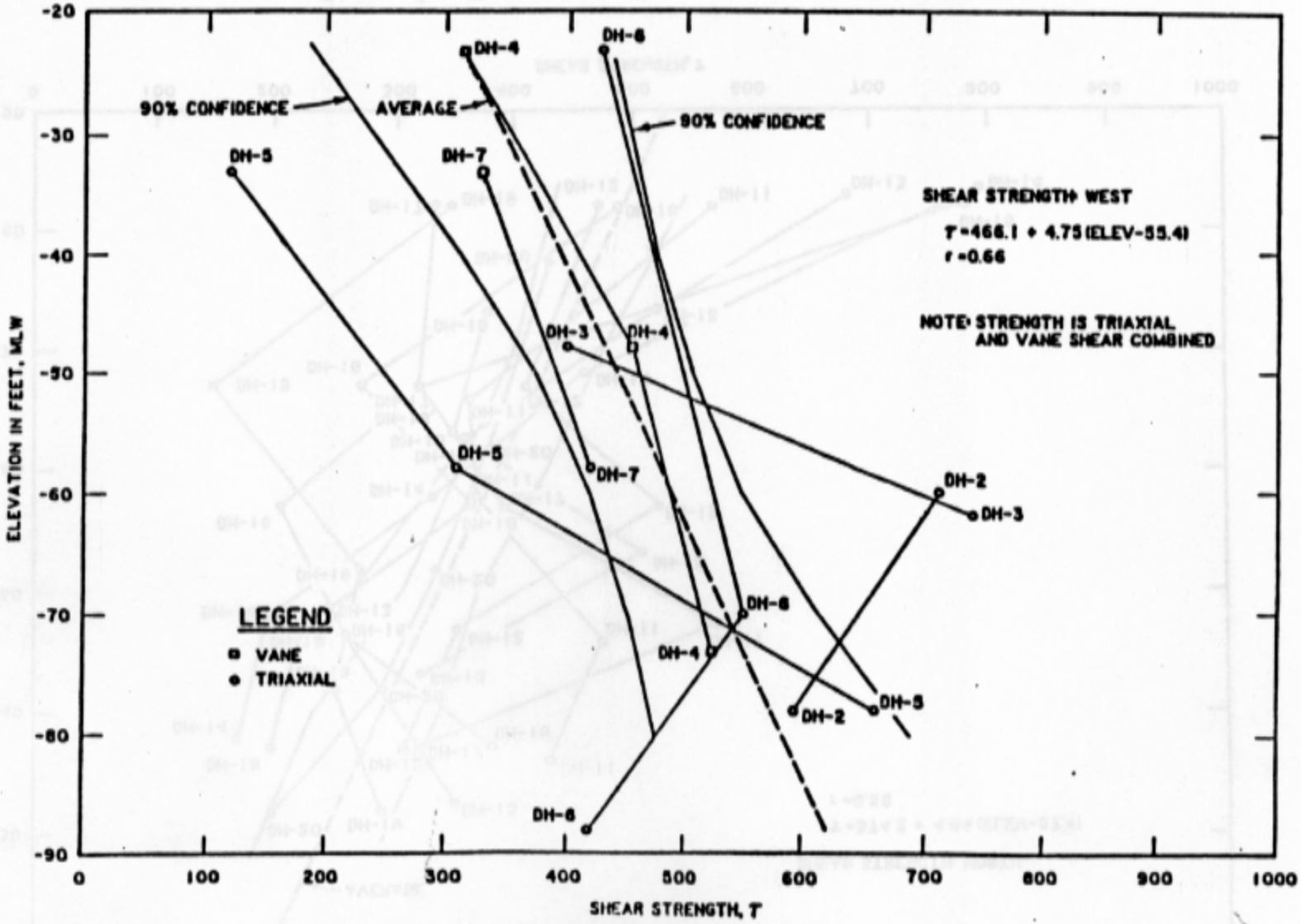


Figure 7. Shear strength vs depth-west

within the matrix clay, with variation in the consolidating pressure from overlying soils, and with the organic content. The Atterberg limits, i.e., liquid limit and plasticity index, will vary directly with the amount of clay mineral and the amount and type of organic matter.

29. The gradual placement of the weight of the sand fill should have the effect of densifying the soil, with its concomitant strength increase, at a rate that will permit the soil to support the load without failure. A statistical relationship has been found between the undrained shear strength (cohesion) of saturated clays, the effective overburden pressure, and the plasticity index of the clay. This the Skempton (1948) c/p ratio in which the cohesion, $c = p'(0.11 + 0.0037\ PI)$, where p' = effective overburden pressure and PI = plasticity index.

30. The extent to which this effect may be expected to occur may be seen by reviewing data from the existing Craney Island facility. A group of tube sample borings was made in 1948-49 along the perimeter dike area prior to construction. The General Design Memorandum (Norfolk District, 1953, p. I-5) stated... "The initial exploration consisted of five drill holes numbered 22 through 26 spaced approximately 5,000 feet apart along the dike centerline..." and... "A second series of drill holes, numbered 81 through 86, located along the dike centerline and spaced midway between the previous five holes...." In an internal memorandum regarding the proposed raising of the Craney Island dikes (Report of Soil Testing, 20 November 1972, Norfolk District, Corps of Engineers) the NAO recorded the results of tube sample tests from three borings made in 1971, CI-1, CI-2, and CI-3, including unconfined compression tests. The locations of these borings are shown on Figure 4. The memorandum compared samples from the 1948 and the 1971 borings from about the same elevation in borings at about the same location. The only data that was amenable to direct comparison regarding consolidation effects was the dry unit weight of the tube samples. This comparison is shown in Table 2. Although this data is not definitive, the comparisons do indicate a general increase in dry unit weight after placement of the dikes. Presumably, this also indicates an increase in shear strength.

31. Figure 8 combines data from the 1949 and 1971 subsurface investigations, which were both made along the centerline of the now-existing dikes. The 1949 borings, 81, 82, 83, and 84, included tube samples and unconfined compression tests. Samples from the three borings from the 1971

series, CI-1, CI-2, and CI-3, also had unconfined compression tests. Taken as a group, the least squares best fitting line to the 1949 test data indicated: (a) the shear strength at the mud line was nearly zero, (b) the average cohesion at el -90 MLW was 177 PSF, and (c) the cohesion increased with depth at an average

Table 2

Comparison of Soil Unit Weight

1948 and 1971 Test Boring Samples

Drill Hole No.	Year Made	Sample No.	Elevation Feet, MLW	Dry Unit Weight, PCF
22	1948	3	-31 to -33	50.2
CI-1	1971	U-9	-26 to -28	59.8
22	1948	10	-72 to -74	48.1
CI-1	1971	U-16	-61 to -63	51.3
23	1948	6	-31 to -33	46.4
CI-3	1971	U-10	-35 to -37	58.0
23	1948	10	-47 to -49	48.4
CI-3	1971	U-12	-43 to -45	51.4
26	1948	2	-29 to -31	55.5
CI-2	1971	U-9	-31 to -33	59.9
26	1948	12	-84 to -86	57.6
CI-2	1971	U-18	-72 to -74	52.4

rate of about 1.9 PSF per foot of depth. The 1971 data in Figure 8 shows a significant increase in shear strength with consolidation of the clays under the weight of the dikes. Further comparison of "before and after" shear strength is obtained by comparing the 1949 borings of Figure 8 with the data of Figures 5, 6, and 7 for the 1981 to 1983 subsurface investigations. All of the data from 1971 to 1983 indicates an average shear strength at Elevation -15 MLW of 170 to 288 PSF and an average shear strength at Elevation -90 MLW of 293 to 630 PSF, with a rate of increase 3.0 to 4.8 PSF per foot of depth. Some of the data of Figures 5 and 6,

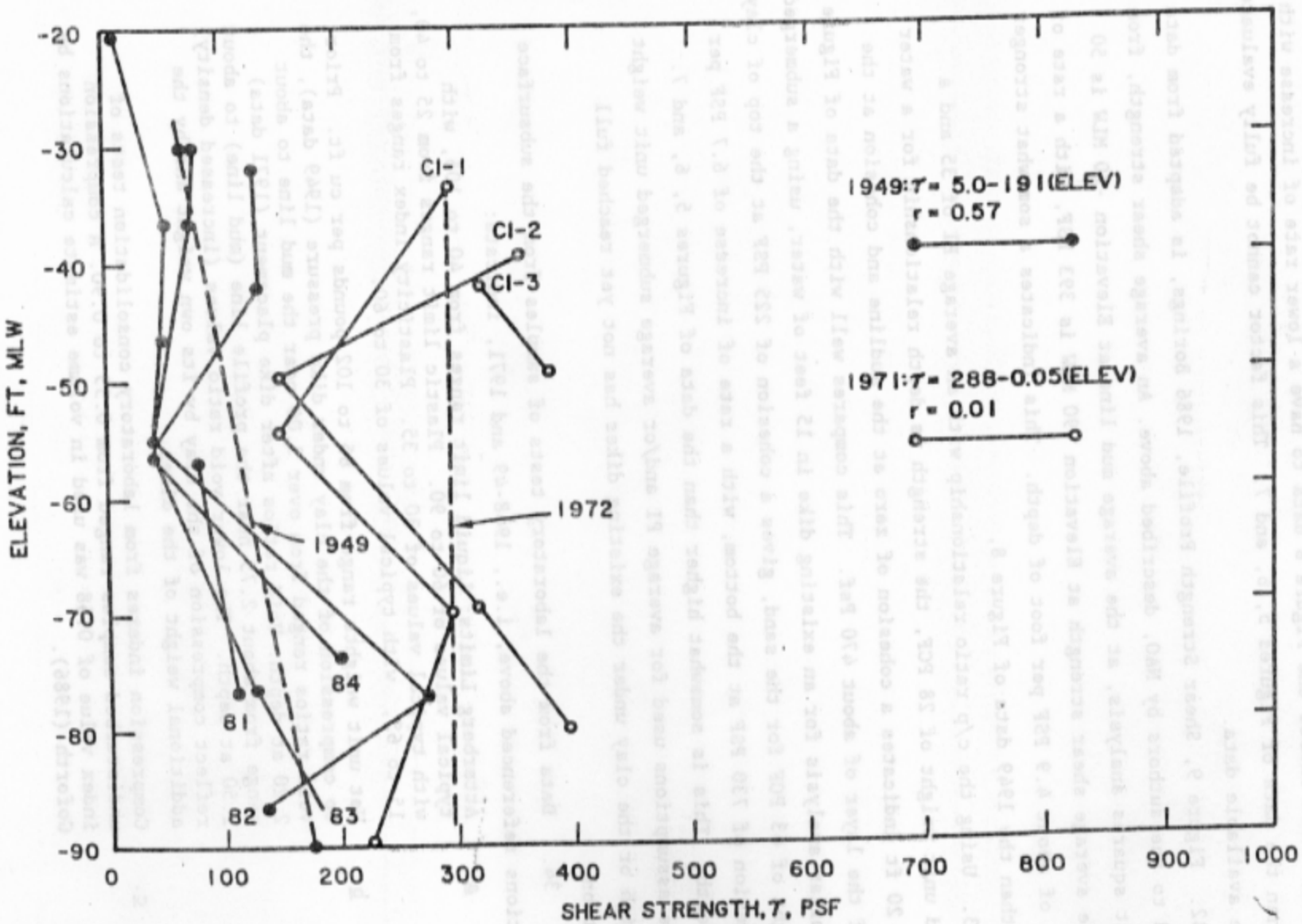


Figure 8. Shear strength profile, 1949 and 1971 borings

and all of the data of Figure 8, tend to show a soft zone at about Elevation -50 to -60 MLW, which causes the Figure 8 data to have a lower rate of increase with depth than the data of Figures 5, 6, and 7. This factor cannot be fully evaluated with the available data.

32. Figure 9, Shear Strength Profile, 1986 Borings, is adapted from data provided to the authors by NAO, described above. An average shear strength, from the least squares analysis, at the average mud line at Elevation -20 MLW is 50 PSF. The average shear strength at Elevation -90 MLW is 393 PSF, with a rate of increase of about 4.9 PSF per foot of depth. This indicates a somewhat stronger profile than the 1949 data of Figure 8.

33. Using the c/p ratio relationship with an average PI of 35 and a submerged unit weight of 28 PCF, the strength vs depth relationship for a water depth of 20 ft indicates a cohesion of zero at the mudline and cohesion at the bottom of the layer of about 470 Psf. This compares well with the data of Figure 9. A similar analysis for an existing dike in 15 feet of water, using a submerged unit weight of 63 PCF for the sand, gives a cohesion of 225 PSF at the top of clay and a cohesion of 730 PSF at the bottom, with a rate of increase of 6.7 PSF per foot of depth. This is somewhat higher than the data of Figures 5, 6, and 7. Either the assumptions used for average PI and/or average submerged unit weight are too high or the clay under the existing dikes has not yet reached full consolidation.

34. Data from the laboratory tests of samples from the subsurface investigations referenced above, i.e., 1948-49 and 1971, indicate:

a. Atterberg Limits: Liquid limit ranges from 40 to 105, with typical values of 60 to 90. Plastic limit ranges from 25 to 40, with typical values of 30 to 35. Plasticity index ranges from 15 to 65, with typical values of 30 to 60.

b. Wet unit weights range from 85 to 102 pounds per cu ft. Prior to compression of the clay under dike pressure (1949 data), the void ratios ranged from over 3.00 near the mud line to about 2.20 at depth. Void ratios after dike placement (1971 data) range from about 2.75 near the profile line (mud line) to about 1.50 at depth. The lower void ratio values (increased density) reflect compression of the clay by its own weight and by the additional weight of the dikes.

c. Compression indexes from laboratory consolidation tests of undisturbed samples ranged from 0.55 to 0.90. A compression index value of 0.58 was used in volume estimate calculations by Goforth (1986).

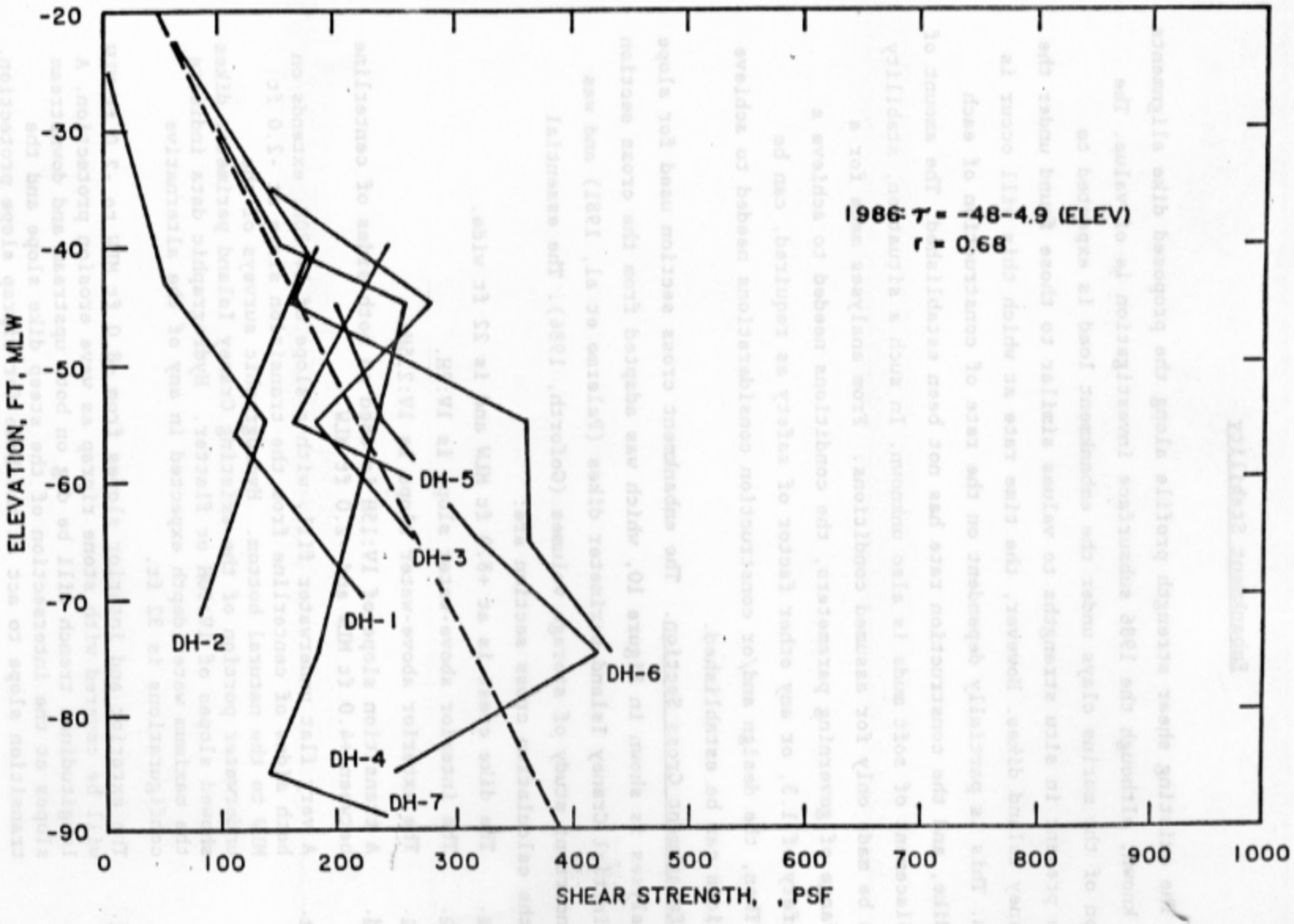


Figure 9. Shear strength profile, 1986 borings

Embankment Stability

35. The existing shear strength profile along the proposed dike alignments is not well known, although the 1986 subsurface investigation is of value. The consolidation of the marine clays under the embankment load is expected to increase the present in situ strengths to values similar to those found under the existing Craney Island dikes. However, the time rate at which this will occur is also unknown. This is partially dependent on the rate of construction of each segment of dike, and the construction rate has not been established. The amount of lateral displacement of soft muds is also unknown. In such a situation, stability analyses can be made only for assumed conditions. From analyses made for a reasonable range of governing parameters, the conditions needed to achieve a factor of safety of 1.3, or any other factor of safety as required, can be determined. Then, the design and/or construction considerations needed to achieve those conditions can be established.

36. Embankment Cross Section. The embankment cross section used for slope stability analyses is shown in Figure 10, which was adapted from the cross section used in the initial Craney Island perimeter dikes (Palermo et al, 1981) and was used in a concurrent study of storage volumes (Goforth, 1986). The essential elements of the calculation cross section are:

a. The dike crest is at +8.0 ft MLW and is 22 ft wide.

b. The interior above-water slope is 1V:2H.

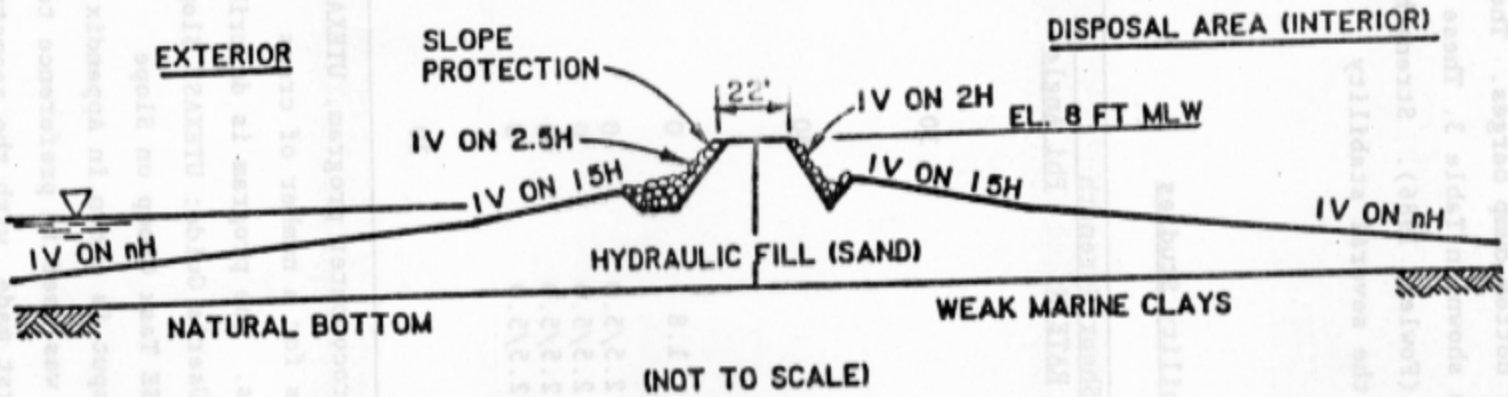
c. The exterior above-water slope is 1V:2.5H.

d. A transition slope of 1V:15H is used on both sides of centerline between +4.0 ft MLW and -2.0 ft MLW.

e. A very flat underwater fill, with a slope of 1V:30H, extends on both sides of centerline from the transition slope at -2.0 ft MLW to the natural bottom. Hydrographic surveys of the underwater portion of the existing Craney Island perimeter dikes showed slopes of 1V:30H or flatter. Hydrographic data indicate the maximum water depth expected in any of the alternative configurations is 32 ft.

f. The exterior and interior slopes from +8.0 ft MLW to -2.0 ft MLW will be covered with stone riprap as wave erosion protection. A longitudinal trench will be dug on both upstream and downstream slopes at the intersection of the steep dike slope and the transition slope to act as the base for riprap slope protection.

37. Embankment Materials. It is assumed that the entire embankment, above and below water level, will be made of sand. The sand below water level will be



(NOT TO SCALE)

NOTE: (a) UNDERWATER FILL SLOPE VARIES 1V:30H TO 1V:70H.
(b) MAXIMUM WATER DEPTH ALONG THE DIKE ALIGNMENT IS 34 FT.

EXTERIOR SLOPE-RIPRAP, 24 IN. THICK WITH A NOMINAL STONE SIZE OF 1000 LB.
PROTECTION-BEDDING LAYER, 9-IN. THICK CRUSHED ROCK; GEOTEXTILE.

INTERIOR SLOPE-RIPRAP, 12-IN. THICK WITH A NOMINAL STONE SIZE OF 200 LB.
BEDDING LAYER, 9-IN. THICK CRUSHED ROCK; GEOTEXTILE.

Figure 10. Typical dike cross section used for slope stability studies

placed hydraulically, either by dredging discharge or bottom dump barges. The material properties used in the computer analyses are shown in Table 3. These are the same or similar properties used in other studies (Fowler, 1986). Strength properties for the marine clay layer were varied for the several stability analyses.

Table 3.

Material Properties Used in Slope Stability Studies

Material	Unit Weight lb/cu ft	Type	Shear Strength CPROFL	RATEIN	Phi Angle
Moist Embankment Sand	110	Conventional Shear Str.	0		30
Saturated Embankment Sand	125	Conventional Shear Strength	0		30
Consolidating Dredged Material	90	Linear Increase w/Depth	35	1.8	0
Soft Marine Bottom Clay	100	Linear Increase w/Depth	200 250 300 350	2.5/5.0 2.5/5.0 2.5/5.0 2.5/5.0	0 0 0 0
Dense Base Sand	125	Conventional Shear Str.	0		30

38. Stability Analysis Computer Program. A microcomputer program, UTEXAS2, Version 1.109, was used in slope stability calculations for a number of cross section configurations for the proposed perimeter dikes. The program is described in the draft WES Instructional Report GL-86 entitled "User's Guide: UTEXAS2 Slope Stability Package; Volume 1, User's Manual" (CAGE,G-CASE Task Group on Slope Stability, 1986). A typical UTEXAS2 computer program input is shown in Appendix A.

39. The wedge method of analysis (noncircular) was used in preference to the circular arc method. A number of analyses were first made, with the geometry and materials properties described above, using the UTEXAS2 program in Circular Arc (automatic) Search mode. In all cases tried, numerous error messages appeared indicating that the portion of the failure arc entering and exiting the

embankment surface was at too steep an angle, not utilizing the shear strength of the sand, and indicating an invalid factor of safety that is far too low. The critical failure circles had centers just above or just below the outside toe of the above-water slope. The effect was that of a shallow bearing capacity failure of a footing (the above-water dike) over a sand layer underlain by a soft clay layer.

40. In the sand embankment, the critical failure surface should approximate an active pressure surface at an angle of about 60° from the horizontal at the driving end and a passive pressure surface at an angle of about 30° from the horizontal at the resisting end. The bottom of the central portion, between the active and passive wedges, may be a horizontal line in the softest part of the clay layer, or it may be an arc of a circle extending downward into the clay layer at some depth, or it may be some form of noncircular surface between these limits.

41. The geometry of the assumed failure surface for the wedge analyses is shown in Figure 11. Points 1 and 2, in the passive pressure wedge, were allowed to move horizontally only. The maximum passive surface angle permitted was 40° from the horizontal. Points 3 and 4, in the central failure zone, were allowed to move vertically during the automatic search so that any geometry from a horizontal line to a circular arc could be approximated. Point 5 was fixed at a position where the greatest active pressure could be generated. Point 6 was allowed to move horizontally to establish the active pressure surface.

42. Slope Stability Analyses. Thirty six slope stability analyses, using the wedge method, were made for this study: 3 values of CPROFL, 3 values of RATEIN, and 4 values of water depth. All analyses were for the end of construction condition, i.e., the full embankment is in place.

43. The assumed values of undrained shear strength at the surface of the marine clay layer, expressed as "cohesion at the profile line" (CPROFL), were 100, 200, and 300 pounds per square foot. The values for rate of increase (RATEIN) of cohesion with depth were zero, 2.5, and 5.0 lbs per sq ft per ft of depth.

44. Water depths of 5 ft, 15 ft, 25 ft, and 35 ft from mean low water to the natural harbor bottom were used. This range of values was determined from National Oceanic Atmospheric Administration (NOAA) charts of the area.

45. Results of the slope stability analyses using the various criteria given above are presented in Table 4.

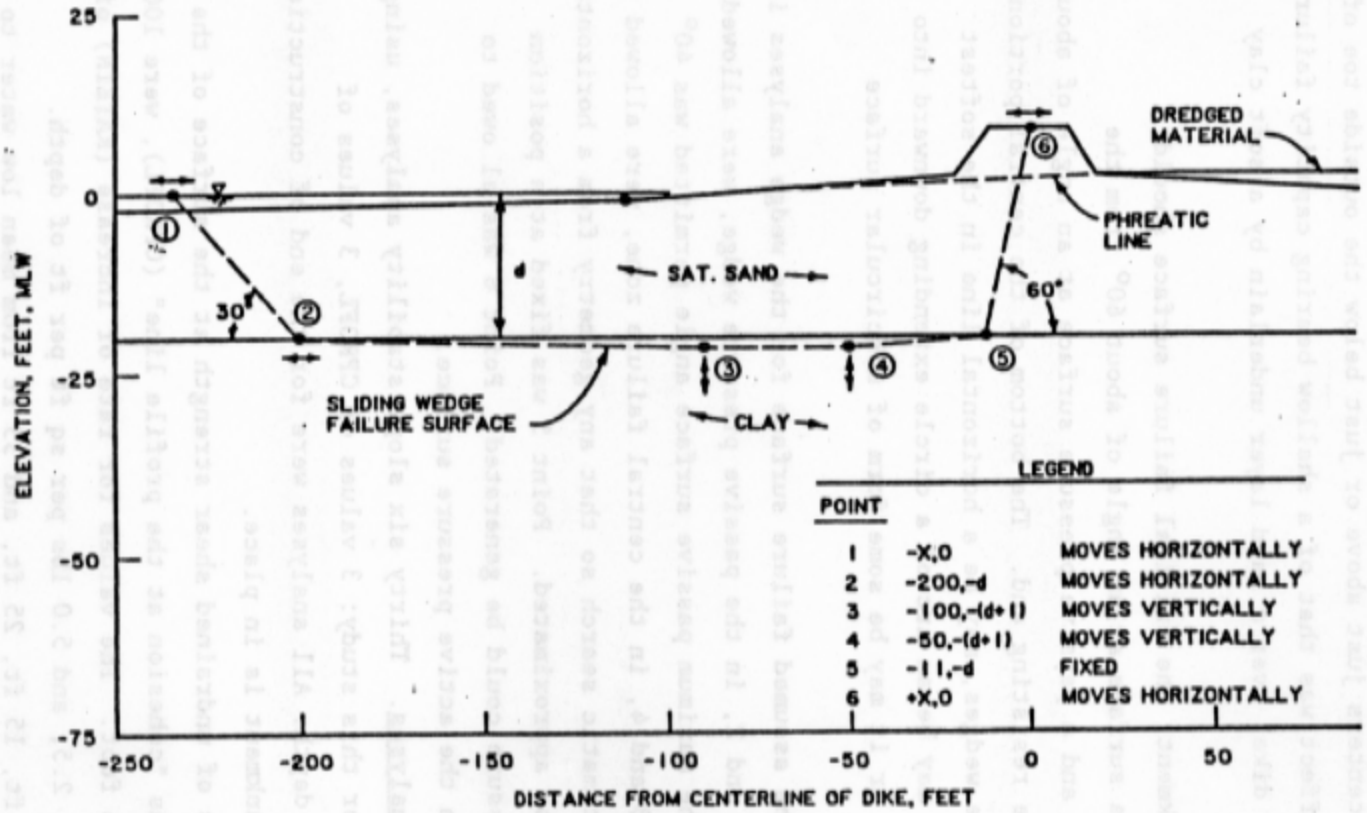


Figure 11. Assumed failure surface used in wedge analyses

Table 4.

Results of Slope Stability Analyses

Profile Depth Ft. MLW	Cohesion at Profile Depth CPROFL, PSF	Rate of Increase of Cohesion with Depth RATEIN, PSF/Ft	Factor of Safety
-05	100	0.0	0.971
-05	100	2.5	1.359
-05	100	5.0	1.571
-05	200	0.0	1.846
-05	200	2.5	2.220
-05	200	5.0	2.464
-05	300	0.0	2.698
-05	300	2.5	3.031
-05	300	5.0	3.250
-15	100	0.0	0.911
-15	100	2.5	1.330
-15	100	5.0	1.550
-15	200	0.0	1.650
-15	200	2.5	2.000
-15	200	5.0	2.110
-15	300	0.0	2.323
-15	300	2.5	2.582
-15	300	5.0	2.675
-25	100	0.0	1.155
-25	100	2.5	1.656
-25	100	5.0	1.927
-25	200	0.0	1.887
-25	200	2.5	2.234
-25	200	5.0	2.557
-25	300	0.0	2.446
-25	300	2.5	2.760
-25	300	5.0	2.970
-35	100	0.0	1.323
-35	100	2.5	1.743
-35	100	5.0	2.164
-35	200	0.0	2.469
-35	200	2.5	2.857
-35	200	5.0	3.229
-35	300	0.0	3.539
-35	300	2.5	3.922
-35	300	5.0	4.292

46. Discussion. The effect of three variables on factor of safety was considered in the stability analyses: cohesion at the profile line (CPROFL), rate of increase of cohesion with depth (RATEIN), and depth of water at mean low water level. Figure 12 contains graphs of the data of Table 4, with separate graphs of factor of safety vs CPROFL for each of the four water depths studied.

47. The most significant variable in the determination of factor of safety was the cohesion at the profile line (CPROFL). The factor of safety increased from 0.75 to 1.1 times for each 100 PSF increase in strength. The rate of increase of shear strength with depth (RATEIN) also significantly affected factor of safety. When the RATEIN was zero, points 3 and 4 of Figure 11 extended almost to the bottom of the marine clay layer, approximating a circular arc failure mode. As RATEIN increased to 2.5 PSF/FT, points 3 and 4 rose higher, and at 5.0 PSF/FT rose almost to the surface of the clay layer, more closely approximating a sliding wedge failure, causing the active and passive wedges to move further apart. Variation in depth to natural bottom caused a slight increase in factor of safety as the thickness of the sand embankment (depth) increased greater than about 15 ft. This effect occurs because of the greater tolerance of the thicker sand layers to the non-uniform loading of the dike configuration.

48. All evidence, including the data of Figures 8 and 9, indicates that RATEIN of zero is not to be expected. Rather, RATEIN ranged from 1.9 to 4.9 PSF/FT in the 1949 and 1986 subsurface investigation data. Therefore, all that is needed to support the design embankment at shallow depths, about 15 ft or less, is a CPROFL of about 100 PSF at the end of construction. As the depth becomes greater than 15 to 20 ft, the needed value drops to 70 PSF. Cohesive strength of this magnitude is nearly present in the clay layer under the deeper waters before placement of the embankment. With gradual placement of the sand, consolidation settlement and displacement of the very soft muds should provide a very safe supporting environment for the embankments placed in waters over about 15 ft deep.

49. Assuming that clay shear strengths are the same for new embankments as is shown in Figures 8 and 9, then for embankments under 15 to 20 ft thick a factor of safety of 1.3 against failure depends on increasing the CPROFL strength to at least 100 PSF by the end of construction by means of displacement of the softest muds followed by consolidation under the embankment load. The rate of

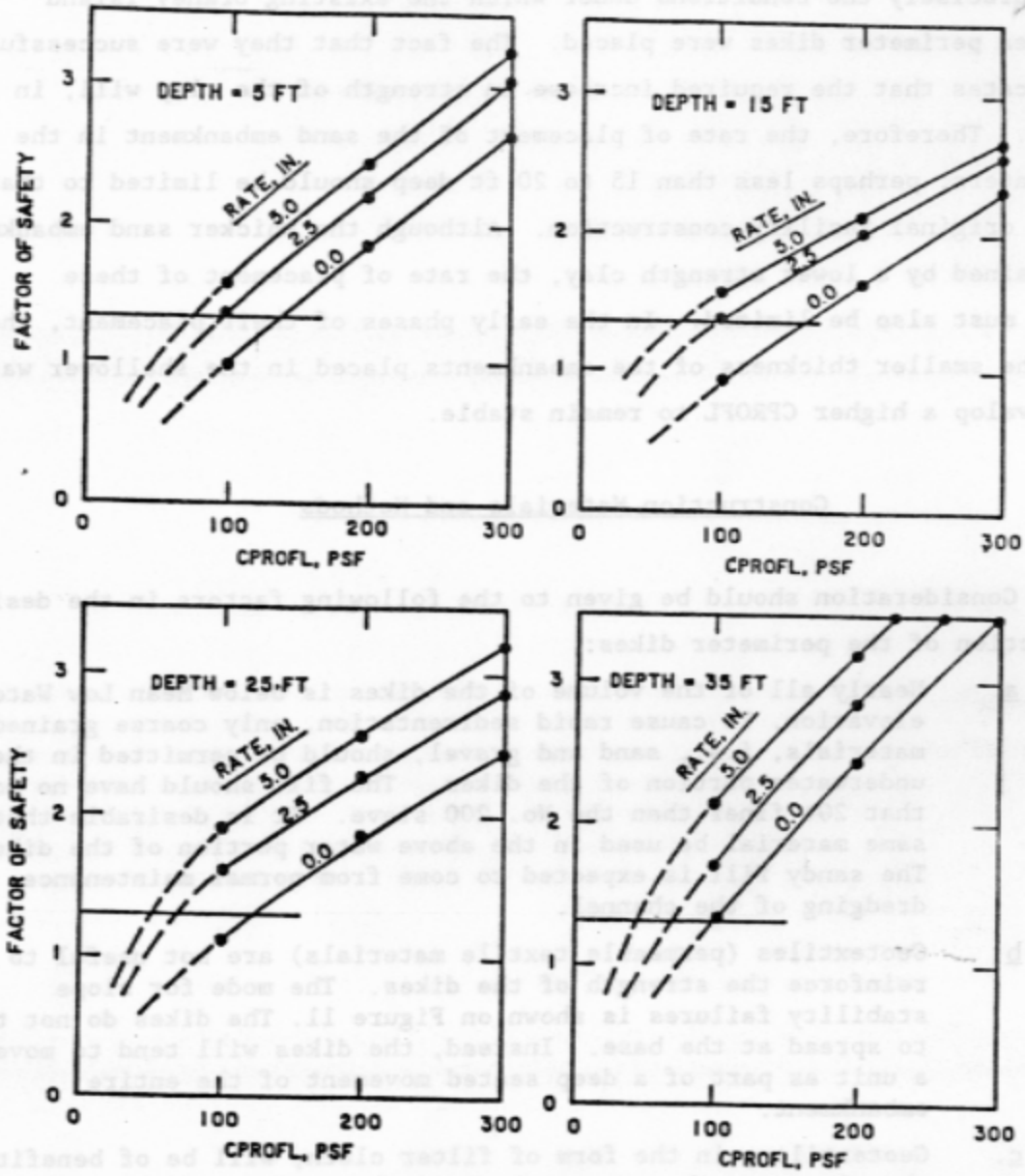


Figure 12. Slope stability factor of safety related to cohesion at profile line (CPROFL)

loading needed to achieve this cannot be determined from existing data. However, these were precisely the conditions under which the existing Craney Island Disposal Area perimeter dikes were placed. The fact that they were successfully placed indicates that the required increase in strength of the clay will, in fact, be achieved. Therefore, the rate of placement of the sand embankment in the shallower waters, perhaps less than 15 to 20 ft deep should be limited to that used in the original facility construction. Although the thicker sand embankments can be sustained by a lower strength clay, the rate of placement of these embankments must also be limited. In the early phases of their placement, they also have the smaller thickness of the embankments placed in the shallower waters and must develop a higher CPROFL to remain stable.

Construction Materials and Methods

50. Consideration should be given to the following factors in the design and construction of the perimeter dikes:

a. Nearly all of the volume of the dikes is below Mean Low Water elevation. To cause rapid sedimentation, only coarse grained materials, i.e., sand and gravel, should be permitted in the underwater portion of the dikes. The fill should have no more that 20% finer than the No. 200 sieve. It is desirable that the same material be used in the above water portion of the dikes. The sandy fill is expected to come from normal maintenance dredging of the channel.

b. Geotextiles (permeable textile materials) are not useful to reinforce the strength of the dikes. The mode for slope stability failures is shown on Figure 11. The dikes do not tend to spread at the base. Instead, the dikes will tend to move as a unit as part of a deep seated movement of the entire embankment.

c. Geotextiles, in the form of filter cloth, will be of benefit for the riprap as the contact between the surface of the dike and the overlying crushed stone bedding layer. This will obviate the need for a graded filter.

d. The placement of granular fill for the underwater sections of the embankments will require close control. It is assumed the sand will be placed either by direct discharge from a dredge or will be placed by bottom dump barges. It will be absolutely necessary that the fill be placed uniformly in relatively thin layers over the entire fill area. The thickness of the layers should be very small at first since the weight of this fill must cause densification, and strength increase, of the upper zone of the clay layer that is nearly liquid in behavior. Once consolidation has started, then the fill layers may get

progressively thicker or they may be placed at a faster rate. The objective is to prevent overloading the soft soils, particularly by nonuniform loading, to the extent that a stability failure occurs.

e. During fill placement, continuous depth soundings should be made on pre-established survey lines. Excessively non-uniform lifts should result in mud waves, or shallow slope failures. These are similar to bearing capacity failures for continuous footings. Therefore, rapid changes in elevation, up and/or down, are indicative of excessive mounding of fill.

f. Compaction of the underwater portion of the fill will not be possible. Compaction of the above water segment need not be any greater than machine compaction, i.e., uniform coverages of the wheels or tracks of the earthmoving equipment.

Slope Erosion Protection

51. Because of the necessity to use hydraulic fill sand for the dikes, protection from the erosive action of waves is imperative. Palermo et al (1983) recommended the use of stone riprap on both faces of the dike, i.e., the inside as well as the outside, since erosive waves can occur during hydraulic fill placement. As indicated in Figure 10, it is recommended that:

a. Exterior slope protection consist of a 24 inch thickness of stone riprap, with nominal 1000 lb. stones, over a bedding layer of 9 inches of crushed rock, placed over a continuous, overlapped geotextile (filter cloth).

b. Interior slope protection consist of a 12 inch thickness of stone riprap, with nominal 200 lb. stones, over a bedding layer of 9 inches of crushed rock, placed over a continuous, overlapped geotextile (filter cloth).

52. Riprap on both sides of the dike exposed to standing water should extend from a ditch at or below -2.0 ft MLW to the top of dike at +8.0 ft MLW.

Instrumentation and Monitoring

53. As a means of monitoring the structural behavior of the dike system during and after filling operations a number of "instrumentation groups", each consisting of a settlement monument and four or five piezometers, should be uniformly spaced along the length of the perimeter dike.

54. The settlement monuments will serve to indicate the time rate of settlement. They will also be of value to indicate amount and rate of

consolidation when the decision is made to raise the dike level of the extension, as was done for the original Craney Island facility. The piezometer data should indicate the degree of consolidation settlement that has occurred under a given loading which will provide information regarding whether the fill is being placed too rapidly.

55. Settlement monuments should be located at the outside upper edge of the dike. This will place the devices away from the area of placement of riprap and also out of the way of construction traffic on the dike center. One instrument group every 3000 to 5000 ft should suffice. The locations for instrument groups must be clearly marked and protected from construction operations. Because they will be installed before completion of the dike, it will be necessary for the dredging contractor to be aware of their locations and, if feasible, be made partially or wholly responsible for their safety and operation.

56. Each settlement monument may consist of a large steel plate, about 10 ft square, placed in dike fill a few feet above channel bottom (profile line) or may be a steel pipe placed or augered in a drilled hole extending below the fill bottom. If the steel plate is used, it can be placed on the surface of the fill after about three to five feet of fill has been placed. If the embedded standpipe is used, the embedment must be firm over the lowermost five to ten feet of pipe. In either instance, vertical sections of steel pipe should be attached to the monument and the pipe extended upward to a short distance above MLW. The standpipe should be clearly flagged to inhibit construction damage. Filling should be done carefully in the vicinity of the monument standpipes. Periodic level surveys should measure the elevation of each monument by determining the elevation of the top of the pipe. When the fill reaches the top of the standpipe, additional sections of pipe must be added until the final dike elevation is reached. Each time a new section of pipe is added, it is imperative that "before and after" level readings be made.

57. The piezometers should be evenly spaced vertically within the marine clay deposit, one at mid-thickness, one each at about 10% and at 25% of the thickness from the bottom and top of the layer. With this, or a similar vertical spacing, the vertical distribution of porewater pressure can be established for the monitoring of consolidation progress. If possible, the piezometer standpipes should be in the same locations as the settlement monument standpipes, perhaps

rising through a hole in the steel plate. However, the settlement standpipes must be free to move downward independently of the piezometer standpipes.

58. An organized and executed plan for placement, observation and measurement, and documentation of data from the instrument groups is essential. If the recorded data are not provided to the design and/or construction groups in a timely manner, then the instrumentation will be valueless.

PART IV: COST ESTIMATE

Estimates of Dike Subsidence

59. The subsidence of the proposed dikes from the sole effect of consolidation settlement may be calculated using standard techniques of geotechnical engineering. The following assumptions were made: the clay is normally consolidated, has an average submerged unit weight of 38 PCF, a compression index of 0.58, and an initial void ratio of 2.0; the embankment sand has a submerged unit weight of 63 PCF; and all layers below the marine clay are incompressible.

60. Fowler (1986) reports measurements of subsidence of the existing Craney Island dikes. Calculations using a dike height of 18 ft result in an estimated consolidation settlement of 6.6 ft. Actual measured subsidence of the east, north, and west legs averaged 17 ft, 13 ft, and 11 ft, respectively. The upper several feet of the river bottom is expected to be so soft that it will be squeezed out laterally under the load of the sand fill. It is expected that similar or more severe displacements will occur under the extension dikes in the deeper water areas to the north and west. Based on the existing data, a very rough estimate may then be made of the amount of displacement subsidence that may be expected under the various thicknesses (water depths) of dike fills for the case of top of dike at elevation +8.0 ft MLW. Subsequent raisings of the extension dikes will cause additional consolidation and displacement subsidence. The estimated total dike subsidence for a series of water (embankment) depths is given in Table 5.

Estimates of Dike Material Volumes

61. The centerlines of each of the proposed dike alignments for the five alternative configurations were plotted to scale on NOAA navigation charts. A profile of centerline depths was made as a series of straight lines connecting points of depth measurements that were recorded on the charts.

62. At any given point along the centerline, the dike fill cross section consisted of two elements, the section above existing bottom and a section representing the subsidence. The above bottom section used was that of

Table 5.

Estimated Total Dike Subsidence

Bottom depth, ft, MLW	5	10	15	20	25	30	35
Consolidation settlement, ft.	1.1	2.2	3.2	4.0	4.5	5.0	5.2
Displacement subsidence, ft.	1.5	3.0	4.5	6.0	7.5	9.0	10.5
Total estimated subsidence, ft.	2.6	5.2	7.7	10.0	12.0	14.0	15.7

Figure 10. The subsidence was expected to be an inverted triangle, with the two ends coinciding with the intersection of the fill with the natural bottom and with the peak of the triangle at the dike centerline. The depth of the inverted peak was estimated from the values given in Table 4. Using average end areas, estimated dike volumes for each of the individual dike segments shown in Figure 2 are given in Table 6.

Table 6.

Estimated Dike Material Volumes for Various Proposed Dike Segments

Proposed Dike Segment From Point	To Point	Length, Ft.	Volume, Cu. Yds.
1	7	3750	1186790
1	2	11535	10748600
2	3	3915	308633
3	4	6020	1802570
4	5	1535	359305
5	6	2915	515415
3	10	4320	1648640
1	9	8685	7436180
9	2	2850	3312420
9	10	3665	2817125
2	8	13955	5314945
3	8	10040	2228610
8	11	8235	159820

Cost Estimates

63. The individual length and volume estimates given in Table 6 were used to calculate total riprap and granular fill quantities needed for the five alternative configurations shown in Figure 2. Table 7 is the compilation of all quantity and cost calculations for the five alternative configurations. Unit prices used in determining costs were obtained from the NAO estimating section and are as follows:

a. Riprap. Riprap stone costs $50.00 per ton and weighs 165 pounds per cu ft in place. Crushed stone for bedding costs $50.00 per ton and weighs 165 pounds per cu ft in place. The geotextile (filter cloth) costs $3.00 per sq yd in place. Forming the dike surface and ditch during riprap placement costs $2.00 per sq yd. Using these figures, the estimated cost of the exterior riprap is $91.62 per sq yd. The estimated cost of interior riprap is $60.12 per sq yd.

b. Dredged Sand Fill. The total cost of dredging, transporting, and placing sand fill, below and/or above water, is estimated to be $1.20 per cu yd in place.

Table 7

Cost Estimate for the Alternative Configurations

Configuration No.	1	2	3	4	5
Total Dike Length, Ft	29,670	37,475	16,100	14,790	22,595
Total Fill Volume, 1000 Cu Yd	17,699	17,410	11,440	4,326	4,037
Est. Cost of Fill, 1000 Dollars	21,239	20,892	13,728	5,191	4,844
Total Riprap Area, Sq Yds:					
a. Exterior	89,066	87,732	48,366	44,063	43,112
b. Interior	73,475	92,831	39,840	36,596	55,987
Est. Riprap Cost, 1000 Dollars	12,578	13,619	7,367	6,238	7,273
Total Cost of Configuration, 1000 Dollars	33,817	34,512	21,095	11,428	12,118
Storage Volume, 1000 Cu Yd*	35,640	45,050	13,440	12,410	20,94[illegible]
Cost Per Cu. Yd. For Storage	$0.95	$0.77	$1.53	$0.92	$0.58

* Goforth, 1986

PART V: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

64. Based on the studies of the dike system design and of the cost estimates reported herein, it is concluded that:

a. A sand dike extending to Elevation +8 ft MLW may be safely constructed in the proposed expansion areas to the north and west of the existing Craney Island Disposal Area. This is contingent on the actual soil conditions in the marine clay layer being equal to or better than those under the existing facility. It is further contingent on the placement rate of the sand being no greater than that of the original facility.

b. Configuration 5 gives the greatest amount of dredged material storage for the construction dollar. However, the storage volume is intermediate among the five alternatives. Configuration 2, which incorporates Configuration 5, has the next lowest storage cost, and gives the highest storage volume of the five alternatives. Configurations 5 and 2 had estimated costs per cubic yard of storage of $0.58 and $0.77, respectively.

Recommendations for Further Work

65. The present study has been made using a number of assumptions regarding soil properties under the proposed dike locations. It has also become apparent that strength increase of the clay under gradually increasing dike load is necessary for dike stability. However, the rate and extent to which this will occur is also unknown. It is recommended that additional studies be made:

a. The soil profile along the proposed dike alignments needs to be intensively investigated. Undisturbed tube samples will be needed for laboratory consolidation tests. It is suggested that field vane shear and/or field cone penetrometer investigations be made to extend the sample boring data rather than relying on laboratory strength tests. Of concern is the rather high probability of sample disturbance using tubes in the soft clays.

b. The effective control of construction operations to prevent a stability failure requires that the time rate relationship between load placement and increase in shear strength in the soil profile be thoroughly investigated. Although some information regarding non-uniform loading can be obtained from the present study (the entire embankment is a non-uniform load), time rate studies should also include evaluation of non-uniformity of loading.

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APPENDIX A: TYPICAL INPUT FOR UTEXAS2 SLOPE STABILITY ANALYSIS PROGRAM

```
HEADING - - - -
CRANEY ISLAND EXTENSION, DEPTH = dd FT
CPROFL = xxx PSF, RATEIN = y.y PSF/FT
NONCIRCULAR SURFACE (SLIDING WEDGE)
PROFILE LINES
  1 1 MOIST EMBANKMENT SAND
  -81 0
  -21 4
  -11 8
  11 8
  19 4

  2 2 SATURATED EMBANKMENT SAND
  -El -dd
  -111 -2
  -81 0
  19 4
  109 -2
  +Er -dd

  3 3 CONSOLIDATING DREDGED MATERIAL
  19 4
  500 4

  4 4 SOFT BOTTOM CLAY
  -500 -dd
  500 -dd

  5 5 DENSE BASE SAND
  -500 -90
  500 -90

  6 6 Water
  -500 0
  -81 0
```

NOTE: This tabulation is not part of the program input.

Depth dd.ft	Left Edge El, ft	Right Edge Er, ft
05	-201	+199
15	-501	+499
25	-801	+799
35	-1101	+1099

```
MATERIAL PROPERTY
  1  MOIST EMBANKMENT SAND
     110
     CONVENTIONAL SHEAR STRENGTH
     0 30
     PIEZOMETRIC LINE
     1
```

(Continued next page. No blank line at this point in the input data.)

```
SATURATED EMBANKMENT SAND
     125
     CONVENTIONAL SHEAR STRENGTH
     0  30
     PIEZOMETRIC LINE
     1
  3  CONSOLIDATING DREDGED MATERIAL
     90
     LINEAR INCREASE WITH DEPTH
     35 1.8
    PIEZOMETRIC LINE
     1
  4  SOFT BOTTOM CLAY
     100
     LINEAR INCREASE WITH DEPTH
     xxx y.y
     PIEZOMETRIC LINE
     1
  5 DENSE BASE SAND
     125
     CONVENTIONAL SHEAR STRENGTH
     0 30
     PIEZOMETRIC LINE
     1
  6 WATER
     62.4
CONVENTIONAL SHEAR STRENGTH
     0 0
     PIEZOMETRIC LINE
     1

PIEZOMETRIC LINE DATA
  1  62.4 Phreatic Line
  -500 0
  -81 0
  19 4
  500 4


ANALYSIS/COMPUTATION
  NONCIRCULAR SEARCH
  -225 0 0
  -200 -dd 0
  -100 -(dd+1) -90
  -50 -(dd+1) -90
  -11 -dd FIX
  0 +8 0

  20 40

COMPUTE
************
```

DRAFT

ADDENDUM TO MISCELLANEOUS PAPER GL-87-9

GEOTECHNICAL FEASIBILITY STUDY REPLACEMENT OR EXTENSION OF THE CRANEY ISLAND DISPOSAL AREA, NORFOLK, VIRGINIA

by

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April 1989

Prepared for:

DEPARTMENT OF THE ARMY
US Army Corps of Engineers
Washington, DC 20314-1000

and

US Army Engineer District, Norfolk
Norfolk, Virginia 23510-1096

ADDENDUM TO MISCELLANEOUS PAPER GL-87-9

GEOTECHNICAL FEASIBILITY STUDY

REPLACEMENT OR EXTENSION OF THE CRANEY

ISLAND DISPOSAL AREA, NORFOLK, VIRGINIA

1. This report is an addendum to Miscellaneous Paper GL-87-9, "Geotechnical Feasibility Study, Replacement or Extension of the Craney Island Disposal Area, Norfolk, Virginia", prepared by the Geotechnical Laboratory, US Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi (Spigolon and Fowler, 1987). That document will be referred to herein as "The Report".

2. The Report was prepared at the request of the US Army Engineer District, Norfolk (NAO) as part of the overall study of methods to increase the capacity, and life, of the existing Craney Island Disposal Area. The Report was concerned only with geotechnical engineering studies and construction cost estimates for each of five alternative configurations for additional disposal areas to the north and/or west of the present Craney Island.

3. A sixth alternative disposal area configuration, west of Craney Island, has been proposed. This configuration is shown as Plan 6 on Figure A-1. The figure also shows Plans 1, 2, 3, 4, and 5 which were the subject of The Report. All six configurations have been the topic of a hydrodynamic study by the Hydraulics Laboratory at WES (Heltzel and Granat, 1988). Plan 6, the subject of this addendum, is Plan F of the Heltzel and Granat report.

4. The objective of this addendum report is to make a cost estimate for the construction of the dike system for the proposed configuration shown as Plan 6 on Figure A-1. That configuration does not introduce any new conditions affecting the geotechnical engineering stability studies or the construction recommendations made in The Report. Therefore, no additional analyses were made in those areas.

5. For consistency, the cost estimating procedures presented in Part IV, Cost Estimate, of The Report were used again in the present study. The formerly used dike cross section and estimates of subsidence were used to determine dike cross-section areas for various water depths, referred to Mean Low Water (MLW). A new source of data for water depths in the immediate vicinity of Craney Island became available in early 1989. This consisted of an extensive hydrographic

survey, performed by the NAO, that became available in late 1988. Water depths used in The Report were determined from an older, 1:20000 scale navigation chart for Hampton Roads, Virginia, sheet no. 7, chart no. 12245.

6. The new (1988) depth data were used to calculate the dike volumes for all six alternatives, utilizing the depth-related estimates of subsidence used in The Report. Estimated dike volumes for each of the dike segments shown in alternate plans of Figure A-1 are given in Table A-1.

Table A-1

Estimated Dike Material Volumes for Various Proposed Dike Segments

Proposed Dike Segment From Point	To Point	Length, Ft.	Volume, Cu. Yds.
1	9	8685	8733510
2	9	2850	3639780
2	3	3915	3278660
3	4	6020	1328965
4	5	1535	327450
1	7	3750	1115250
3	8	10040	1631645
3	10	4320	2705720
3	12	515	202960
5	6	2915	703930
8	11	8235	191190
9	10	3665	4233950
12	13	1835	660370
13	14	6250	1023870
14	15	5535	1149190

7. Consistent with The Report, unit prices used in the cost estimate were obtained from the NAO estimating section (1986 prices). They are repeated here for completeness of this report.

a. Dredged Sand Fill. The total cost of dredging, transporting, and placing sand fill in the dikes, below and/or above water, is estimated to be $1.20 per cu yd in place.

b. Riprap. Riprap stone costs $50.00 per ton and weighs 165 lb per cu ft in place. Crushed stone for bedding costs $50.00 per ton and weighs 165 lb per cu ft in place. The geotextile (filter cloth)

costs $3.00 per sq yd in place. Forming the dike surface and ditch during riprap placement costs $2.00 per sq yd. The rip rap is two ft thick on exterior surfaces and one ft thick on interior slopes. Using these figures, the estimated cost of the exterior riprap is $91.62 per sq yd and of the interior riprap is $60.12 per sq yd.

8. Table A-2 contains the estimated costs for all six of the configurations being considered. The data for fill volumes is taken from Table A-1 above.

Table A-2

Cost Estimate for the Alternative Configurations

Configuration No.	1	2	3	4	5	6
Total Dike Length, Ft.	29,670	37,475	16,100	14,790	22,595	18,455
Total Fill Volume, 1000 Cu Yds.	19,128	18,590	14,083	5,066	4,529	5,742
Estimated Cost of Fill, 1000 Dollars.	22,953	22,308	16,899	6,079	5,434	6,891
Total Riprap Area, Sq Yds:						
a. Exterior	89,066	87,732	48,366	44,063	43,112	55,365
b. Interior	73,475	92,831	39,840	36,596	55,987	45,533
Estimated Cost of Riprap, 1000 Dollars.	12,578	13,619	7,367	6,238	7,273	7,500
Total Cost of Configuration, 1000 Dollars.	35,531	35,927	24,266	12,317	12,707	14,391
Storage Volume, 1000 Cu Yds.	35,640*	45,050*	13,440*	12,410*	20,940*	19,490
Cost Per Cu Yd For Storage.	$1.00	$0.80	$1.81	$0.99	$0.61	$0.74

* Goforth, 1986

9. Plan 6 is very similar in configuration to Plan 5 of The Report. Total fill volume, total storage volume, and the ratio of storage to fill volume, are all nearly the same. Plan 5 has a lower cost per cu yd of storage mainly due to the assumption that riprap would not be needed on the land (exterior) side of leg 8-11, on the south side of the proposed configuration.

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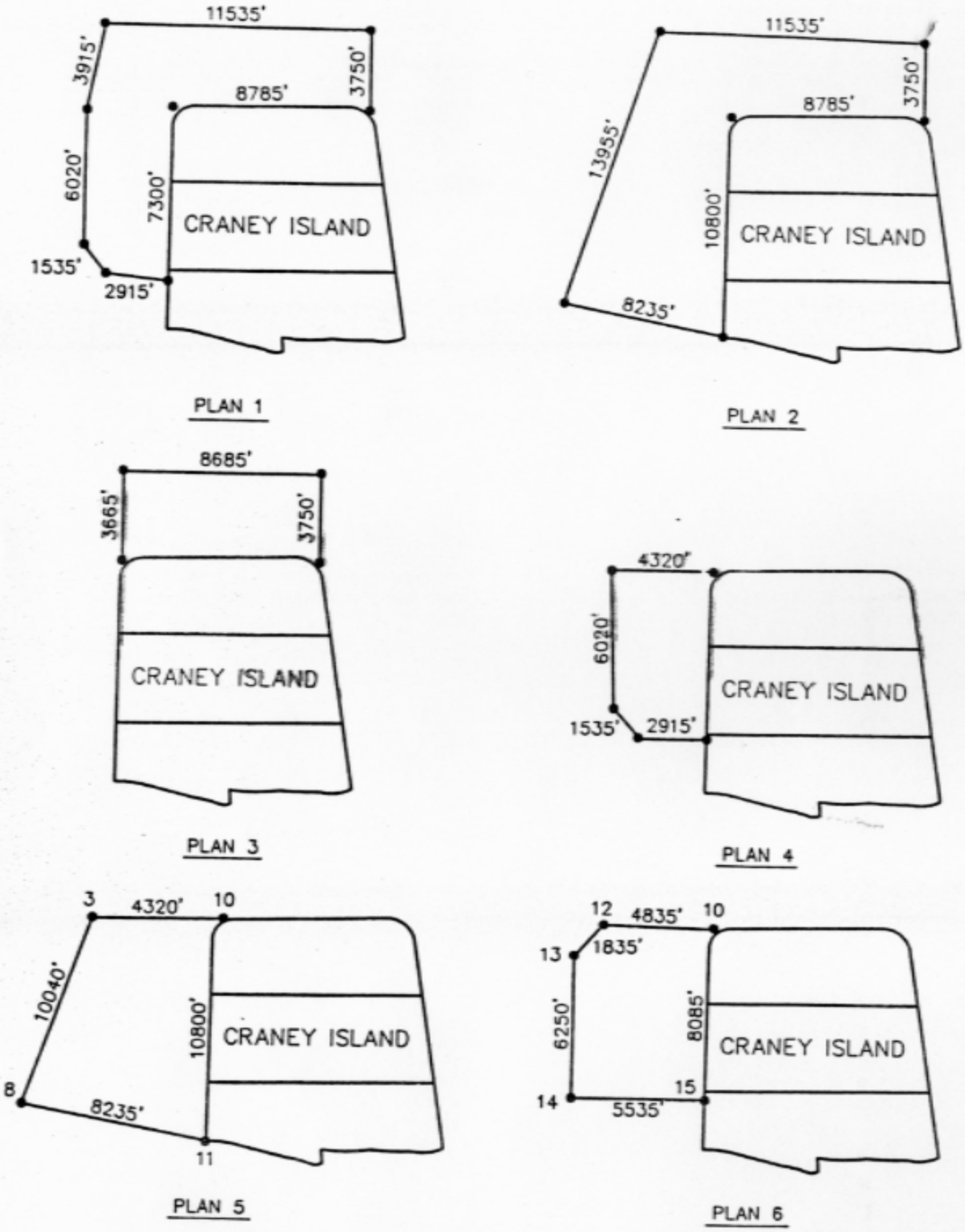


Figure A-1. Dimensions of Craney Island enlargement alternatives

PROPOSED ADDENDUM #2 TO MISCELLANEOUS PAPER GL-87-9

GEOTECHNICAL FEASIBILITY STUDY
REPLACEMENT OR EXTENSION OF THE CRANEY
ISLAND DISPOSAL AREA, NORFOLK, VIRGINIA

1. This is the second addendum (Addendum #2) to Miscellaneous Paper GL-87-9, "Geotechnical Feasibility Study, Replacement or Extension of the Craney Island Disposal Area, Norfolk, Virginia," prepared by Jack Fowler of the Geotechnical Laboratory (GL), US Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi, and S. J. Spigolon, SJS Corporation, June 1987. That document will be referred to herein as the "Report". Addendum #1 was submitted in July 1988 and was concerned with the cost estimate for a sixth additional configuration of perimeter dikes.

2. The original draft of the Report was submitted for review in September 1986. The reply consisted of a review letter (1986 letter), dated 5 November 1986, from J. G. Starr, Chief, Engineering Division, Norfolk District (CENAO-EN-WT) and review comments (1986 comments) by M. T. Byrne, Geotechnical Engineering Section, Norfolk District, (CENAO-EN-DG). As will be discussed below, these review comments were incorporated into the Report, which was issued June 1987. Additional review comments on the Report were prepared by M. T. Byrne, (CENAO-EN-DG) on 31 August 1987; however, the comments were received at the GL on 7 November 1988. The purpose of this Addendum #2 is to reply in full to both the 1986 and the 1987/1988 commentaries.

1986 LETTER BY J. G. STARR

3. The 1986 letter, para 2, questioned the method of introducing the external ocean water in stability calculations using the UTEXAS2 program. The Report placed the water as a separate material of zero shear strength instead of as a surface pressure. This was done, simply, to facilitate the calculation of the coordinates of Point 1, the left-most point, for entry into the input data, i.e., the point was always at the water surface, elevation 0 MLW. Reference is made to para 19 of WES Instruction Report GL-87-1, "User's Guide: UTEXAS2 Slope-Stability Package, Volume 1, User's Manual," August 1987, for

further discussion. Subsequent evaluations of several of the slope stability analyses made for the Report, using water as only a surface pressure, showed no essential change in calculated factors of safety.

4. Para 2b of the 1986 letter suggested using Mean Low Water as the datum for calculations. This was incorporated into the Report.

5. Para 3 of the 1986 letter indicated the correct values for capacity and life of Craney Island. This was incorporated into the Report.

6. Para 4 of the 1986 letter indicated the correct manner of referring to Craney Island. This was incorporated into the Report.

1986 COMMENTS BY M. T. BYRNE

7. The 1986 comments presented preliminary boring log data for the 1986 series of borings. THe 1986 information was incorporated in the Report as Figure 9, page 23.

8. Paragraphs 1 through 7 of the 1986 comments dealt with the shear strength profiles of the foundation soils shown in the draft report. In particular, the comments indicated:

a. Pre-1980 shear strength data, from laboratory tests, showed considerable scatter. This was partially ascribed to sampling disturbance.

b. Later shear tests, made in situ during 1981 and 1983, also showed considerable scatter.

c. Individual borings in all investigations displayed a tendency to either increase in strength with depth, no increase, or even a decrease with depth. There did not appear to be a pattern, from boring to boring, for such behavior.

d. Trapped gas was found in borings outside the project area and it is probable that trapped gas exists under the proposed site. The gas is considered a likely cause for underconsolidation of the clays.

9. All of the comments given above were discussed at length in the Report, paragraphs 28 through 34. Scatter of undrained shear strength with depth is the rule rather than the exception, particularly in estuarine materials. Natural horizontal and vertical variations in the amount of the inert materials, ranging from fine sand (-#40) through inorganic silt sizes, and of the clay minerals, can cause considerable scatter in the in situ void ratio, compressibility, and strength. Variations in inert material content also

greatly affect the Atterberg limits, particularly the liquid limit. Vane shear tests of a non-plastic silt (acting as a granular material) are affected by confining pressure, whereas a very low permeability clay will act in an undrained manner.

10. Fortunately, the question of variability need not be resolved at this time. Slope stability analyses generally tend to depend on the "average" strength of the soil profile at any depth, unless there is a soft, thin, almost horizontal, continuous layer in a potential shear zone. Therefore, the stability analyses of the Report assumed an average strength at the profile line and an average increase of strength with depth.

11. The question of an increase in strength of the subsoil from the embankment loading was discussed in detail in paragraphs 29-31 and 33 of the Report. There appeared to be some evidence to demonstrate most of the decrease in void ratio and increase in strength which is expected to occur after placement of the embankment. (See paragraph 19 of this addendum.) As discussed in para 33, it appears that the soils under the existing embankment area not yet fully consolidated.

12. The only real questions, however, affecting the stability calculations of the Report, are: (1) the adequacy of the strength profile now existing under the proposed embankment, and (2) if it is not adequate, whether that strength can be increased sufficiently rapidly during embankment placement to support the load. (If the existing soil strength is adequate to support the proposed embankment loads, then strength increase is of no concern to stability. If not, then a slower placement schedule is needed, or displacement of the near-surface muds can be expected, with the embankment sinking to a level where the supporting soils have adequate strength.)

<u>1987 COMMENTS BY M. T. BYRNE</u>

13. Para 8 of the 1987 comments dealt with the circular arc analyses made for the draft report. These were later changed to a non-circular arc analysis method for the reasons given in para 39 of the Report.

14. The comments of paragraph 9 and subsequent hand-written comments were incorporated in the Report.

15. The comments made in 1987 can be reduced to three topics:

a. A question regarding the applicability of the "sliding wedge" method of stability analysis versus the conventional circular arc.

b. A question regarding Figure 8, page 21, of the Report. The 1949 shear strengths appear to be plotted at one-half of their correct values.

c. A question about the shear strength to be used for the sandy embankment material.

16. As discussed in para 13 above, and in para 39 of the Report, the original slope stability analyses reported in the draft report of the miscellaneous paper dated September 1986 used the Spencer's complete equilibrium analysis procedure contained in the UTEXAS2 computer program. Searches for circular shear surfaces were originally conducted. After review of the analyses, it was recognized that results were not valid because of the manner the circles passed through the cohesionless material. This type of stratification, where a sand layer overlies a clay layer, results in circles which have negative stresses in the toe slices. These negative stresses lower the factor of safety. To resolve this problem and still use a complete equilibrium analysis procedure, non-circular searches were used. The initial shear surface in the search process was shown in Figure 11 of the Report. Point No. 5 was fixed at -11, -d (d = depth, MLW), which was assumed to be the maximum active earth pressure. The searches generated surfaces that approximated circular surfaces. An example of the surfaces is shown in Figure A-2-5. The results of these calculations were contained in Table 4 of the Report.

17. Following receipt of the 1987 comments in November 1988, expert WES personnel were employed to review the method of analysis. A recommendation was made, and followed, to use the circular search with Bishop's analysis procedure. Bishop's method only satisfies moment and vertical forces whereas Spencer's method also satisfies horizontal forces. All of the circular searches initiated from a circle located at x = -150 and elevation of 250 and were tangent to the base of the soft clay layer (elevation -90). The same geometry and soil strengths as used for the non-circular searches were used in this reanalysis. The results are tabulated in Table A-2-1 and plotted in

Figures A-2-1 through A-2-12. Figure A-2-5 shows a comparison of the non-circular and circular shear surfaces. Although slightly lower factors of safety were found for circular surfaces in most instances, most of the results are in good agreement with Table 4 of the Report.

18. The values for shear strength contained in the 1949 borings of Figure 8, page 21, of the Report may have been prepared and plotted at one-half of their recorded values. The source of the data was the General Design Memorandum of the Norfolk District, 1953, Exhibit III, Summary of Laboratory Tests. The values were those given in the column for Unconfined Compression Tests marked "Maximum Shear, p.s.i.". Since the Direct Shear Tests and Triaxial Shear Tests had columns marked "Cohesion, t.s.f.", it was not clear what was meant in the Unconfined Compression column. This was interpreted as compressive strength, and a value of one-half the reported values was used as the cohesion. Then, the results of the 1971 series of borings was reviewed in the Norfolk District Report of Soil Testing, November, 1972. There, values of "Cohesion, t.s.f." were reported for all types of shear tests, including unconfined compression. It now appears that the interpretation of the 1949 data as strength rather than cohesion was not appropriate and Figure 8, page 21, of the Report is not valid. Accordingly, a revised Figure 8 is enclosed.

19. Several observations may be made about the revised Figure 8. There appears to be a soft zone at elevation -45 to -65 ft MLW in both groups of borings. Therefore, using the revised figure, an analysis was made of the cohesion values for the limited number of tests. Three depth groups were used. The average cohesion values (with number of tests in parentheses) for each group are:

	1949	1971
Average cohesion, psf, for -25' to -45'	183 (5)	321 (3)
Average cohesion, psf, for -45' to -65'	104 (5)	321 (3)
Average cohesion, psf, for -65' to -100'	356 (6)	306 (4)

This data is very limited and should not be considered definitive. However, some interesting trends are revealed.

20. The intent of the Report was (a) to evaluate the potential stability of dikes that could be built for the extension, and (b) assuming the dikes

could be built, to develop a reasonable estimate of costs. Subsurface data was limited to the information presented in the Report. With the possible exception of the 1986 borings, there was no subsurface data available for the proposed project sites. Therefore, there was no way to analyze existing, valid data. Where the angle of internal friction ϕ is changed from 30 deg to 20 deg, the factor of safety changes significantly as shown below:

Elevation at Base of Sand Fill ft	Cohesion at Top of Clay Layer, psf	Rate of Cohesion Increase With Depth psf/ft	Factor of Safety $\phi = 20$	Factor of Safety $\phi = 30$
-35	100	0.0	1.04	1.33
		2.5	1.50	1.82
		5.0	1.88	2.28

21. The technique chosen for slope stability evaluation was (a) to evaluate existing data for general soil profile characteristics and to define the general range of those characteristics, and (b) using that data, to solve for a broad range of possible subsurface profiles to find the factors that governed, i.e., the minimum values of CPROFL and RATEIN that governed for any given embankment thickness (depth). It was recognized that these analyses, in themselves, were not useful for design. They only pointed the way to the design calculations, to be made when the design values were accurately known. Using the UTEXAS2 program, with the computer program input included in the Report, more definite analyses could be made after more subsurface information was available, both for the foundation soils and for the embankment materials. Therefore, any soil profile and/or any source of embankment materials may be evaluated, for comparison purposes, by inserting the characteristics of that material in the appropriate location of the program input.

Table A-2-1

Results of Slope Stability Analyses

Elevation at Base of Sand Fill ft	Cohesion at Top of Clay Layer psf	Rate of Cohesion Increase w/Depth psf/ft	Factor of Safety	Circle Coordinates X	Y	Radius
-5	100	0.0	.64	-92	48	122
-5	100	2.5	1.03	-50	52	84
-5	100	5.0	1.27	-44	48	72
-5	200	0.0	1.27	-86	42	114
-5	200	2.5	1.65	-52	42	78
-5	200	5.0	1.90	-42	40	66
-5	300	0.0	1.90	-90	48	120
-5	300	2.5	2.27	-52	40	76
-5	300	5.0	2.53	-42	40	66
-15	100	0.0	.71	-174	226	316
-15	100	2.5	1.28	-80	80	134
-15	100	5.0	1.54	-58	50	90
-15	200	0.0	1.29	-138	122	212
-15	200	2.5	1.81	-66	52	102
-15	200	5.0	2.04	-54	42	80
-15	300	0.0	1.87	-128	96	186
-15	300	2.5	2.33	-60	42	86
-15	300	5.0	2.54	-54	44	80
-25	100	0.0	.92	-206	348	438
-25	100	2.5	1.53	-154	172	262
-25	100	5.0	1.94	-88	86	150
-25	200	0.0	1.49	-154	172	262
-25	200	2.5	2.07	-132	122	210
-25	200	5.0	2.43	-76	60	150
-25	300	0.0	2.03	-138	130	220
-25	300	2.5	2.61	-128	112	200
-25	300	5.0	2.90	-70	46	98
-35	100	0.0	1.33	-192	338	438
-35	100	2.5	1.82	-150	190	280
-35	100	5.0	2.28	-142	164	254
-35	200	0.0	1.86	-150	190	280
-35	200	2.5	2.33	-140	158	248
-35	200	5.0	2.78	-132	134	224
-35	300	0.0	2.37	-140	158	248
-35	300	2.5	2.83	-132	134	224
-35	300	5.0	3.28	-122	144	202

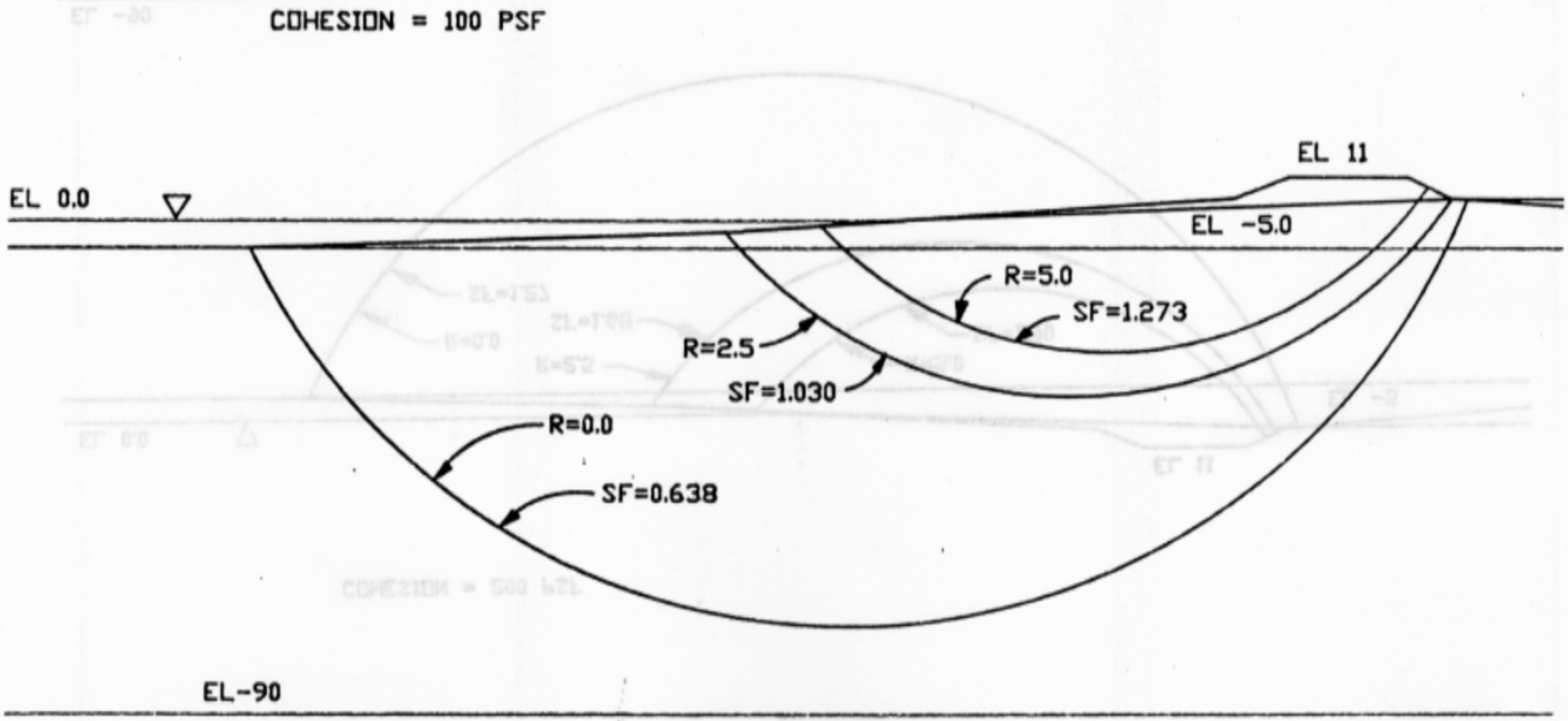


Figure A-2-1. Results of stability analysis using Bishop's method. Profile depth -5 ft, cohesion 100 psf, and rate of increase 0.0, 2.5, and 5.0 psf/ft.

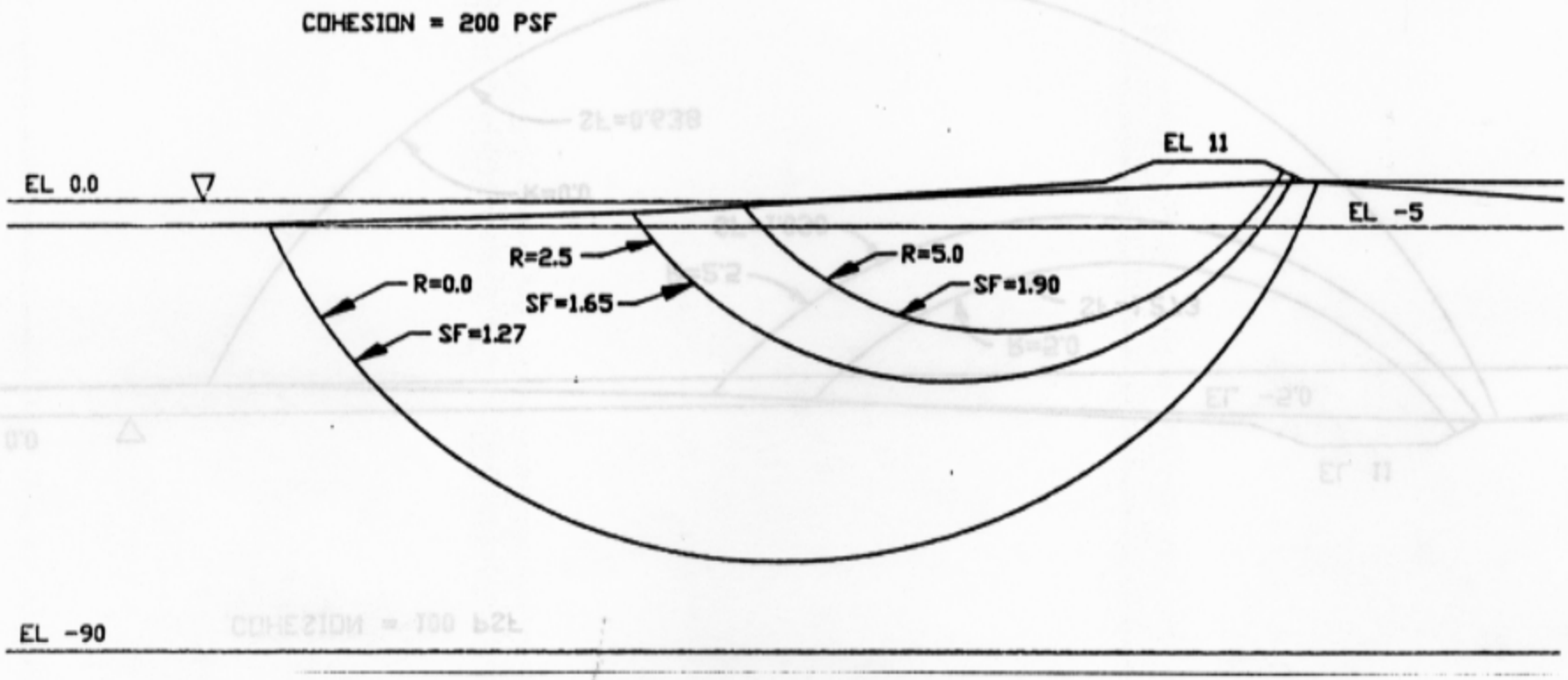


Figure A-2-2. Results of stability analysis using Bishop's method. Profile depth -5 ft, cohesion 200 psf, and rate of increase 0.0, 2.5, and 5.0 psf/ft.

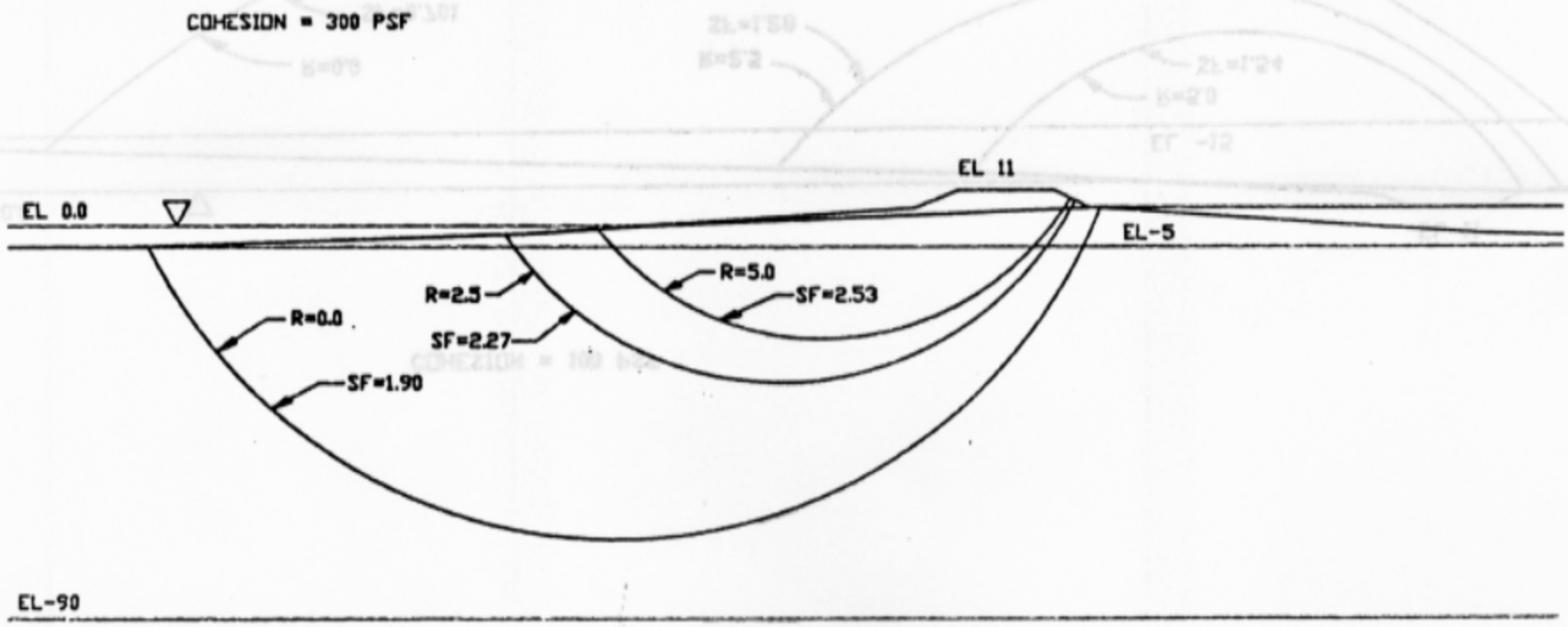


Figure A-2-3. Results of stability analysis using Bishop's method. Profile depth -5 ft, cohesion 300 psf, and rate of increase 0.0, 2.5, and 5.0 psf/ft.

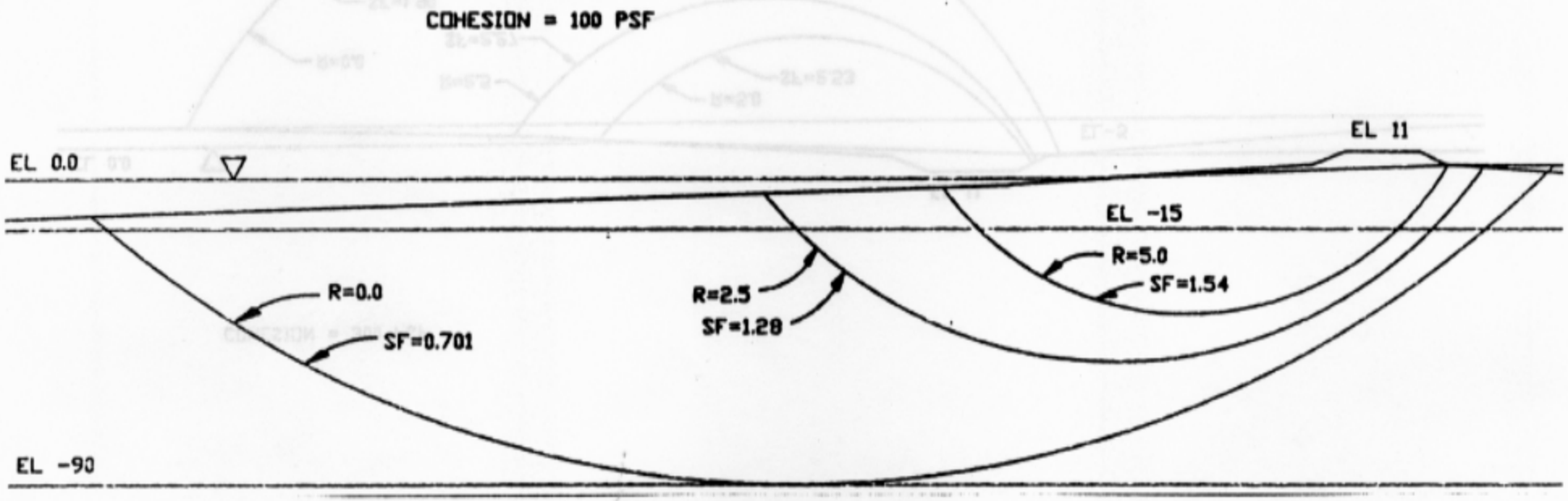


Figure A-2-4. Results of stability analysis using Bishop's method. Profile depth -15 ft, cohesion 100 psf, and rate of increase 0.0, 2.5, and 5.0 psf/ft.

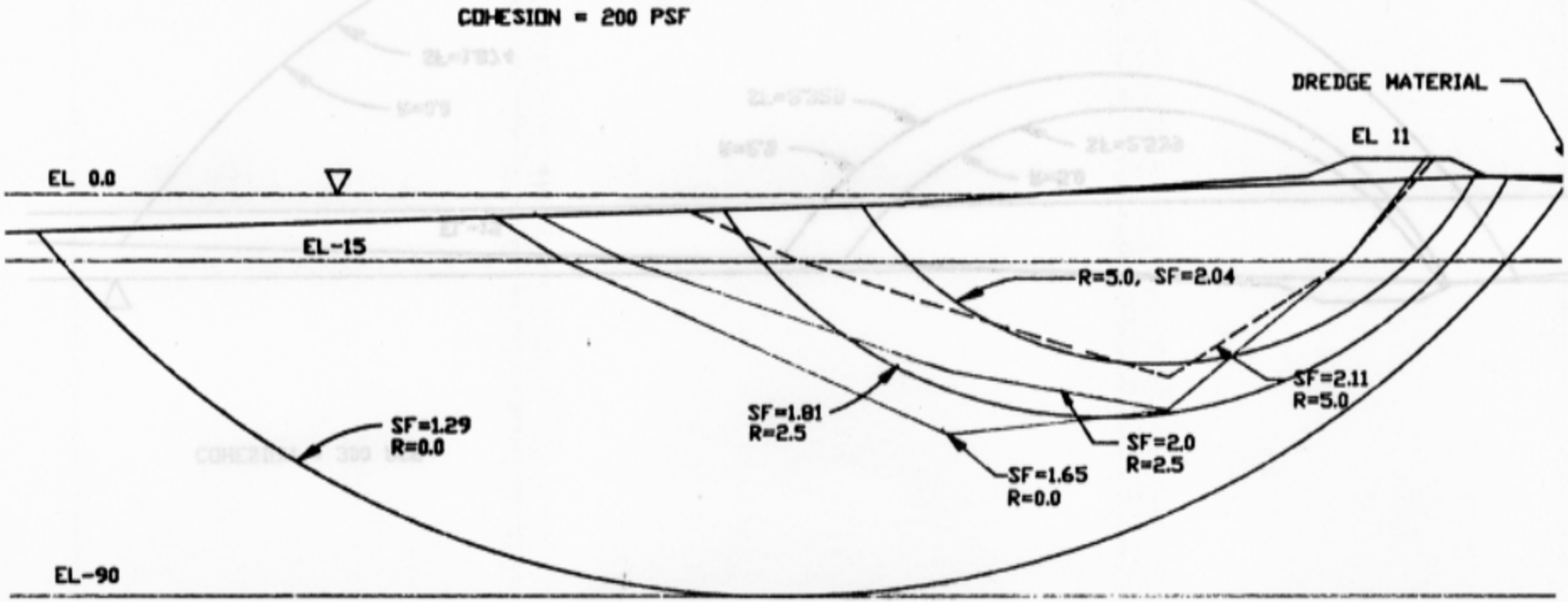


Figure A-2-5. Results of stability analysis using non-circular and Bishop's circular method. Profile depth -5 ft, cohesion 300 psf, and rate of increase 0.0, 2.5, and 5.0 psf/ft.

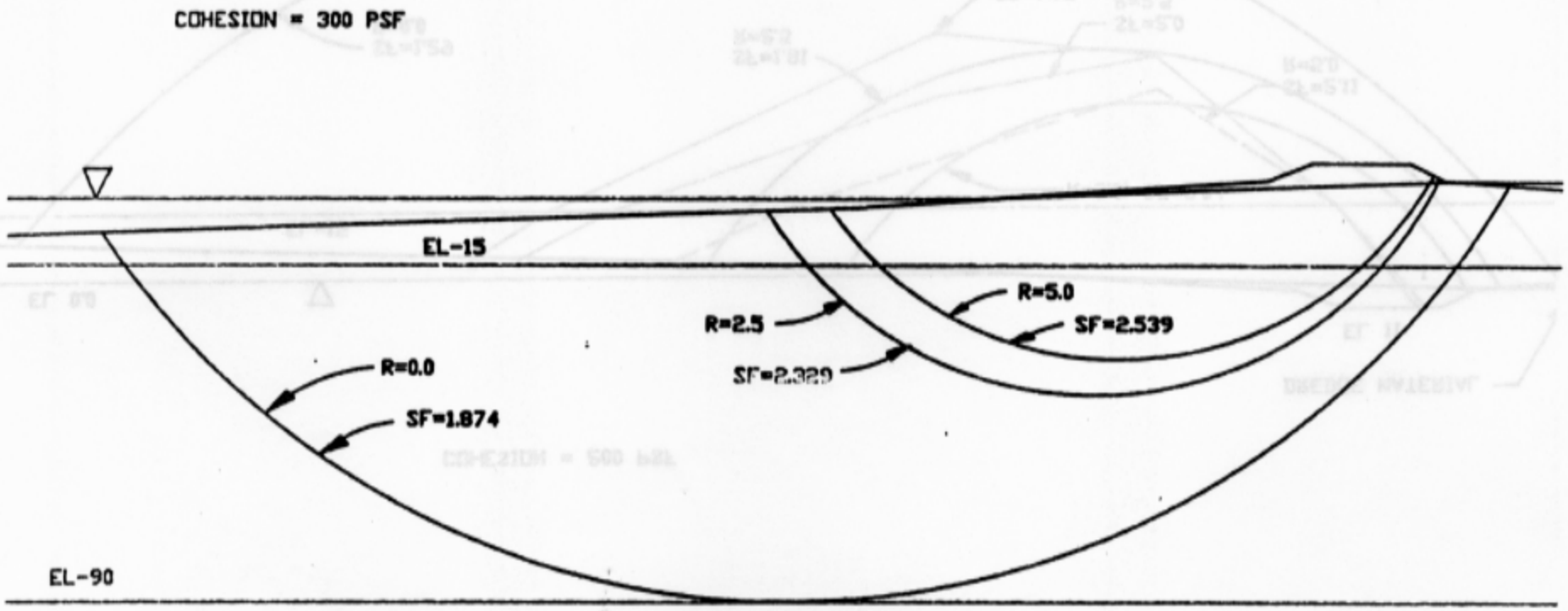


Figure A-2-6. Results of stability analysis using Bishop's method. Profile depth -15 ft, cohesion 300 psf, and rate of increase 0.0, 2.5, and 5.0 psf/ft.

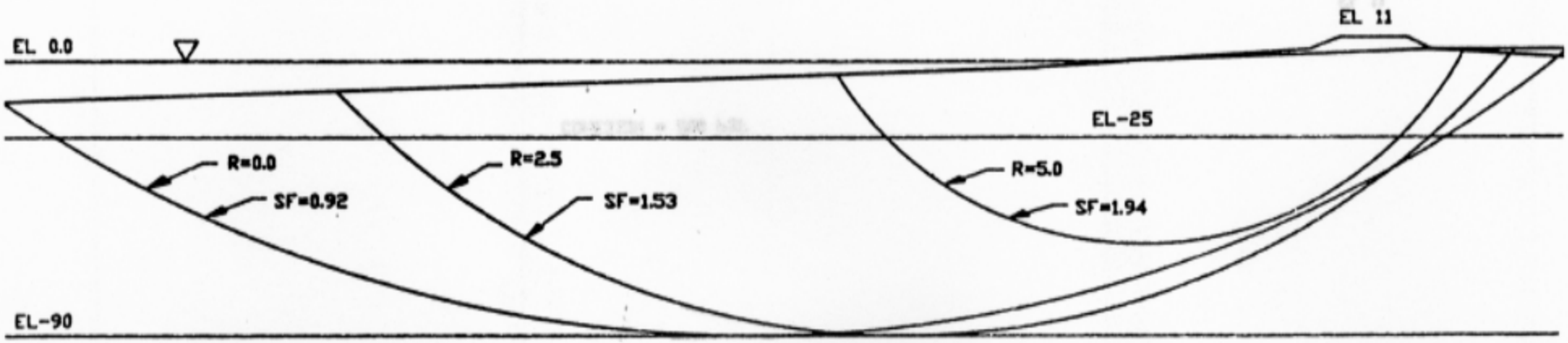


Figure A-2-7. Results of stability analysis using Bishop's method. Profile depth -25 ft, cohesion 100 psf, and rate of increase 0.0, 2.5, and 5.0 psf/ft.

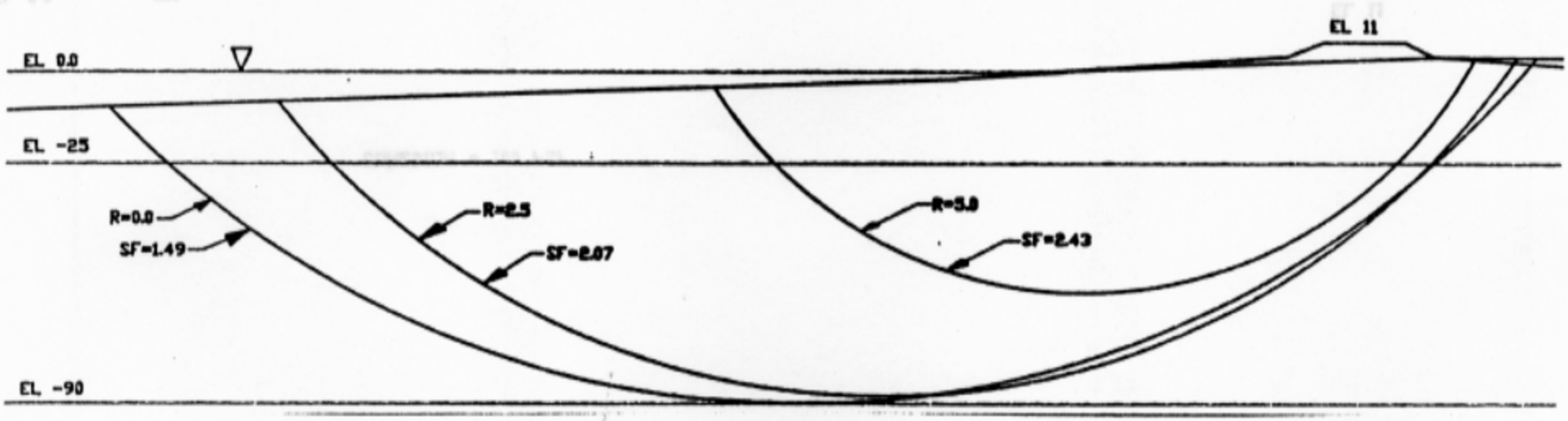


Figure A-2-8. Results of stability analysis using Bishop's method. Profile depth -25 ft, cohesion 200 psf, and rate of increase 0.0, 2.5, and 5.0 psf/ft.

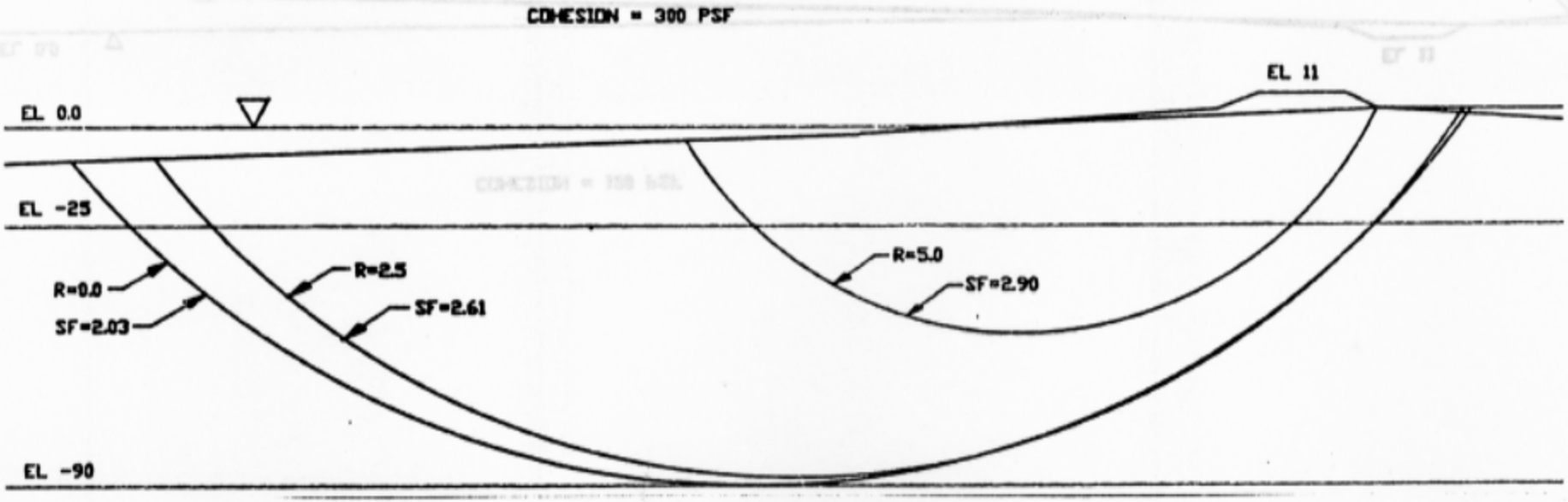


Figure A-2-9. Results of stability analysis using Bishop's method. Profile depth -25 ft, cohesion 300 psf, and rate of increase 0.0, 2.5, and 5.0 psf/ft.

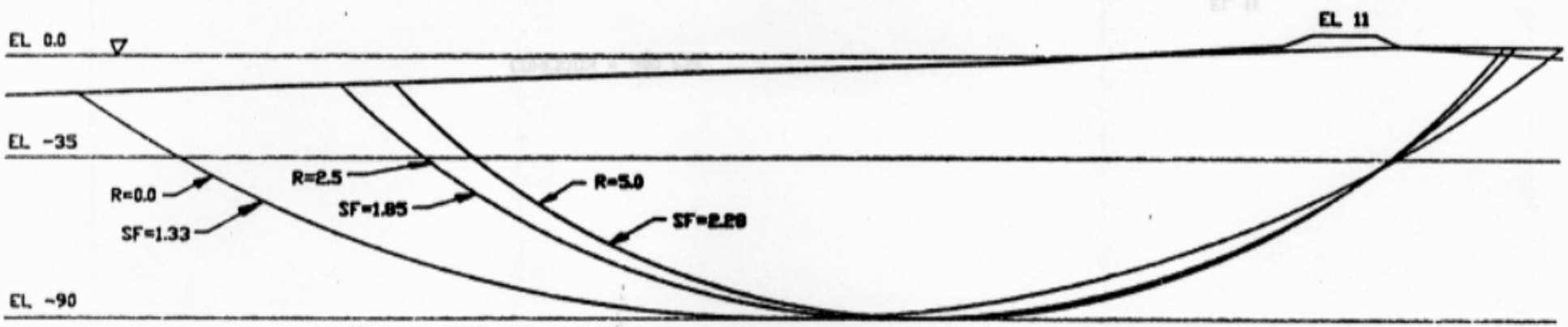


Figure A-2-10. Results of stability analysis using Bishop's method. Profile depth -35 ft, cohesion 100 psf, and rate of increase 0.0, 2.5, and 5.0 psf/ft.

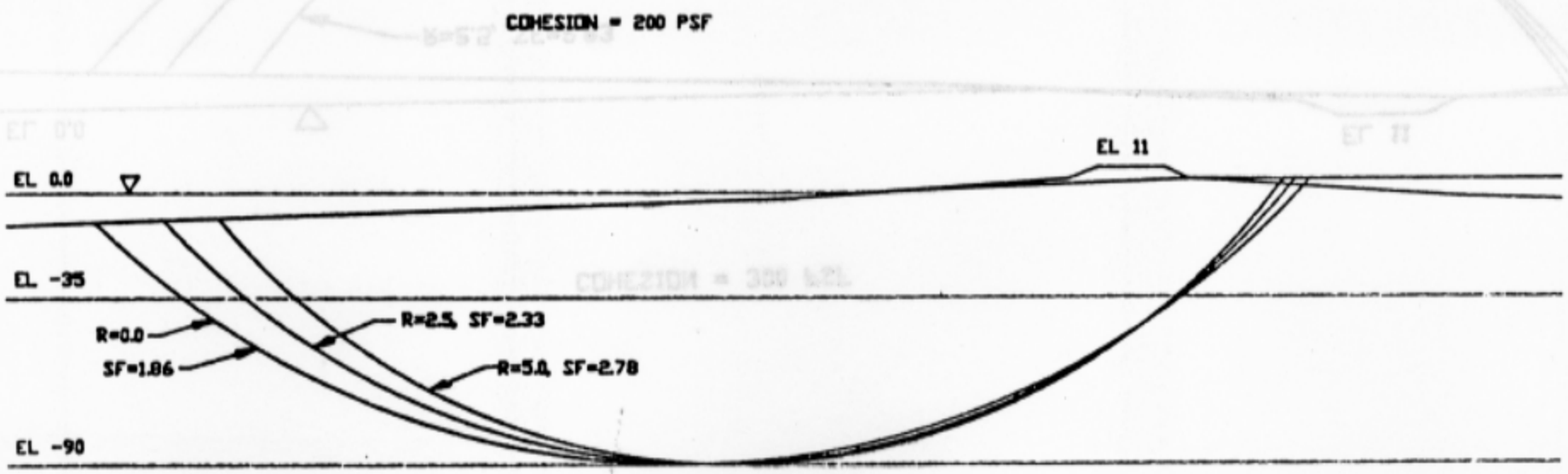


Figure A-2-11. Results of stability analysis using Bishop's method. Profile depth -35 ft, cohesion 200 psf, and rate of increase 0.0, 2.5, and 5.0 psf/ft.

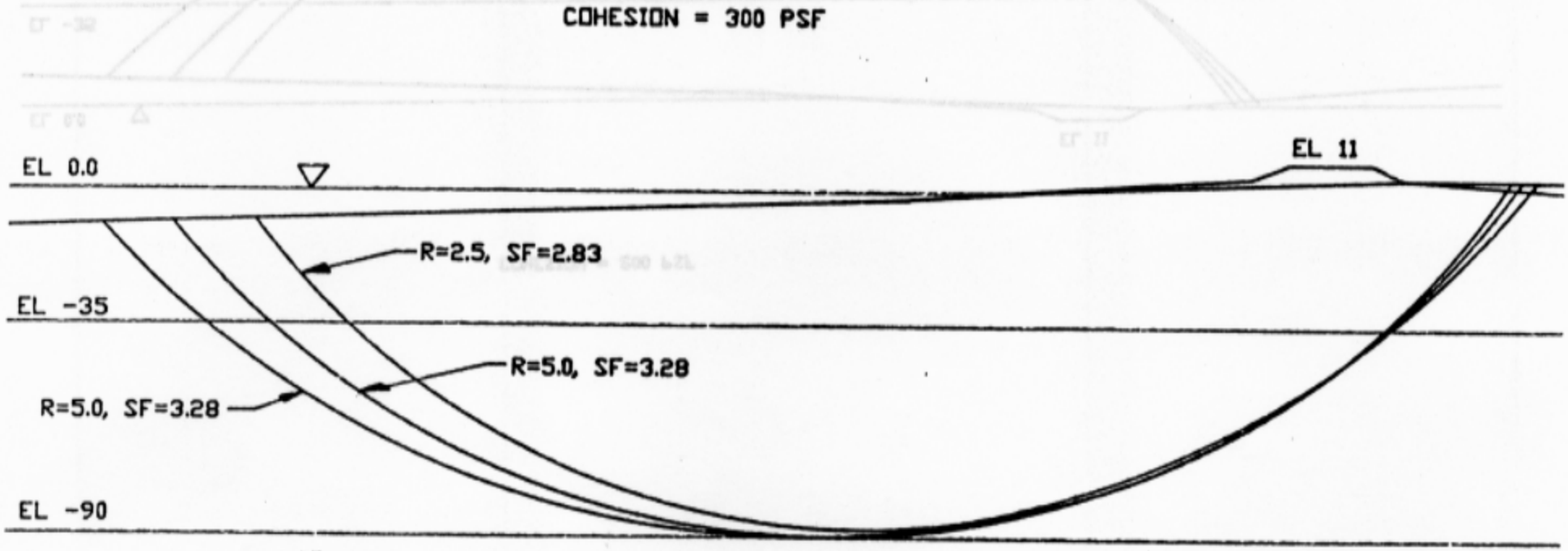


Figure A-2-12. Results of stability analysis using Bishop's method. Profile depth -35 ft, cohesion 300 psf, and rate of increase 0.0, 2.5, and 5.0 psf/ft.

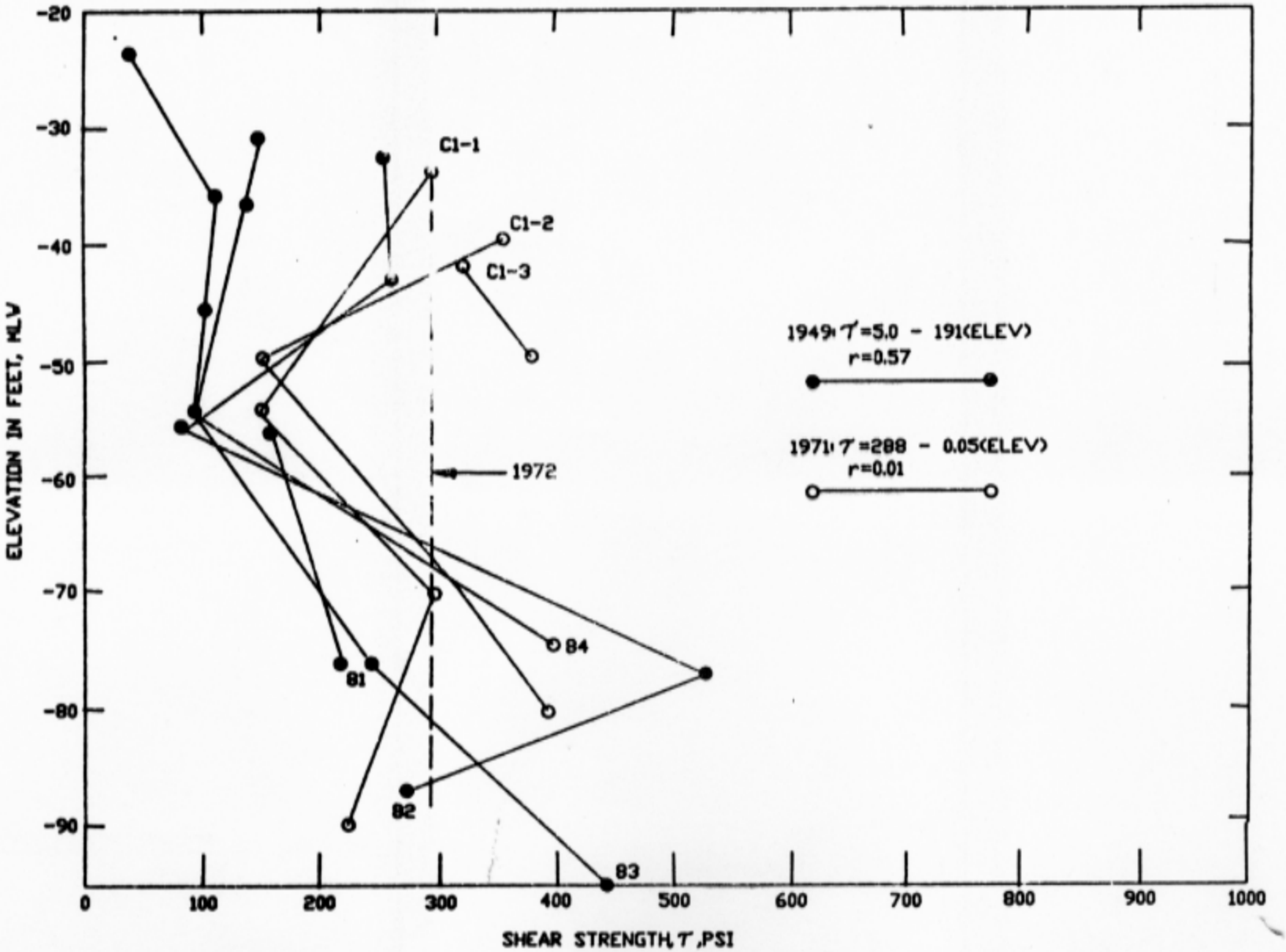
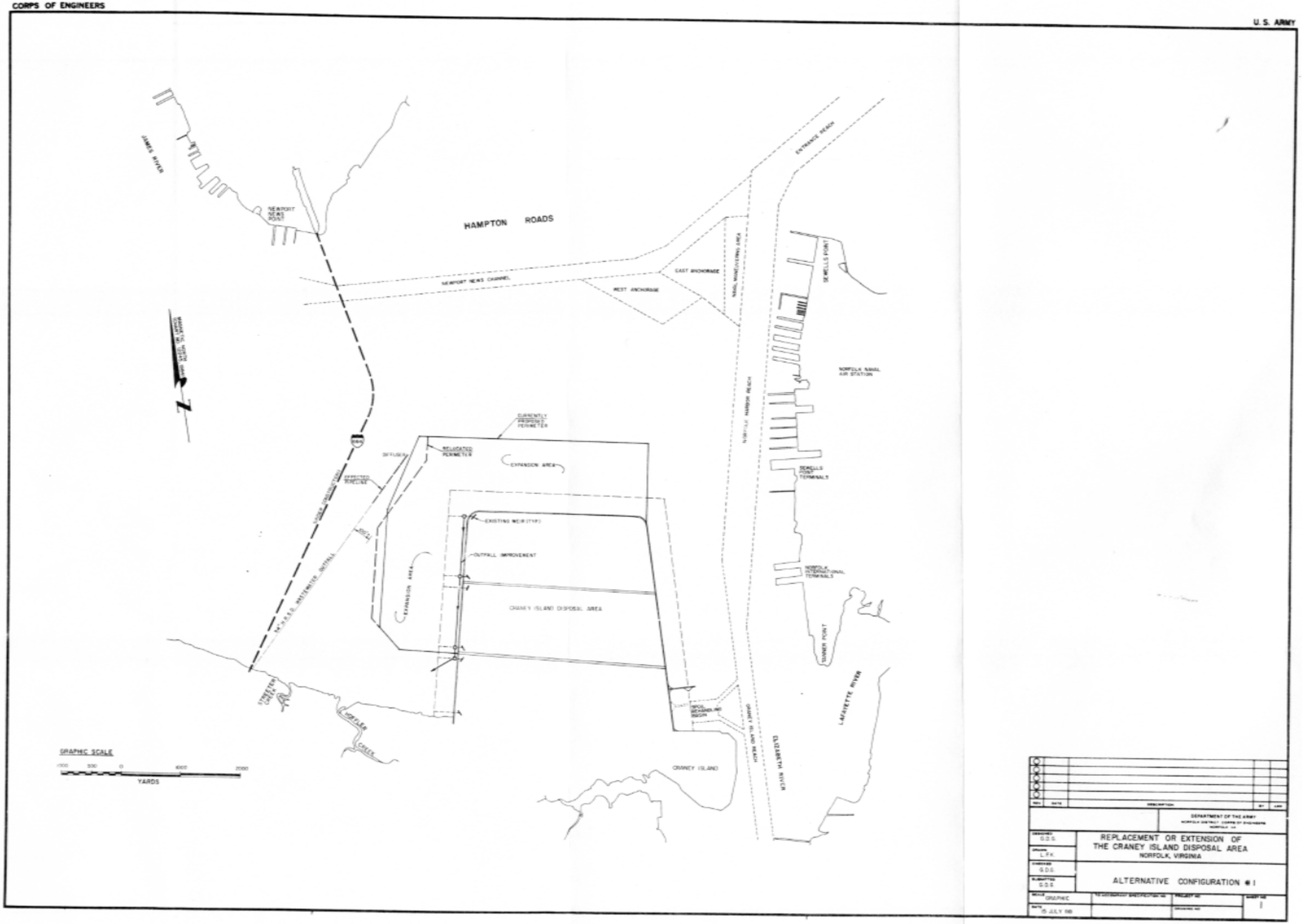


Figure 8 (Revised). Shear strength profile, 1949 and 1971 borings.

ATTACHMENT 3

CORPS OF ENGINEERS

U. S. ARMY



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DEPARTMENT OF THE ARMY
NORFOLK DISTRICT CORPS OF ENGINEERS
NORFOLK, VA

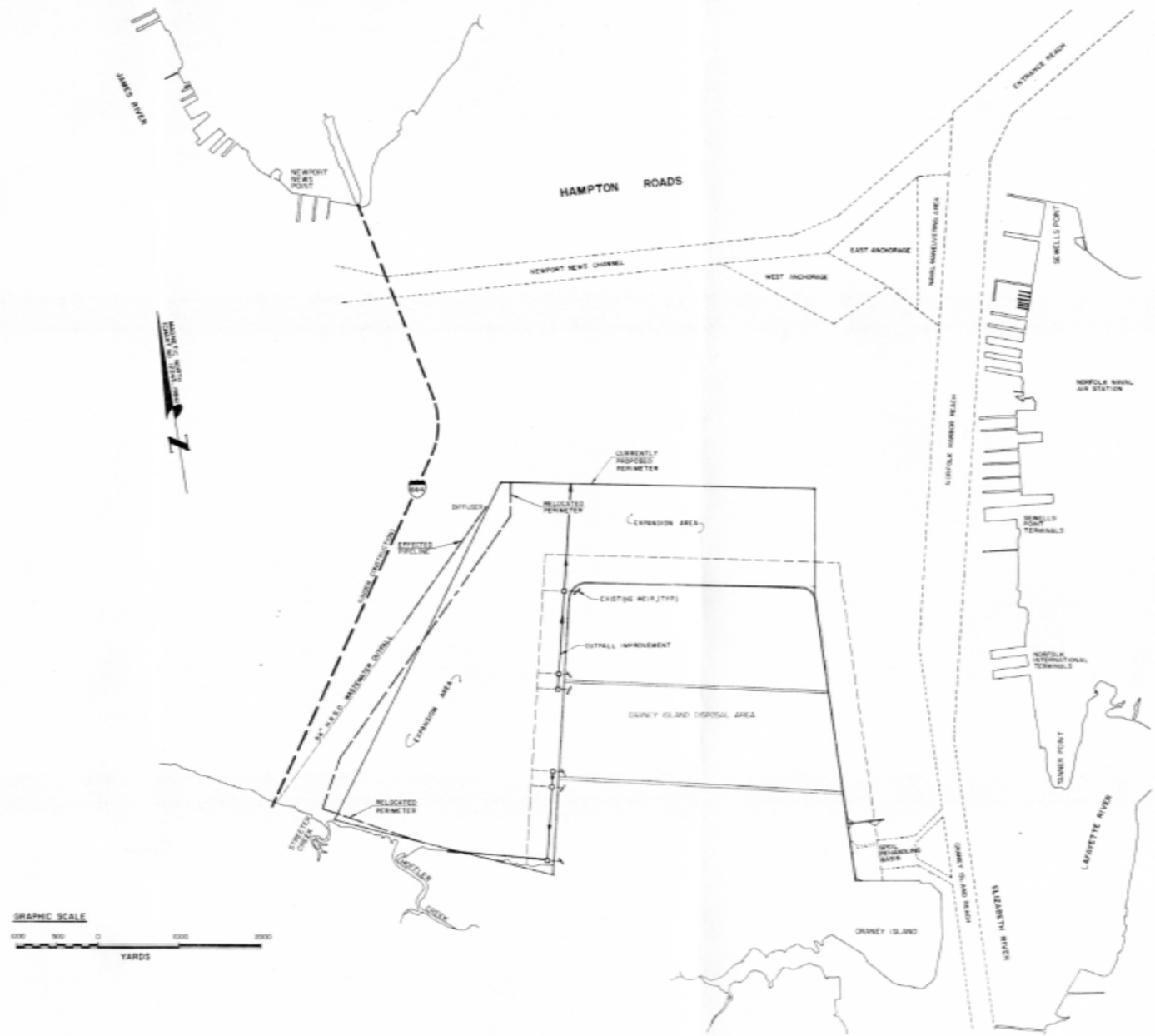
DESIGNED: G.D.S.
DRAWN: L.F.K.
CHECKED: G.D.S.
SUBMITTED: G.D.S.

REPLACEMENT OR EXTENSION OF THE CRANEY ISLAND DISPOSAL AREA
NORFOLK, VIRGINIA

ALTERNATIVE CONFIGURATION # 1

SCALE: GRAPHIC
DATE: 15 JULY 88
TO ACCOMPANY SPECIFICATION NO.
PROJECT NO.
DRAWING NO.
SHEET NO. 1

NORFOLK DISTRICT FILE NO



REV	DATE	DESCRIPTION	BY	APP

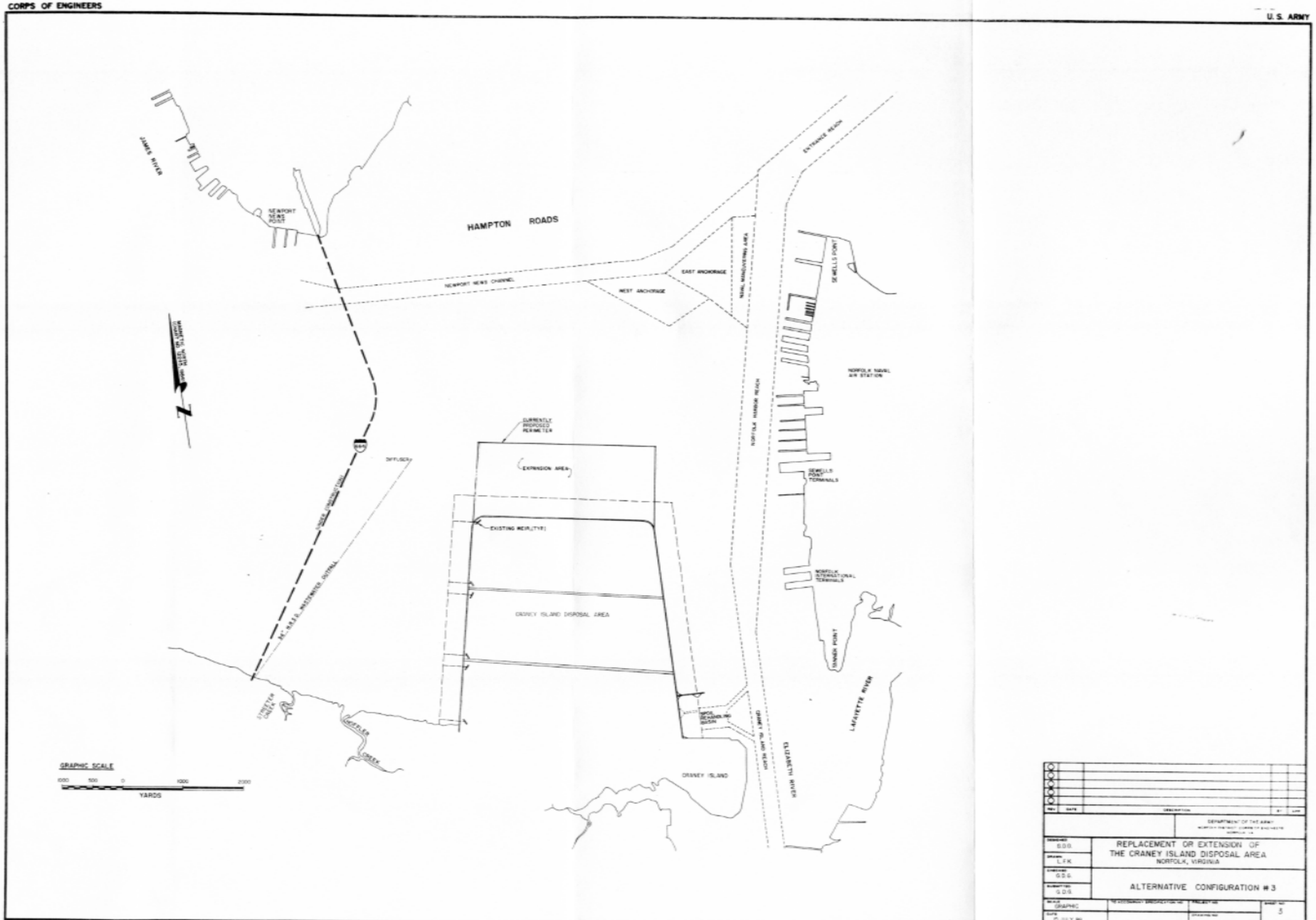
DEPARTMENT OF THE ARMY
NORFOLK DISTRICT CORPS OF ENGINEERS
NORFOLK, VA

DESIGNED: G.D.G.	REPLACEMENT OR EXTENSION OF THE CRANEY ISLAND DISPOSAL AREA NORFOLK, VIRGINIA
DRAWN: L.F.K.	
CHECKED: S.D.G.	ALTERNATIVE CONFIGURATION #2
SUBMITTED: G.D.G.	
SCALE: GRAPHIC	TO ACCOMPANY SPECIFICATION NO. / PROJECT NO. / SHEET NO. 2
DATE: 15 JULY 88	DRAWING NO.

NORFOLK DISTRICT FILE NO.

CORPS OF ENGINEERS

U. S. ARMY



REV	DATE	DESCRIPTION	BY	APP

DEPARTMENT OF THE ARMY
NORFOLK DISTRICT, CORPS OF ENGINEERS
NORFOLK, VA

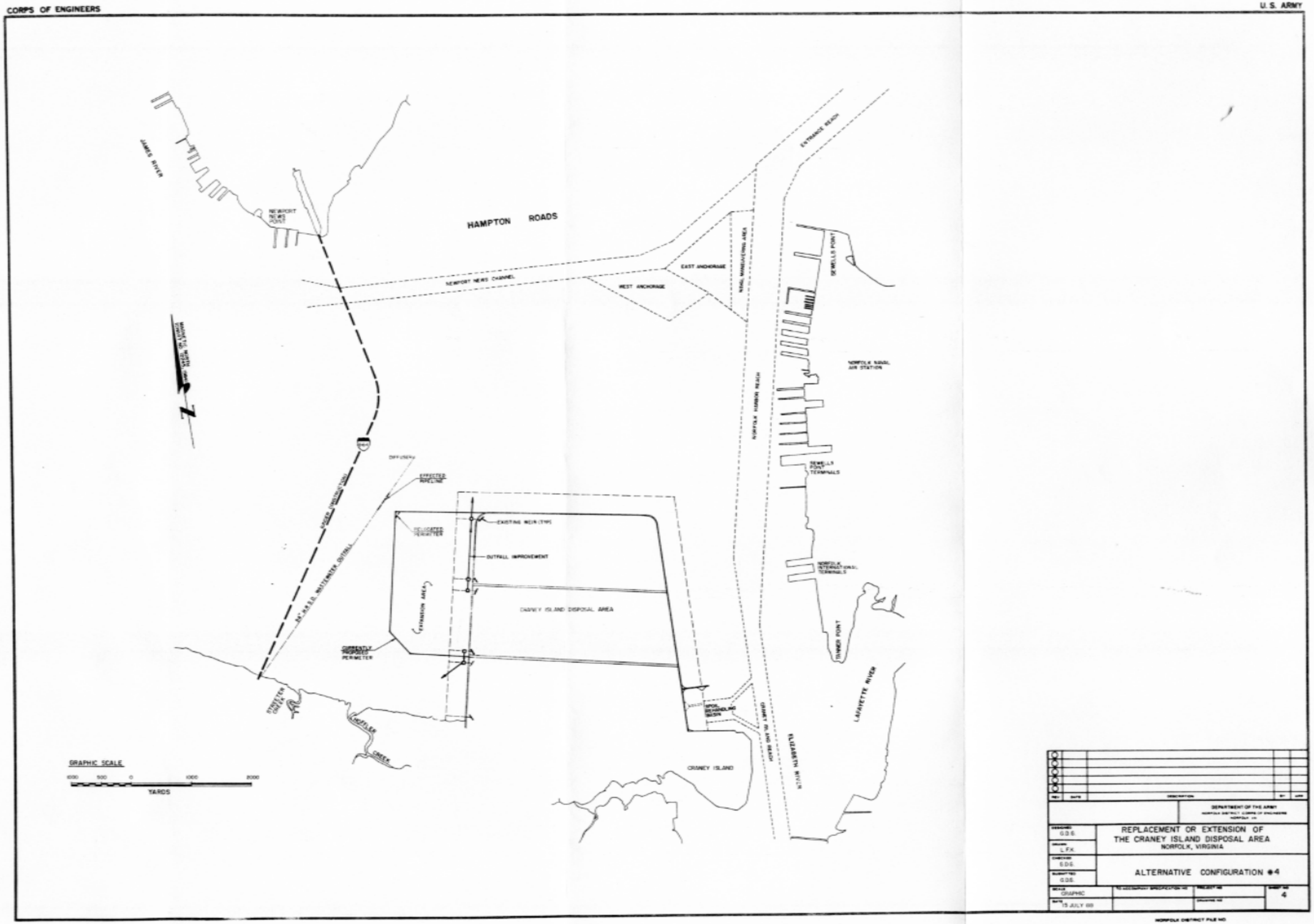
DESIGNED: G.D.G.
DRAWN: L.F.K.
CHECKED: G.D.G.
SUBMITTED: G.D.G.

REPLACEMENT OR EXTENSION OF
THE CRANEY ISLAND DISPOSAL AREA
NORFOLK, VIRGINIA

ALTERNATIVE CONFIGURATION # 3

SCALE: GRAPHIC
DATE: 15 JULY 86
TO ACCOMPANY SPECIFICATION NO.
PROJECT NO.
DRAWING NO.
SHEET NO. 5

NORFOLK DISTRICT FILE NO.



REV.	DATE	DESCRIPTION	BY	APR

DEPARTMENT OF THE ARMY
NORFOLK DISTRICT, CORPS OF ENGINEERS
NORFOLK, VA

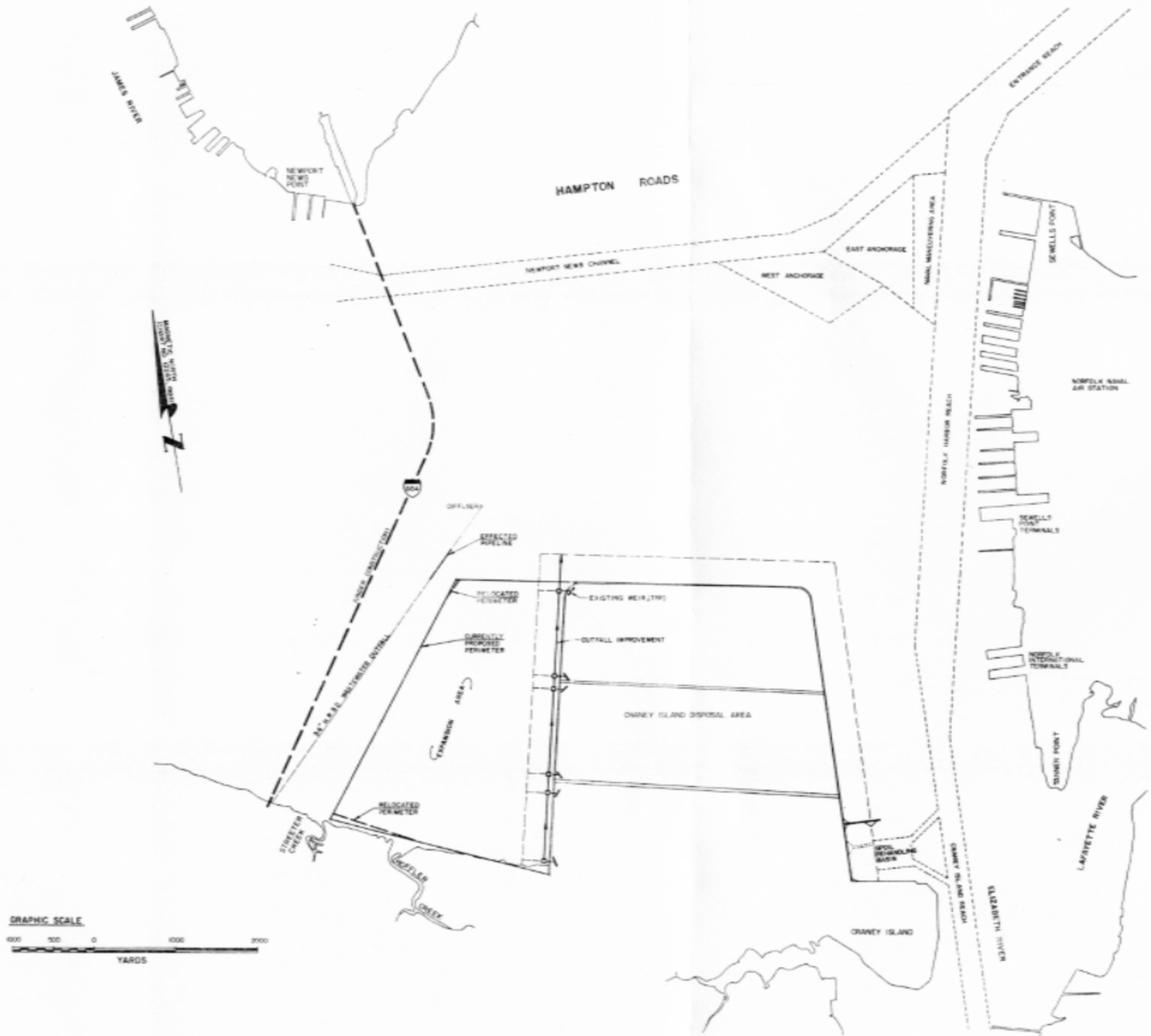
DESIGNED: G.D.S.
DRAWN: L.F.K.
CHECKED: G.D.S.
SUBMITTED: G.D.S.

REPLACEMENT OR EXTENSION OF
THE CRANEY ISLAND DISPOSAL AREA
NORFOLK, VIRGINIA

ALTERNATIVE CONFIGURATION #4

SCALE: GRAPHIC
DATE: 15 JULY 88
TO ASSEMBLY SPECIFICATION NO.
PROJECT NO.
DRAWING NO.
SHEET NO. 4

NORFOLK DISTRICT FILE NO.



REV	DATE	DESCRIPTION	BY	APR

DEPARTMENT OF THE ARMY
NORFOLK DISTRICT, CORPS OF ENGINEERS
NORFOLK, VA

DESIGNED: G.D.G.
DRAWN: L.F.K.
CHECKED: G.D.G.
SUBMITTED: G.D.G.

REPLACEMENT OR EXTENSION OF
THE CRANEY ISLAND DISPOSAL AREA
NORFOLK, VIRGINIA

ALTERNATIVE CONFIGURATION #5

SCALE: GRAPHIC
DATE: 15 JULY 88
PROJECT NO.
DRAWING NO.
SHEET NO. 5

NORFOLK DISTRICT FILE NO.

ATTACHMENT 4

INVENTORY OF EXISTING

UTILITIES

AND ADJUSTMENT RECOMMENDATIONS

RELATED TO

REPLACEMENT OR EXTENSION

OF

THE CRANEY ISLAND DISPOSAL AREA

NORFOLK, VIRGINIA

BY

LANGLEY AND McDONALD, P.C.
ENGINEERS - PLANNERS - SURVEYORS
484 Newtown Road
Virginia Beach, Virginia 23462

15 JULY 1988

PREFACE

This report presents the results of a utility inventory around a portion of Craney Island. The inventory area is bounded by the following; the west perimeter dike, shoreline west of Craney Island, a line parallel to and 2000 feet east of I-664, a line 4000 feet north of the north perimeter dike and the north perimeter dike. this report also addresses the effects of the proposed expansion on the weirs located on the west perimeter dike of Craney Island.

This report uses: Spigolop, S.J. and Fowler, J. 1987. "Geotechnical Feasibility Study, Replacement or Extension of the Craney Island Disposal Area, Norfolk, Virginia". Miscellaneous Paper G-87-9, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.; Craney Island Disposal Area Hydrographic Survey dated 17 Oct. 1986 by Waterway Surveys & Engineering Ltd., Virginia Beach, Virginia and Hampton Roads Sanitation District Nansemond Wastewater Treatment Plant, Plan Outfall - Phase 2 plans dated 16 July 1978 by McGaughy, Marshall & McMillan of Norfolk, Virginia and Hazen & Sawyer of New York, New York as sources of information.

CONTENTS

		PAGE
PREFACE		1
PART I:	INTRODUCTION	
	Background	3
	Objective	3
PART II:	UTILITIES	
	Existing Facilities	4
	Conflicts	4
	Adjustment - Recommendations	5
PART III:	WEIRS	
	Existing Facilities	7
	Impact of Proposed Expansion	7
	Modification Recommendations	8
PART IV:	HOFFLER AND STREETER CREEKS	
	Existing Conditions	9
	Impact of Proposed Expansion	9
	Recommended Accommodation	9
PART V:	COST ESTIMATES	
	Utility Relocation	11
	Weir Adjustments	12
PART V:	CONCLUSION	13
APPENDIX A:	Drawings	
	Alternate Configuration No. 1	
	Alternate Configuration No. 2	
	Alternate Configuration No. 3	
	Alternate Configuration No. 4	
	Alternate Configuration No. 5	

PART I: INTRODUCTION

Background

1. The Craney Island Disposal Area is a 2,500 acre dredged material containment area operated by the U.S. Army Engineer District, Norfolk (NAO). Four previous studies have been undertaken which have resulted in five options for expansion of the disposed area.

2. The U.S. Army Engineer Waterways Experiment Station (WES) has conducted four studies for NAO. These studies are:

a) "Fowler et al., 1986" report related to raising the existing perimeter dikes at Craney Island to el. +34 ft. MLW.

b) "Goforth, 1986" report on estimated storage volumes which will be generated by five alternative configurations of the extension of Craney Island to the west and north.

c) "Heltzel, 1986" report on the effects of the five proposed extensions of Craney Island on hydrodynamics in the project vicinity.

d) "Spigdon et al, 1987" report on geotechnical feasibility of replacement or extension of Craney Island.

Objective

3. The objectives of this report are: (a) to inventory the existing utilities within the proposed expansion area; (b) recommend adjustments needed with regard to those utilities; (c) recommend methods for maintaining operation of existing weirs along the western perimeter dike; and (d) consider the impact of expansion on Hoffler and Streeter Creeks. These evaluations are to be made for each of the five proposed configurations.

PART II: UTILITIES

Existing Facilities

4. Existing facilities are limited to U.S. Navy fuel lines which depart the northeastern corner of Craney Island to cross the Elizabeth River and a 54" subaqueous pipeline which lies to the west of the existing limits of Craney Island.

5. The Navy fuel lines carry fuel from the fuel depot, south of Craney Island, to the Naval Base, Sewells Point, Norfolk.

6. The 54" subaqueous pipeline belongs to the Hampton Road Sanitation District (HRSD). This pipeline is the outfall from the HRSD Nansemond Wastewater Treatment Plant.

Conflicts

7. The U.S. Navy fuel lines will not be effected by the proposed expansion plans for Craney Island. The connection point of the new dike with the northeastern corner of Craney Island can be selected to eliminate these pipelines from consideration.

8. The 54" subaqueous HRSD Wastewater Outfall will be an obstacle to the westward expansion of Craney Island. We have considered the treatment of this pipeline and discussed it with Mr. Richard Norman, P.E. at the Hampton Roads Sanitation District. There are two questions which must be addressed regarding the H.R.S.D. pipeline. Physical displacement of the pipeline, caused by displacement of the river bottom, must not occur. Changes in the dispersion of effluent from the Nansemond Treatment Plant should be considered. Appropriate geotechnical and hydrodynamic studies should be conducted to evaluate these issues. Since such studies would be extensions of studies already completed by others and since they are outside the scope of this study, we and H.R.S.D. have selected 1,000 feet as a "worst case" clear zone. Should evaluation of this question by Messrs. Heltzel and Spigdon, et. al. determine that another clear zone dimension is appropriate, this report

will be amended by the authors. The alternate configurations will be effected as follows:

a) Alternate 1: Approximately 3,200 ft. of the 54" pipeline will be within 1000 ft. of the proposed expansion. This includes 200 ft. of diffuser pipe which is above the river bottom, on a timber cradle supported by timber piles.

b) Alternate 2: Approximately 5,300 ft. of the 54" pipeline will be within 1000 ft. of the proposes expansion. This also includes 200 ft. of diffuser pipe.

c) Alternate 3: The 54" pipeline will not be effected.

d) Alternate 4: Approximately 1,100 ft. of the 54" pipeline will be within 1000 ft. of the proposed expansion. This portion does not include the diffuser at the northern end of the pipeline.

e) Alternate 5: Approximately 1,100 ft. of the 54" pipeline will be within 1000 ft. of the proposed expansion. This portion does not include the diffuser at the northern end of the pipeline.

Adjustment Recommendations

9. Adjustments to either the proposed expansion of Craney Island or the existing 54" HRSD Wastewater Outfall will be necessary for four of the five alternative configurations for expansion of Craney Island. Only Alternate 3 requires no adjustment.

10. Relocation of the existing 54" HRSD Wastewater Outfall Pipeline will be difficult and costly. The difficulty and cost are amplified by the need for the Nansemond Sewage Treatment Plant to remain in operation during the work.

11. The northwest corner of the proposed expansion to Craney Island can be relocated to the east with no increase in cost of construction. The increase area lost by this adjustment can be recouped in Alternative 1 by adjusting the southwestern corner. The area lost in Alternative 2 can be recouped by moving the northern boundary to the north. The area lost to Alternatives 4 and 5 is trivial.

12. The effected portions of the HRSD pipeline and the proposed adjustments to the new limits of Craney Island are shown on the drawings in Appendix A of this report.

PART III: WEIRS

Existing Facilities

13. Six weirs presently exist along the western perimeter dike of Craney Island. These are distributed two to each of the cells in the disposal area. The weirs have adjustable overflow elevations and each discharges through four 36" diameter pipes. Discussion with Mr. Henry Williamson on Craney Island staff indicates that these weirs are functional and that no changes are needed at this time. The most recently constructed weir includes improvements over the older weirs which should be applied to any new construction.

Impact of Proposed Expansion

14. The five alternative configurations for expansion of Craney Island will effect the existing weirs to varied degrees.

a) Alternative 1 will effect the five northernmost weirs. Of these five, the southernmost can gain an outfall to the river by relocation of its outfall pipes.

b) Alternative 2 will effect all six existing weirs, none of which offer the possibility of easy modification for access to a river outfall.

c) Alternative 3 may require some minor modification to the outfall pipes from the northernmost weir. The others will not be effected.

d) Alternative 4 will effect the five northernmost weirs. Of these, the northernmost and southernmost can gain access to a river outfall by modification of their outfall piping.

e) Alternative 5 will effect all six of the existing weirs. The northernmost weir can gain a river outfall with modification of its discharge pipes.

Modification Recommendation

15. In all of the alternatives for expansion, except No. 2, at least one effected weir structure can gain access to a direct outfall into the river. This can be accomplished by relocation of the existing 36" outfall pipes from these weirs. The remaining weirs will require more extensive treatment to regain their outfalls into the river.

16. Two primary options are available for restoration of river outfalls to the weirs which are being completely blocked by the proposed expansion:

a) The existing outfall pipes could be intercepted by large diameter pipes which would carry their flow to the river. These pipes would be installed under the lower section of the existing west perimeter dike. This solution will allow continued use of the roadway along the western perimeter of Craney Island without expansion of the existing dike, however, a parallel dike along the expanded area will be required.

b) The second option for connecting the weirs to the river involves the creation of an open ditch to carry the weirs discharge. This drainage ditch would parallel the existing dike. A rip-rap liner and stone check dams would be provided to limit erosion of the ditch and to trap any material which is eroded.

17. The two options discussed above, for maintaining river outfalls for all existing weirs, will allow continued use of the existing facilities while diverting flows out of the expansion areas. The modification discussed are shown on the drawings in Appendix A of this report.

PART IV: HOFFLER AND STREETER CREEKS

Existing Facilities

18. Hoffler and Streeter Creeks are tidal estuaries off the southern shore of the James River. These creeks extend 2500 yards and 1500 yards, respectively, into the south shore of the James River and flow into an area of the James River which is less than 2' deep for a distance of 1200 yards offshore from their mouths. These creeks, while shallow, provide storm drainage outfalls for a significant area. The function of these two creeks should be maintained.

Impact of Proposed Expansion

19. Only proposed expansions #2 and #5 impact these two creeks. Expansion of the dredged material containment area to abut the existing shoreline will effectively close both Hoffler and Streeter Creeks.

Recommended Accommodation

20. Both the creeks in question and the James River at their mouths are very shallow (under 2' at MLW). While shallow, these two creeks provide storm drain outfalls for significant areas and would require very large pipes to carry their flows. This combined with the shallow depth makes the piping of these creeks to connect them to the James River a poor alternative. The proposed southern berm of expansion options #2 and #5 should be located sufficiently north to provide for continued function of Hoffler and Streeter Creeks. Such a perimeter shift can be balanced with a minor westward adjustment of the western perimeter dike to conserve the net containment area increase.

21. There should be no significant cost increase associated with this recommended relocation of the perimeter dike. As with the clear zone

dimension related to H.R.S.D.'s outfall pipe, determination of the appropriate distance to relocate the southernmost dike would best be determined through an extension of the existing geotechnical and hydrodynamic studies which have been completed by Messrs. Heltzel and Spigdon, et al.

PART V: COST ESTIMATES

Utility Relocation

ALTERNATIVE 1:

Mobilization	$ 100,000.00
3000 L.F. 54" Pipe @ $600/Ft.	1,800,000.00
200 L.F. Diffuser @ $2000/Ft.	400,000.00
Construction Cost	$2,300,000.00
+ 20% Engineering & Contingency	460,000.00
TOTAL COST	$2,760,000.00

ALTERNATIVE 2:

Mobilization	$ 100,000.00
5100 L.F. 54" Pipe @ $600/Ft.	3,060,000.00
200 L.F. Diffuser @ $2000/Ft.	400,000.00
Construction Cost	$3,560,000.00
+ 20% Engineering & Contingency	712,000.00
TOTAL COST	$4,272,000.00

ALTERNATIVE 3: NO ADJUSTMENT NEEDED

ALTERNATIVE 4 AND 5:

Mobilization	$ 100,000.00
1100 L.F. 54" Pipeline @ $600/Ft.	660,000.00
Construction Cost	$ 760,000.00
+20% Engineering & Contingency	132,000.00
TOTAL COST	$ 792,000.00

Weir Adjustments

ALTERNATIVE 1:

OPEN DITCH SYSTEM

7600 L.F. Ditch @ $165/Ft.	$1,254,000.00
+20% Engineering & Contingency	250,800.00
TOTAL COST	$1,504,800.00

PIPED SYSTEM

7600 L.F. Twin 72" Pipe @ $335/Ft.	$2,546,000.00
5 EA. Basins @ $2600 Ea.	13,000.00
+20% Engineering & Contingency	511,800.00
TOTAL COST	$3,070,800.00

ALTERNATIVE 2:

OPEN DITCH SYSTEM

14,465 L.F. Ditch @ $165/Ft.	$2,386,725.00
+20% Engineering & Contingency	477,345.00
TOTAL COST	$2,865,070.00

PIPED SYSTEM

13,500 L.F. Twin 72" Pipe @ $335/Ft.	$4,522,500.00
6 EA. Basins @ $2600 Ea.	15,600.00
+20% Engineering & Contingency	907,620.00
TOTAL COST	$5,445,720.00

ALTERNATIVE 4:

OPEN DITCH SYSTEM

7600 L.F. Ditch @ $165/Ft.	$1,254,000.00
+20% Engineering & Contingency	250,800.00
TOTAL COST	$1,504,800.00

PIPED SYSTEM

4700 L.F. Twin 73" Pipe @ $335/Ft.	$1,574,500.00
5 Ea. Basins @ $2600/Ea.	13,000.00
+20% Engineering & Contingency	317,500.00
TOTAL COST	$1,905,000.00

ALTERNATIVE 5:

OPEN DITCH SYSTEM

1100 L.F. Ditch @ $165/Ft.	$ 181,500.00
+20% Engineering & Contingency	36,300.00
TOTAL COST	$ 217,800.00

PIPED SYSTEM

1100 L.F. Twin 72" Pipe @ $335/Ft.	$ 368,500.00
6 EA. Basins @ $2600	15,600.00
+20% Engineering & Contingency	76,820.00
TOTAL COST	$ 460,920.00

PART VI: CONCLUSION

22. Relocation of the existing 54" HRSD Wastewater Outfall can and should be avoided. The modifications to the expansion alternatives recommended in the text and shown on the drawings in Appendix A eliminate any impact by Craney Island on the HRSD pipeline.

23. Continued operation of the existing weir structures can be accomplished. Two viable options are presented with their associated costs for each expansion alternative. Selection of piped outfall or open ditch outfall should be made based upon operational considerations.

24. Flow should be maintained from Hoffler and Streeter Creeks in an open system.

25. Expansion of existing geotechnical and hydrodynamic studies should be made with regard to the H.R.S.D. pipeline and Hoffler and Streeter Creeks.

DREDGING IN HAMPTON ROADS

NORFOLK HARBOR

Prepared by:

Rich & Associates
1825 Cedar Road
Chesapeake, Va 23323
24 October 1988

DREDGING IN HAMPTON ROADS
NORFOLK HARBOR

TABLE OF CONTENTS

Table of Contents..... 1

Discussion..... 2

Assumptions:
- New Work..... 3
- Maintenance..... 4

Chart of Costs..... 5

Graphs:
- New Work Dredging Summary..... 6
- New Work Individual..... 7-10
- Maintenance Dredging Summary..... 11
- Maintenance Individual.....12-15

Estimate Sheets:
- New Work.....16-39
- Maintenance.....40-79

Discussion:

Costs shown in this report are based upon average conditions. Specific conditions assumed are shown in assumptions. Dredging costs as shown by bid results vary greatly. The actual cost shown can be expected to be in the middle of the bidding range.

Hydraulic dredging costs are based upon a 27" Manhatten Class Dredge pumping directly into Craney Island.

Bucket dredging costs are based upon an 10 cy bucket dredge for quantities under 50,000 cy and a 18 cy bucket dredge for larger quantities. Loading will be directly to scows which are then towed to the disposal area. Production calculations were made on each of these operations with the number of sets of scows required rounded to the nearest whole number. Costs were then developed using the lower of the two productions. For disposal directly into Craney Island, a barge rehandler with a capacity of 1,000 cy/hr was used.

The most practical approach to assumptions was to keep those made to whole numbers. This has caused some slight spikes to appear on the charts. Production times were carried out to one decimal. This was done to produce differences in the very small quantities.

Fuel costs of $0.90/gallon were used. Total fuel costs can be calculated as follows:

Bucket:
Fuel Costs = Cost/mo X (1 + OH&P) X 1/30 X eff time (days)
X 1.09 (E&D/S&A) X 1.20 (Contingencies)

Hydraulic:
7000 HP X .067 gal/hr/hp X 85% x Pumping Hours/day
X operating day/mo X dredging time months X cost/gal.
X 1.09 (E&D/S&A) x 1.20 (contingencies)

Craney Island toll charges are not included. An allowance of 9% for Engineering and Design/Supervision and Administration and a contingency allowance of 20% is included.

ASSUMPTIONS
DREDGING IN HAMPTON ROADS - NORFOLK HARBOR

1. NEW WORK
A. Directly to Craney Island

1. Hydraulic - 15000 lf pumping distance

cy (1,000)	500	750	1,000	2,000	4,000	6,000
cy/hour	1640	1640	1640	1640	1640	1640
hours/day	18	19	19	20	20	20
day/month	20	21	22	22	22	22
boosters	1	1	1	1	1	1
OH & P	25	24	24	23	21	20

2. Bucket - 1 mile into Southern Branch, 6 mile haul
Fuel costs $0.90/gallon

cy (1,000)	500	750	1000	2000	4000	6000
dredge size	18 cy	18 cy	18 cy	18 cy	18 cy	18 cy
gross to pay	1.2	1.2	1.2	1.2	1.2	1.2
cycle time/min	1.2	1.2	1.2	1.2	1.2	1.2
efficency factor	.65	.65	.70	.75	.75	.75
scows (set)	1	1	1	1	1	1
lost time	20	19	19	18	18	17
OH & P	25	24	24	23	21	20
dump (pump out)	7	7	7	7	6	6

B. Ocean Disposal - Dam Neck Ocean Disposal Site, 37 mile haul.
C. Ocean Disposal - Norfolk Ocean Disposal Site, 45 mile haul.

cy (1,000)	500	750	1000	2000	4000	6000
dredge size	18 cy	18 cy	18 cy	18 cy	18 cy	18 cy
gross to pay	1.2	1.2	1.2	1.2	1.2	1.2
cycle time/min	1.2	1.2	1.2	1.2	1.2	1.2
efficency factor	.65	.65	.70	.70	.70	.70
scows (set)	3	3	3	3	3	3
lost time	20	19	19	18	18	17
OH & P	25	24	24	23	21	20
dump (pump out)	1	1	1	1	1	1

ASSUMPTIONS
DREDGING IN HAMPTON ROADS - NORFOLK HARBOR

2. MAINTENANCE

A. Into rehandling basin, clean material, 6 mile haul.

cy (1,000)	5	10	20	50	75	100	250	500	1000	3000
dredge size	10 cy	10 cy	10 cy	10 cy	18 cy	18 cy	18 cy	18 cy	18 cy	18 cy
gross to pay	1.3	1.3	1.3	1.3	1.25	1.25	1.25	1.25	1.25	1.25
cycle time/min	1	1	1	1	1.2	1.2	1.2	1.2	1.2	1.2
efficency factor	.65	.65	.65	.65	.65	.65	.65	.65	.70	.70
scows (set)	1	1	1	1	1	1	1	1	1	1
lost time	23	22	21	20	20	20	20	20	19	18
OH & P	27	26	26	26	25	25	25	25	24	22
dump (pump out)	1	1	1	1	1	1	1	1	1	1

B. Into Craney Island, Barge Rehandler, contaminated material, 6 mile haul.

cy (1,000)	5	10	20	50	75	100	250	500	1000	3000
dredge size	10 cy	10 cy	10 cy	10 cy	18 cy	18 cy	18 cy	18 cy	18 cy	18 cy
gross to pay	1.35	1.35	1.3	1.3	1.25	1.25	1.25	1.25	1.25	1.25
cycle time/min	1	1	1	1	1	1	1.2	1.2	1.2	1.2
efficency factor	.65	.65	.65	.65	.65	.65	.65	.65	.70	.70
scows (set)	1	1	1	1	1	1	1	1	1	1
lost time	23	22	21	21	20	20	20	20	19	18
OH & P	27	26	26	26	25	25	25	25	24	22
dump (pump out)	8	8	8	7	7	7	7	7	7	7

C. Ocean Disposal - Dam Neck Ocean Disposal Site, 37 mile haul.
D. Ocean Disposal - Norfolk Disposal Site, 45 mile haul.

cy (1,000)	5	10	20	50	75	100	250	500	1000	3000
dredge size	10 cy	10 cy	10 cy	10 cy	18 cy	18 cy	18 cy	18 cy	18 cy	18 cy
gross to pay	1.35	1.35	1.3	1.3	1.25	1.25	1.25	1.25	1.25	1.25
cycle time/min	1	1	1	1	1.2	1.2	1.2	1.2	1.2	1.2
efficency factor	.65	.65	.65	.65	.65	.65	.65	.65	.70	.70
scows (set)	2	2	2	2	3	3	3	3	3	3
lost time	23	22	21	21	20	20	20	20	19	18
OH & P	27	26	26	26	25	25	25	25	24	22
dump (pump out)	1	1	1	1	1	1	1	1	1	1

DREDGING UNIT COST SUMMARY

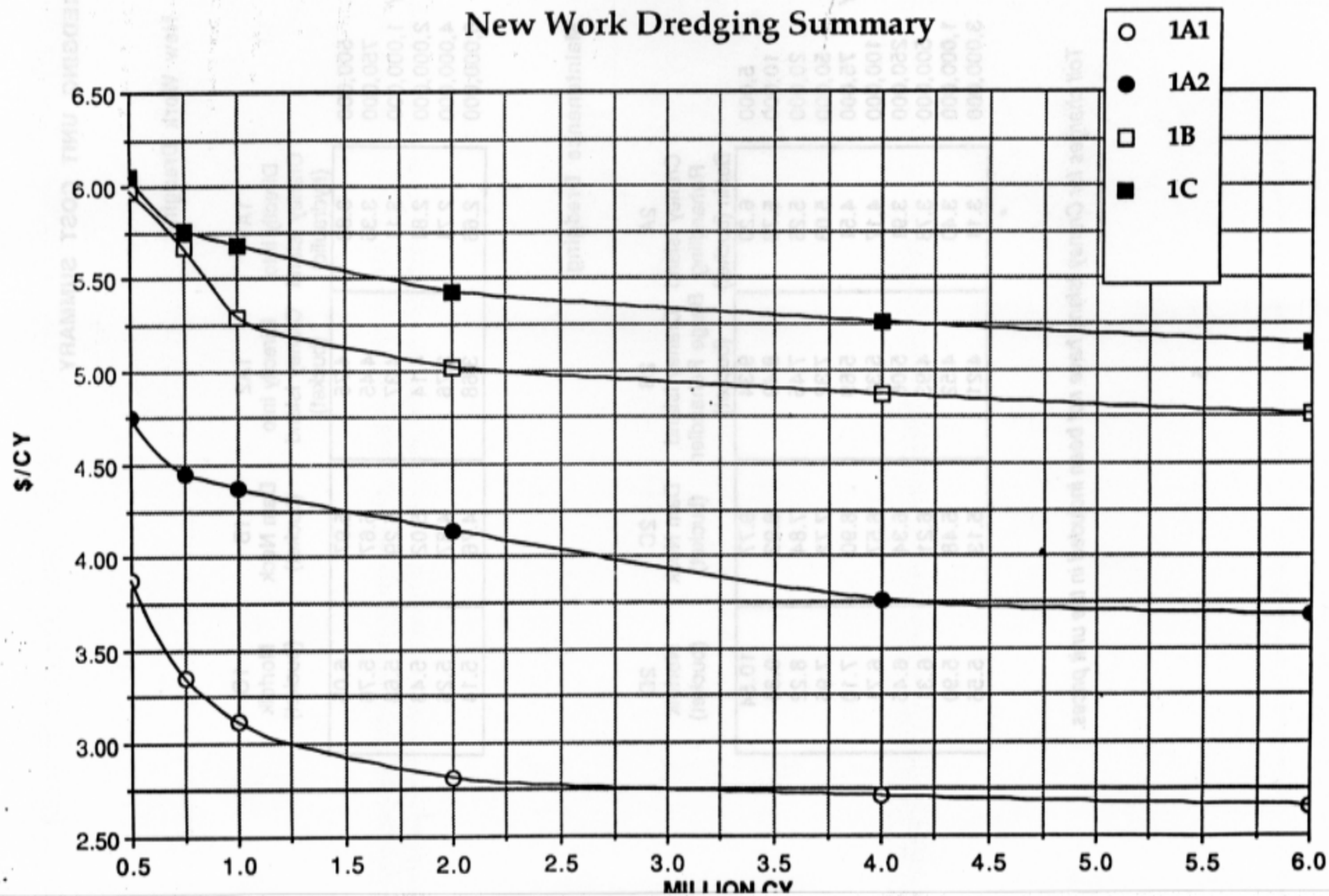
1. New Work Dredging

	1A1 Directly into Craney Island (hydraulic)	1A2 Directly into Craney Island (bucket)	1B Dam Neck (bucket)	1C Norfolk (bucket)
500,000	3.88	4.75	5.97	6.05
750,000	3.35	4.45	5.67	5.76
CY 1,000,000	3.11	4.37	5.29	5.68
2,000,000	2.81	4.14	5.02	5.43
4,000,000	2.71	3.76	4.87	5.26
6,000,000	2.66	3.68	4.76	5.14

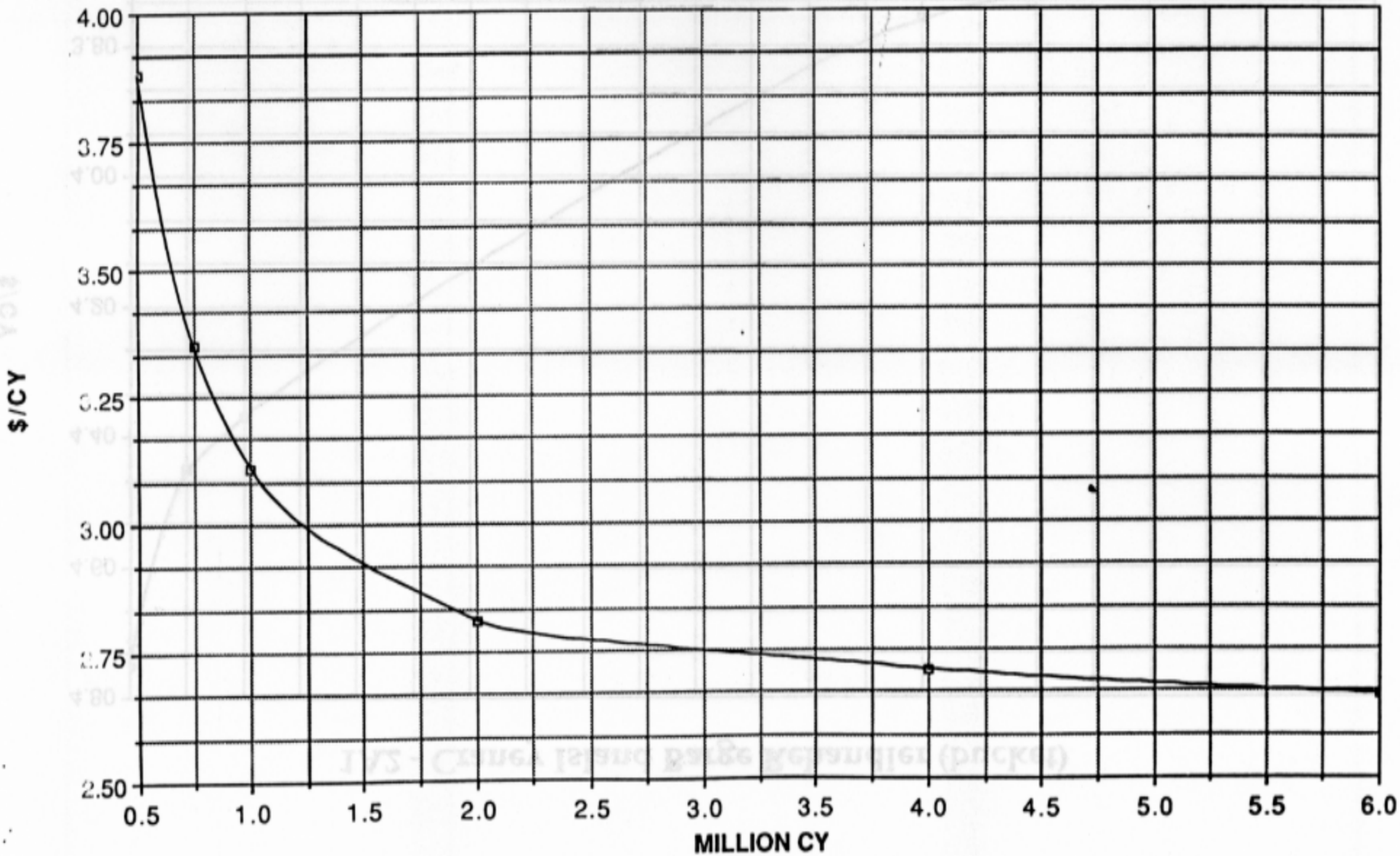
2. Maintenance Dredging

	2A Craney Island Rehandling Basin (bucket)	2B Craney Island Barge Rehandler (bucket)	2C Dam Neck (bucket)	2D Norfolk (bucket)
5,000	6.20	9.34	9.77	10.54
10,000	5.78	8.49	8.93	9.31
20,000	5.26	7.45	7.84	8.22
50,000	5.03	7.32	7.72	7.95
CY 75,000	4.51	5.69	6.90	7.10
100,000	4.17	5.30	6.57	6.71
250,000	3.91	5.06	6.34	6.45
500,000	3.78	4.93	6.21	6.31
1,000,000	3.40	4.52	5.48	5.90
3,000,000	3.11	4.21	5.13	5.55

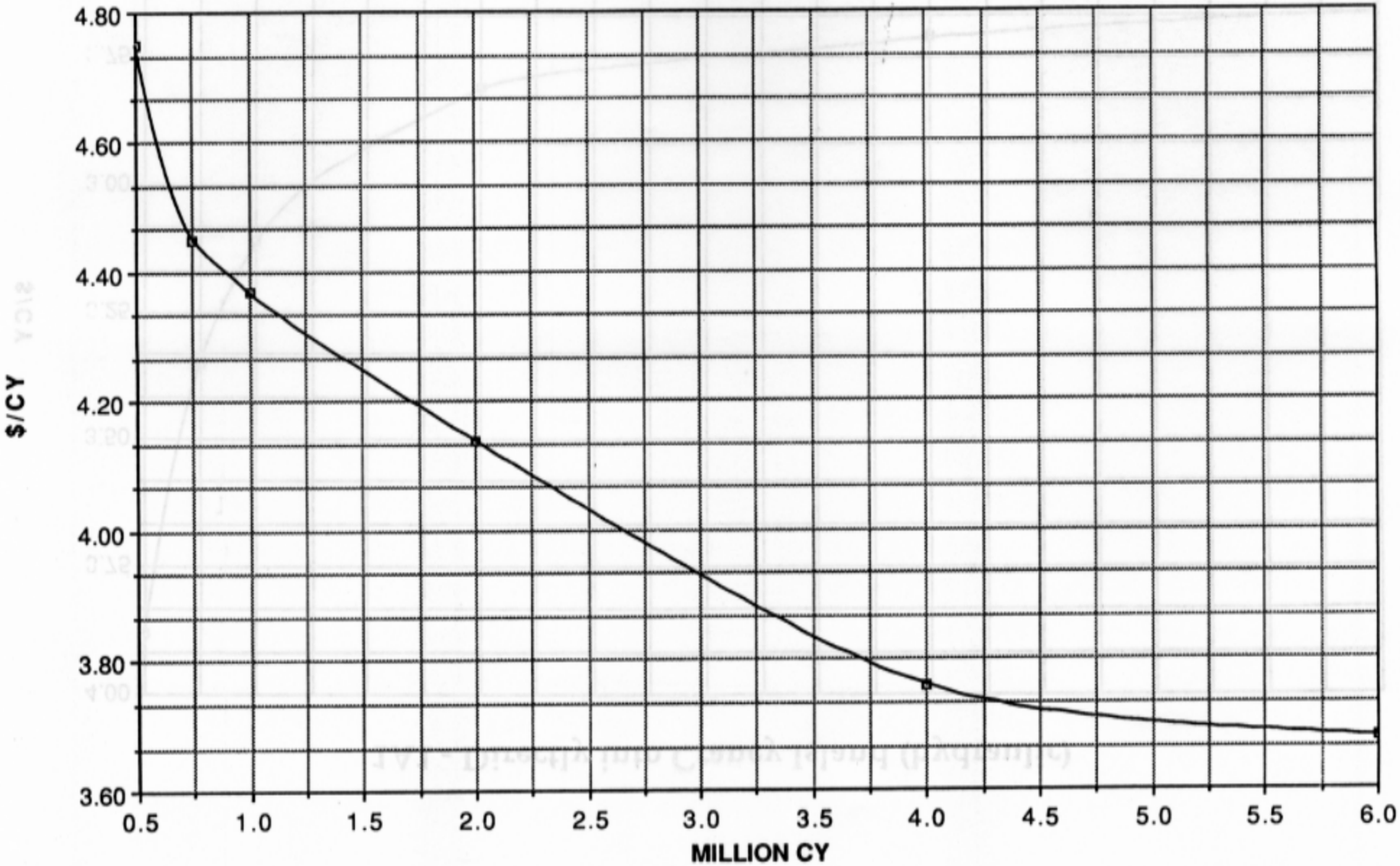
Toll charges for Craney Island have not been included in the unit prices.


New Work Dredging Summary
1A1
1A2
1B
1C
$/CY
6.50
6.00
5.50
5.00
4.50
4.00
3.50
3.00
2.50
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
MILLION CY

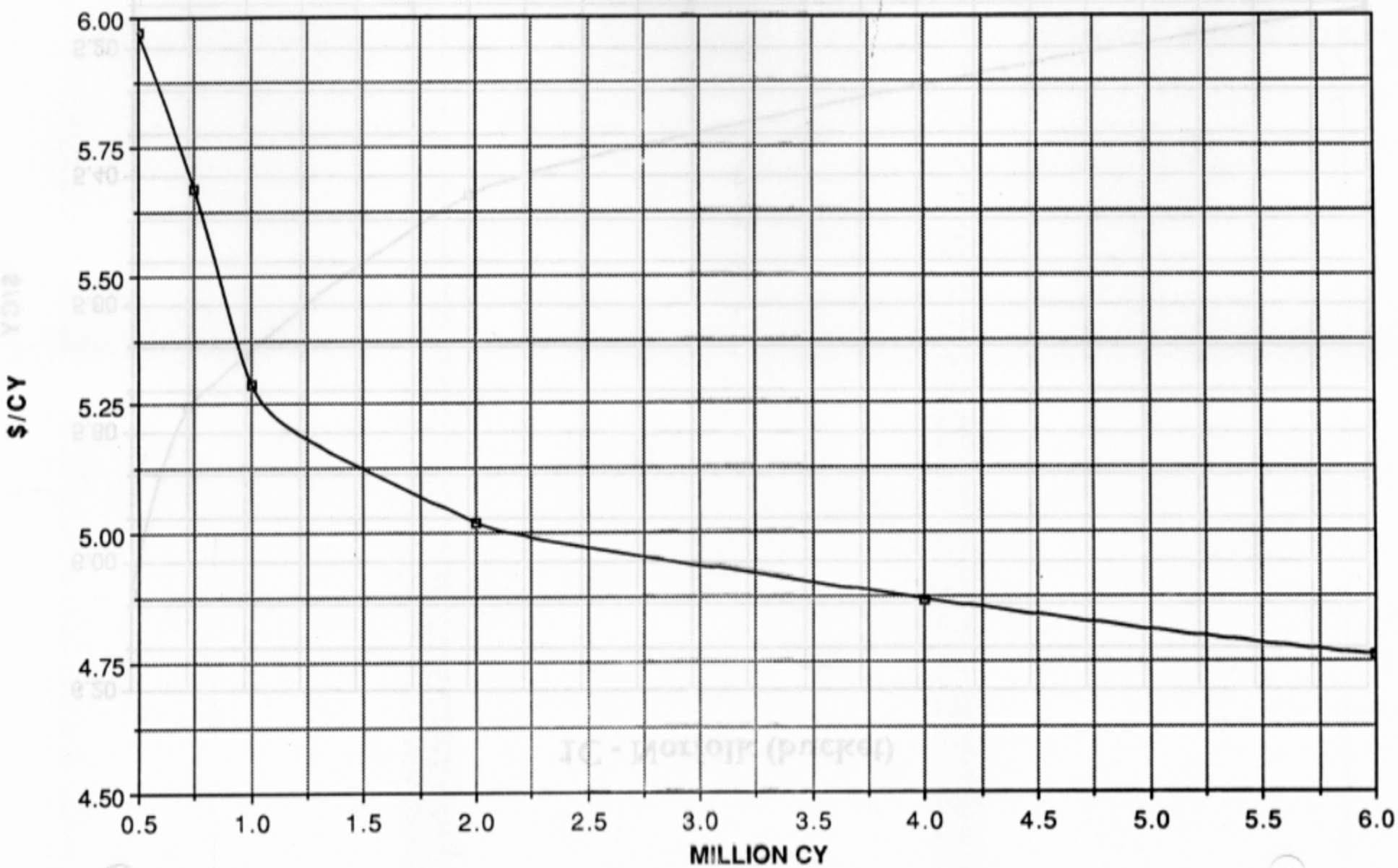
1A1 - Directly into Craney Island (hydraulic)



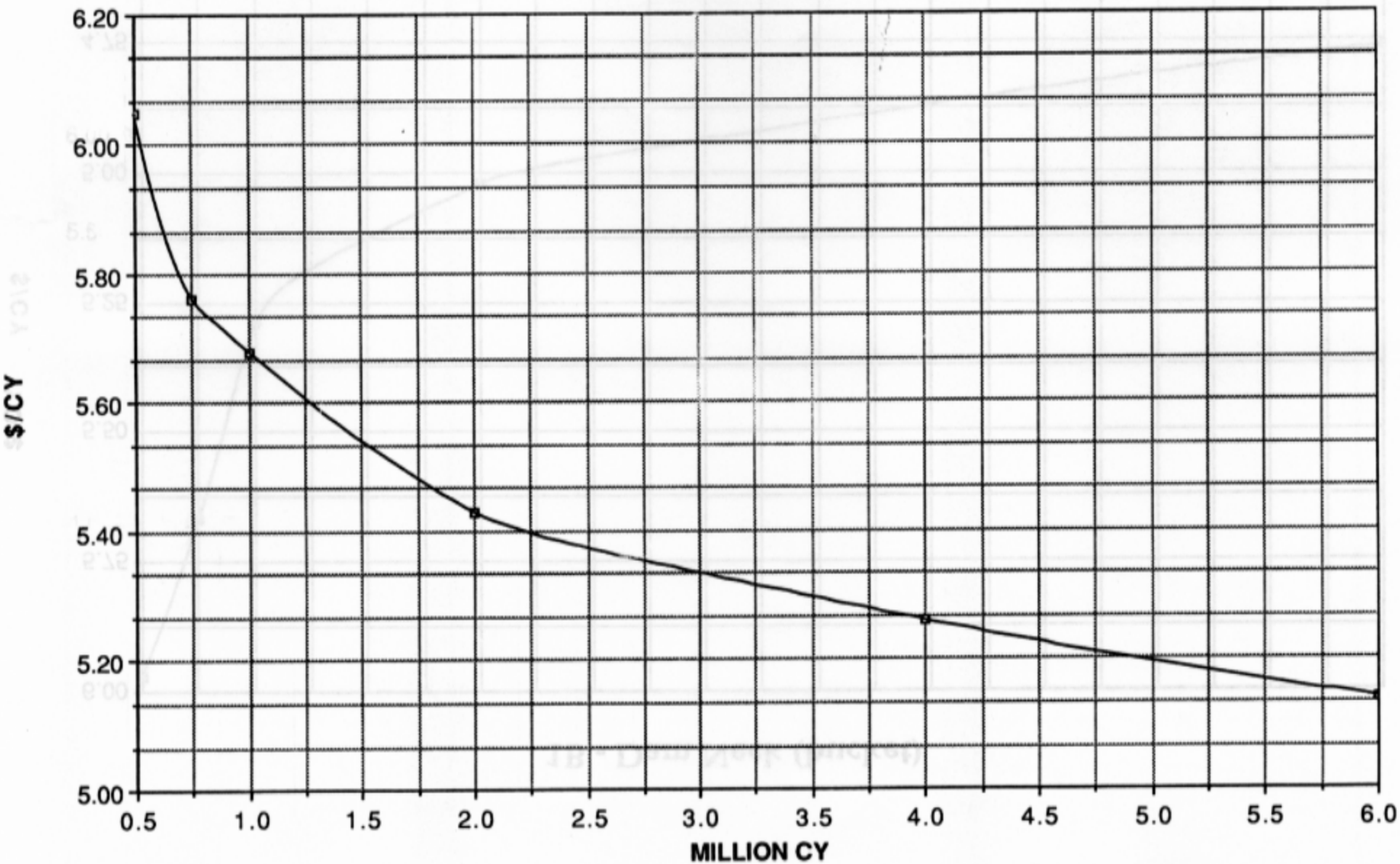
1A2 - Craney Island Barge Rehandler (bucket)



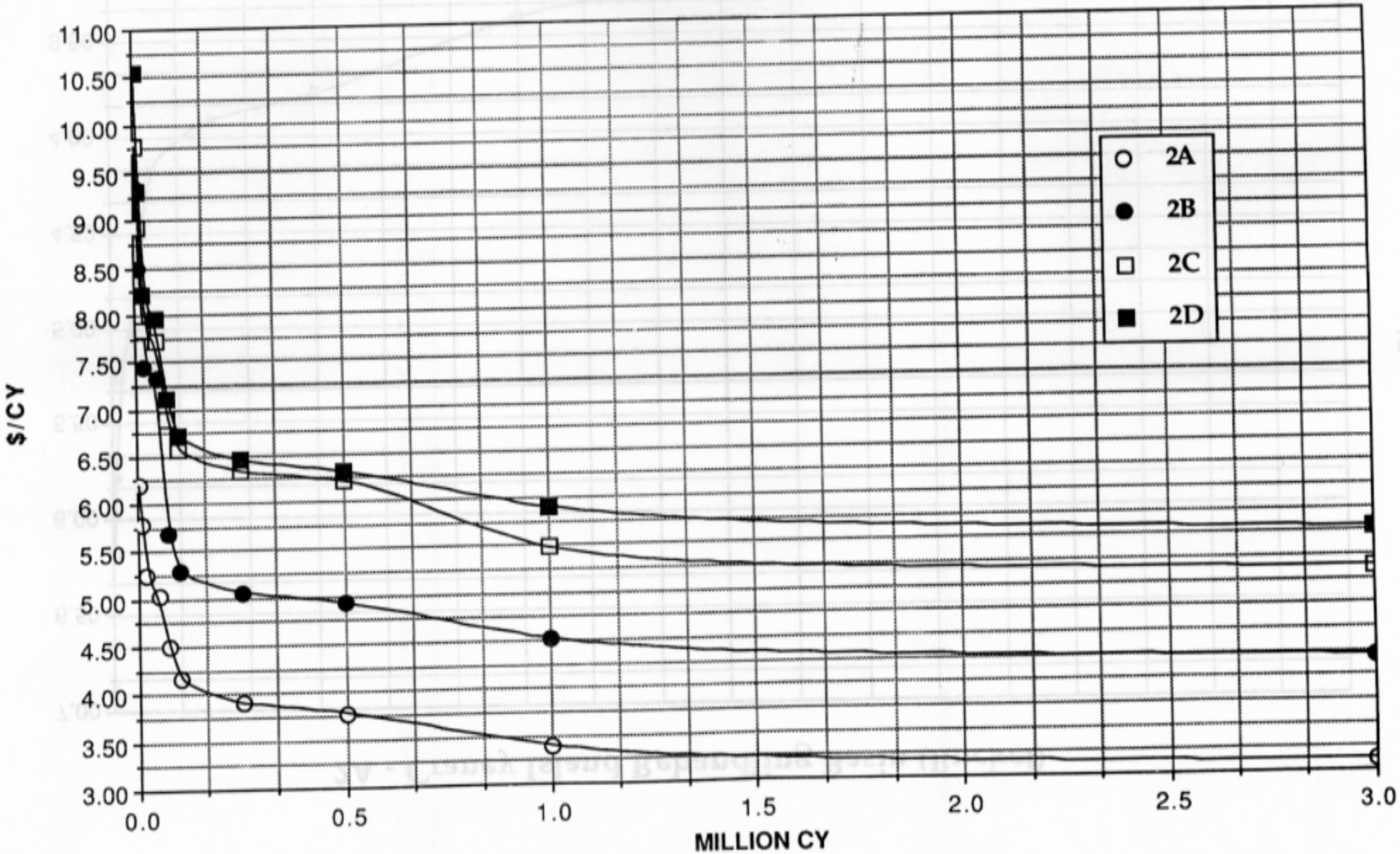
1B - Dam Neck (bucket)



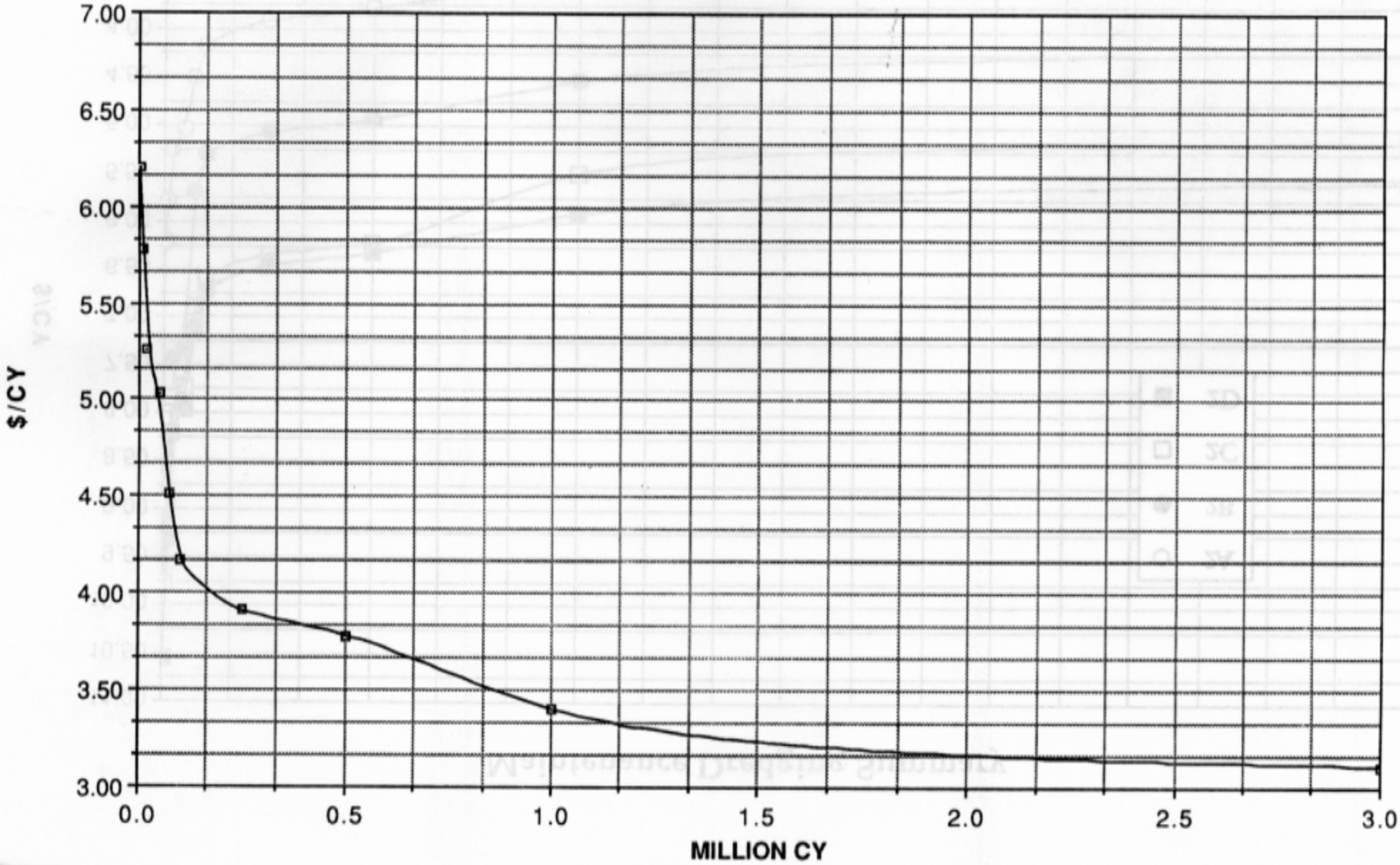
1C - Norfolk (bucket)



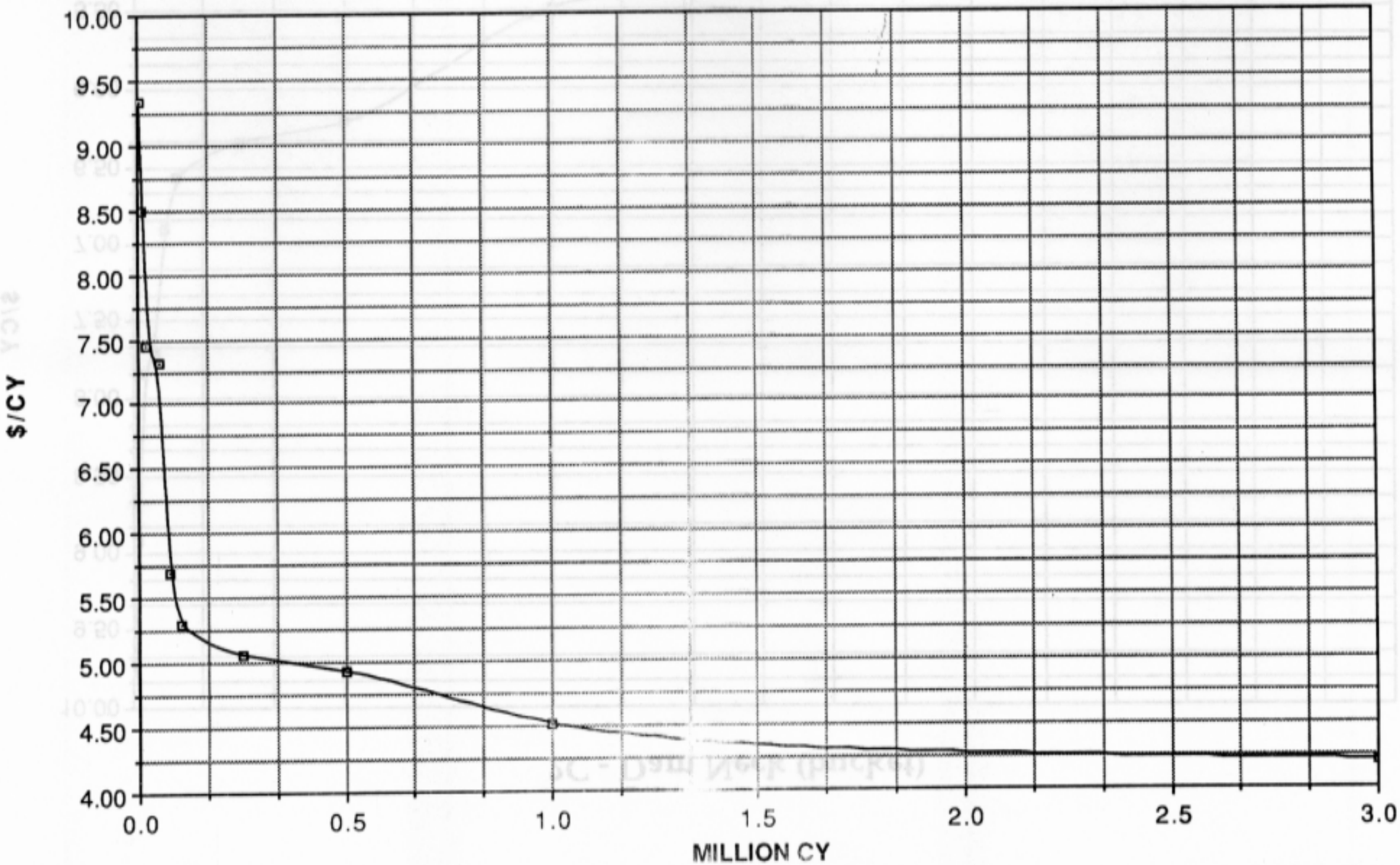
Maintenance Dredging Summary



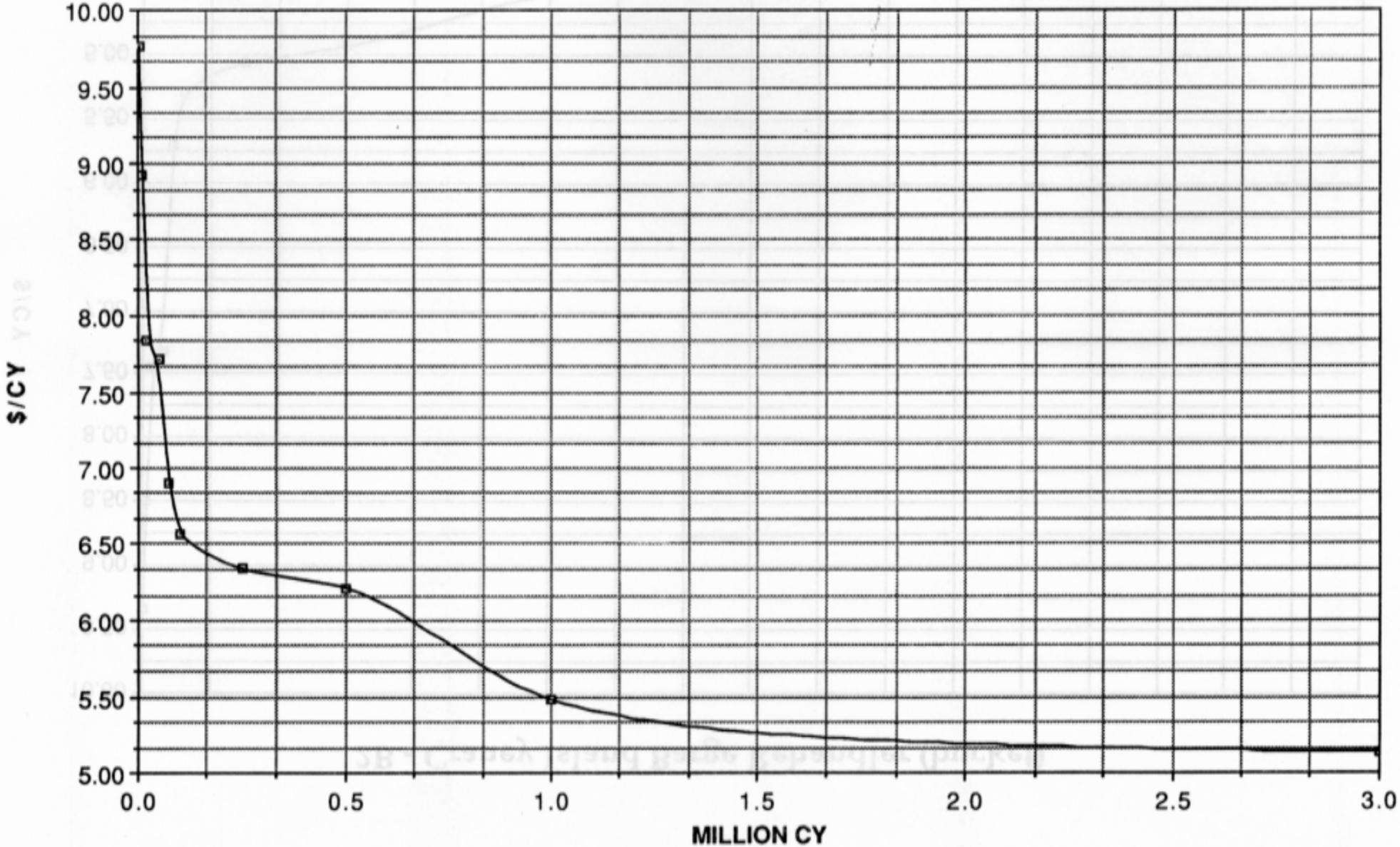
2A - Craney Island Rehandling Basin (Bucket)



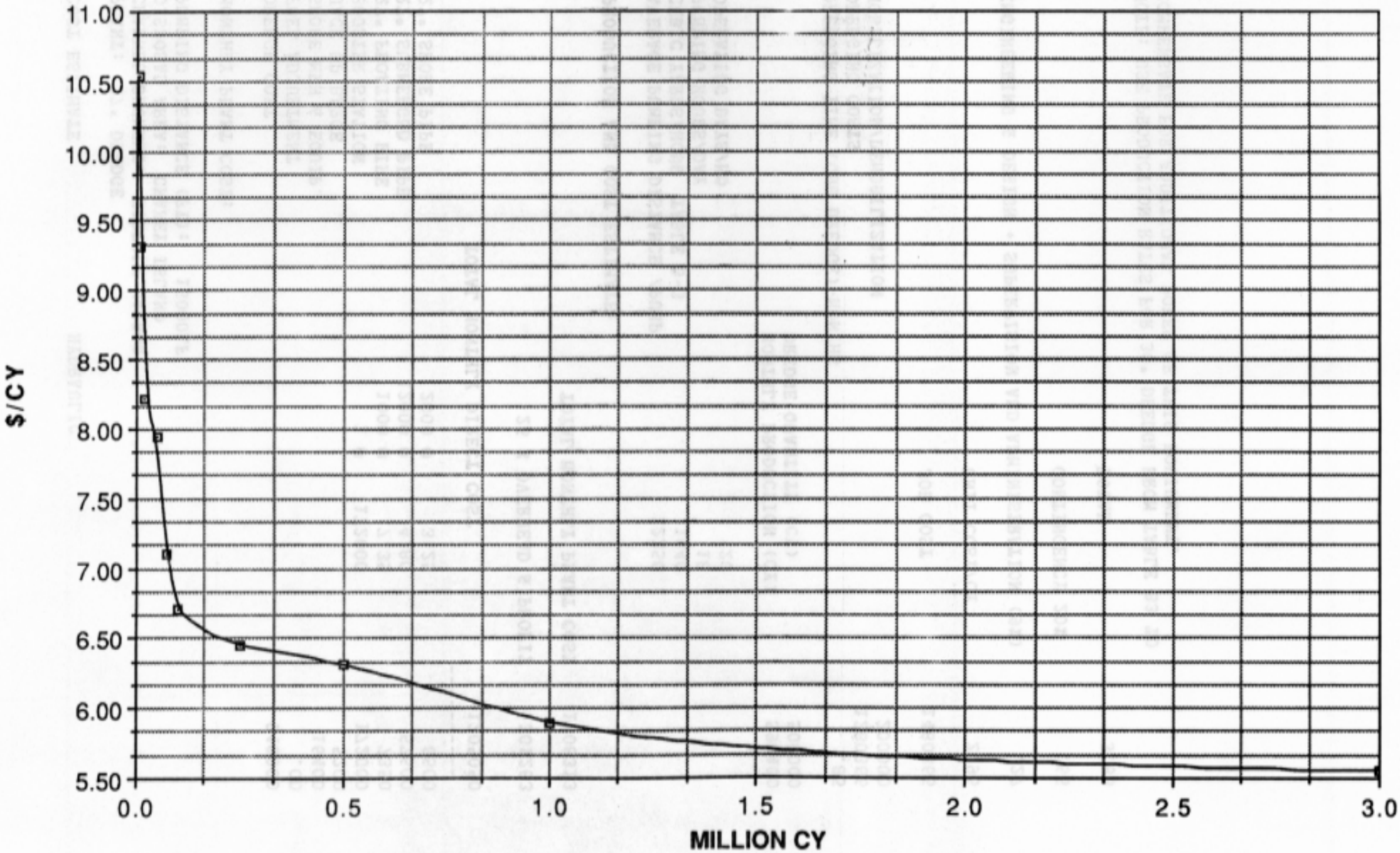
2B - Craney Island Barge Rehandler (bucket)



2C - Dam Neck (bucket)



2D - Norfolk (bucket)



COST ESTIMATE HYDRAULIC

PLANT: 27" DREDGE
CHANNEL SEGMENT: NORFOLK HARBOR
DISPOSAL AREA: CRANEY ISLAND
PUMPING DISTANCE (FT): 15000LF

MONTHLY PLANT COST:

DREDGE COST			940000
FUEL ADJUSTMENT			.00
SHORE MEN & EQUIP.			16400
JACK UP BARGE			5200
BOOSTER STATION	1 @	172000	172000
27" FLOATING PIPE	1000 @	7.35	7350
27" SUBMERGED PIPE	12000 @	4.80	57600
27" SHORE PIPE	2000 @	3.25	6500

TOTAL MONTHLY DIRECT COST			1205050
25 % OVERHEAD & PROFIT			301263
TOTAL MONTHLY PLANT COST			1506313

PRODUCTION AND COST ESTIMATE:

AVERAGE PUMPING DISTANCE /PUMP	12250	
CUBIC YARDS/HOUR TABLE B-3	1640	
PUMPING HOURS/DAY	18	
OPERATING DAYS/MO	20	
MONTHLY PRODUCTION (CY)		590400
DREDGE QUANTITY (CY)		500000
DREDGING TIME (ONE DREDGE)-MONTHS		.85
DREDGING COSTS		1280366
MOBILIZATION/DEMOBILIZATION		200000
JOB COST		1480366
UNIT COST/CY		2.96
ENGINEERING & DESIGN + SUPERVISION AND ADMINISTRATION (9%)		.27
CONTINGENCY 20%		.65
TOTAL		3.88

NOTE: USE PRODUCTION RATES FOR 30" DREDGE FROM TABLE B3 TO COMPENSATE FOR ADDITIONAL POWER OF THIS EQUIPMENT.

COST ESTIMATE HYDRAULIC

PLANT: 27" DREDGE
CHANNEL SEGMENT: NORFOLK HARBOR
DISPOSAL AREA: CRANEY ISLAND
PUMPING DISTANCE (FT): 15000LF

MONTHLY PLANT COST:

DREDGE COST			940000
FUEL ADJUSTMENT			.00
SHORE MEN & EQUIP.			16400
JACK UP BARGE			5200
BOOSTER STATION	1 @	172000	172000
27" FLOATING PIPE	1000 @	7.35	7350
27" SUBMERGED PIPE	12000 @	4.80	57600
27" SHORE PIPE	2000 @	3.25	6500
TOTAL MONTHLY DIRECT COST			1205050
24 % OVERHEAD & PROFIT			289212
TOTAL MONTHLY PLANT COST			1494262

PRODUCTION AND COST ESTIMATE:

AVERAGE PUMPING DISTANCE /PUMP	12250
CUBIC YARDS/HOUR TABLE B-3	1640
PUMPING HOURS/DAY	19
OPERATING DAYS/MO	21
MONTHLY PRODUCTION (CY)	654360
DREDGE QUANTITY (CY)	750000
DREDGING TIME (ONE DREDGE)-MONTHS	1.15
DREDGING COSTS	1718401
MOBILIZATION/DEMOBILIZATION	200000
JOB COST	1918401
UNIT COST/CY	2.56
ENGINEERING & DESIGN + SUPERVISION AND ADMINISTRATION (9%)	.23
CONTINGENCY 20%	.56
TOTAL	3.35

NOTE: USE PRODUCTION RATES FOR 30" DREDGE FROM TABLE B3 TO COMPENSATE FOR ADDITIONAL POWER OF THIS EQUIPMENT.

COST ESTIMATE HYDRAULIC

PLANT: 27" DREDGE
CHANNEL SEGMENT: NORFOLK HARBOR
DISPOSAL AREA: CRANEY ISLAND
PUMPING DISTANCE (FT): 15000LF

MONTHLY PLANT COST:

DREDGE COST			940000
FUEL ADJUSTMENT			.00
SHORE MEN & EQUIP.			16400
JACK UP BARGE			5200
BOOSTER STATION	1 @	172000	172000
27" FLOATING PIPE	1000 @	7.35	7350
27" SUBMERGED PIPE	12000 @	4.80	57600
27" SHORE PIPE	2000 @	3.25	6500
TOTAL MONTHLY DIRECT COST			1205050
24 % OVERHEAD & PROFIT			289212
TOTAL MONTHLY PLANT COST			1494262

PRODUCTION AND COST ESTIMATE:

AVERAGE PUMPING DISTANCE /PUMP	12250	
CUBIC YARDS/HOUR TABLE B-3	1640	
PUMPING HOURS/DAY	19	
OPERATING DAYS/MO	22	
MONTHLY PRODUCTION (CY)		685520
DREDGE QUANTITY (CY)		1000000
DREDGING TIME (ONE DREDGE)-MONTHS		1.46
DREDGING COSTS		2181623
MOBILIZATION/DEMOBILIZATION		200000
JOB COST		2381623
UNIT COST/CY		2.38
ENGINEERING & DESIGN + SUPERVISION AND ADMINISTRATION (9%)		.21
CONTINGENCY 20%		.52
TOTAL		3.11

NOTE: USE PRODUCTION RATES FOR 30" DREDGE FROM TABLE B3 TO COMPENSATE FOR ADDITIONAL POWER OF THIS EQUIPMENT.

COST ESTIMATE HYDRAULIC

PLANT: 27" DREDGE
CHANNEL SEGMENT: NORFOLK HARBOR
DISPOSAL AREA: CRANEY ISLAND
PUMPING DISTANCE (FT): 15,000LF

MONTHLY PLANT COST:

DREDGE COST			940,000
FUEL ADJUSTMENT			.00
SHORE MEN & EQUIP.			16,400
JACK UP BARGE			5,200
BOOSTER STATION	1 @	172,000	172,000
27" FLOATING PIPE	1,000 @	7.35	7,350
27" SUBMERGED PIPE	12,000 @	4.80	57,600
27" SHORE PIPE	2,000 @	3.25	6,500
TOTAL MONTHLY DIRECT COST			1,205,050
23 % OVERHEAD & PROFIT			277,162
TOTAL MONTHLY PLANT COST			1,482,212

PRODUCTION AND COST ESTIMATE:

AVERAGE PUMPING DISTANCE /PUMP	12,250	
CUBIC YARDS/HOUR TABLE B-3	1,640	
PUMPING HOURS/DAY	20	
OPERATING DAYS/MO	22	
MONTHLY PRODUCTION (CY)		721,600
		2,000,000
DREDGING TIME (ONE DREDGE)		2.77
DREDGING COSTS		4,105,727
MOBILIZATION/DEMOBILIZATION		200,000
JOB COST		4,305,727
UNIT COST/CY		2.15
ENGINEERING & DESIGN + SUPERVISION AND ADMINISTRATION (9%)		.19
CONTINGENCY 20%		.47
TOTAL		2.81

NOTE: USE PRODUCTION RATES FOR 30" DREDGE FROM TABLE B3 TO COMPENSATE FOR ADDITIONAL POWER OF THIS EQUIPMENT.

COST ESTIMATE HYDRAULIC

PLANT: 27" DREDGE
CHANNEL SEGMENT: NORFOLK HARBOR
DISPOSAL AREA: CRANEY ISLAND
PUMPING DISTANCE (FT): 15000LF

MONTHLY PLANT COST:

DREDGE COST			940000
FUEL ADJUSTMENT			.00
SHORE MEN & EQUIP.			16400
JACK UP BARGE			5200
BOOSTER STATION	1 @	172000	172000
27" FLOATING PIPE	1000 @	7.35	7350
27" SUBMERGED PIPE	12000 @	4.80	57600
27" SHORE PIPE	2000 @	3.25	6500

TOTAL MONTHLY DIRECT COST			1205050
21 % OVERHEAD & PROFIT			253061
TOTAL MONTHLY PLANT COST			1458111

PRODUCTION AND COST ESTIMATE:

AVERAGE PUMPING DISTANCE /PUMP	12250
CUBIC YARDS/HOUR TABLE B-3	1640
PUMPING HOURS/DAY	20
OPERATING DAYS/MO	22
MONTHLY PRODUCTION (CY)	721600
DREDGE QUANTITY (CY)	4000000
DREDGING TIME (ONE DREDGE)-MONTHS	5.54
DREDGING COSTS	8077935
MOBILIZATION/DEMOBILIZATION	200000
JOB COST	8277935
UNIT COST/CY	2.07
ENGINEERING & DESIGN + SUPERVISION AND ADMINISTRATION (9%)	.19
CONTINGENCY 20%	.45
TOTAL	2.71

NOTE: USE PRODUCTION RATES FOR 30" DREDGE FROM TABLE B3 TO COMPENSATE FOR ADDITIONAL POWER OF THIS EQUIPMENT.

COST ESTIMATE HYDRAULIC

PLANT: 27" DREDGE
CHANNEL SEGMENT: NORFOLK HARBOR
DISPOSAL AREA: CRANEY ISLAND
PUMPING DISTANCE (FT): 15000LF

MONTHLY PLANT COST:

DREDGE COST			940000
FUEL ADJUSTMENT			.00
SHORE MEN & EQUIP.			16400
JACK UP BARGE			5200
BOOSTER STATION	1 @	172000	172000
27" FLOATING PIPE	1000 @	7.35	7350
27" SUBMERGED PIPE	12000 @	4.80	57600
27" SHORE PIPE	2000 @	3.25	6500
TOTAL MONTHLY DIRECT COST			1205050
20 % OVERHEAD & PROFIT			241010
TOTAL MONTHLY PLANT COST			1446060

PRODUCTION AND COST ESTIMATE:

AVERAGE PUMPING DISTANCE /PUMP	12250
CUBIC YARDS/HOUR TABLE B-3	1640
PUMPING HOURS/DAY	20
OPERATING DAYS/MO	22
MONTHLY PRODUCTION (CY)	721600
DREDGE QUANTITY (CY)	6000000
DREDGING TIME (ONE DREDGE)-MONTHS	8.31
DREDGING COSTS	12016759
MOBILIZATION/DEMOBILIZATION	200000
JOB COST	12216759
UNIT COST/CY	2.04
ENGINEERING & DESIGN + SUPERVISION AND ADMINISTRATION (9%)	.18
CONTINGENCY 20%	.44
TOTAL	2.66

NOTE: USE PRODUCTION RATES FOR 30" DREDGE FROM TABLE B3 TO COMPENSATE FOR ADDITIONAL POWER OF THIS EQUIPMENT.

COST ESTIMATE 1A2-50 BUCKET DREDGE

PLANT:	18 CY BUCKET DREDGE		
CHANNEL SEGMENT:	NORFOLK HARBOR		
DISPOSAL AREA:	DIRECTLY INTO CRANEY ISLAND		
HAUL DISTANCE (MILES):	6		
QUANTITY PAY:	500,000 CY	GROSS:	600,000 CY
BUCKET TYPE DREDGE CAPACITY:			18 CY
		LOAD FACTOR =	.90
CYCLE TIME (MINUTES):			1.2 MIN.
CYCLES/HR			50 EA
CY/HR			810 CY/HR
EFFICIENCY FACTOR	(24HRS X	65 %)	16 HRS/DAY
CY/DAY			12,960 CY
NUMBER SCOWS PER TOW			2 EA
HAUL	6 MILES @	3.00MPH	2.00 HRS
LOAD & DUMP			14 HRS
RETURN	6 MILES @	3.50MPH	1.71 HRS
TOTAL CYCLE TIME (SCOWS)			17.71 HRS
20	WORK HOURS/DAY /	CYCLE TIME	1.13 LOADS/DAY
2	3000 CY SCOWS @	2,850 CY/LOAD=	5,700 CY/TRIP
SCOWS			
5,700	CY/TRIP X	1.13 LOADS/DAY	6,435 CY/DAY
SCOWS REQ			2 SETS
TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.			46.6 DAYS
LOST TIME	20%		9 DAYS
TOTAL TIME (EFFECTIVE + LOST)			55.9 DAYS
PLANT COST			301,000 /MONTH
FUEL COST		.90/GAL	133,263 /MONTH
MAINTENANCE AND INSURANCE COST			45,000 /MONTH
LABOR COST			62,900 /MONTH
TOTAL DIRECT MONTHLY COST + 130K FOR REHANDLER			672,163 /MONTH
25% OVERHEAD & PROFIT			168,041 /MONTH
TOTAL MONTHLY COST			840,204
TOTAL DAILY COST			28,007
DREDGING COSTS			1,565,580
MOBILIZATION/DEMOBILIZATION			
	10	DAYS @ 25,000	250,000
TOTAL JOB COST			1,815,580
UNIT COST/CY			3.63
E&D / S&A	9%		.33
CONTINGENCIES @		20%	.79
TOTAL UNIT COST			4.75

COST ESTIMATE 1A2-75 BUCKET DREDGE

PLANT:	18 CY BUCKET DREDGE		
CHANNEL SEGMENT:	NORFOLK HARBOR		
DISPOSAL AREA:	DIRECTLY INTO CRANEY ISLAND		
HAUL DISTANCE (MILES):	6		
QUANTITY PAY:	750,000 CY	GROSS:	900,000 CY
BUCKET TYPE DREDGE CAPACITY:			18 CY
		LOAD FACTOR =	.90
CYCLE TIME (MINUTES):			1.2 MIN.
CYCLES/HR			50 EA
CY/HR			810 CY/HR
EFFICIENCY FACTOR	(24HRS X	65 %)	16 HRS/DAY
CY/DAY			12,960 CY

NUMBER SCOWS PER TOW			2 EA
HAUL	6 MILES @	3.00MPH	2.00 HRS
LOAD & DUMP			14 HRS
RETURN	6 MILES @	3.50MPH	1.71 HRS
TOTAL CYCLE TIME (SCOWS)			17.71 HRS
20	WORK HOURS/DAY /	CYCLE TIME	1.13 LOADS/DAY
2	3000 CY SCOWS @	2,850 CY/LOAD=	5,700 CY/TRIP
SCOWS			
5,700	CY/TRIP X	1.13 LOADS/DAY	6,435 CY/DAY
SCOWS REQ			2 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.	69.9 DAYS
LOST TIME 19%	13 DAYS
TOTAL TIME (EFFECTIVE + LOST)	83 DAYS

PLANT COST		301,000 /MONTH
FUEL COST	.90/GAL	133,263 /MONTH
MAINTENANCE AND INSURANCE COST		45,000 /MONTH
LABOR COST		62,900 /MONTH
TOTAL DIRECT MONTHLY COST + 130K FOR REHANDLER		672,163 /MONTH
24% OVERHEAD & PROFIT		161,319 /MONTH
TOTAL MONTHLY COST		833,482

TOTAL DAILY COST	27,783
DREDGING COSTS	2,303,189
MOBILIZATION/DEMOBILIZATION	
10 DAYS @ 25,000	250,000
TOTAL JOB COST	2,553,189
UNIT COST/CY	3.40
E&D / S&A 9%	.31
CONTINGENCIES @ 20%	.74
TOTAL UNIT COST	4.45

COST ESTIMATE 1A2-100 BUCKET DREDGE

PLANT: 18 CY BUCKET DREDGE
CHANNEL SEGMENT: NORFOLK HARBOR
DISPOSAL AREA: DIRECTLY INTO CRANEY ISLAND
HAUL DISTANCE (MILES): 6
QUANTITY PAY: 1,000,000 CY GROSS: 1,200,000 CY
BUCKET TYPE DREDGE CAPACITY: 18 CY
LOAD FACTOR = .90
CYCLE TIME (MINUTES): 1.2 MIN.
CYCLES/HR 50 EA
CY/HR 810 CY/HR
EFFICIENCY FACTOR (24HRS X 70 %) 17 HRS/DAY
CY/DAY 13,770 CY

NUMBER SCOWS PER TOW 2 EA
HAUL 6 MILES @ 3.00MPH 2.00 HRS
LOAD & DUMP 14 HRS
RETURN 6 MILES @ 3.50MPH 1.71 HRS
TOTAL CYCLE TIME (SCOWS) 17.71 HRS
20 WORK HOURS/DAY / CYCLE TIME 1.13 LOADS/DAY
2 3000 CY SCOWS @ 2,850 CY/LOAD= 5,700 CY/TRIP
SCOWS
5,700 CY/TRIP X 1.13 LOADS/DAY 6,435 CY/DAY
SCOWS REQ 2 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD. 93.2 DAYS

LOST TIME 19% 18 DAYS
TOTAL TIME (EFFECTIVE + LOST) 111 DAYS

PLANT COST 301,000 /MONTH
FUEL COST .90/GAL 133,263 /MONTH
MAINTENANCE AND INSURANCE COST 45,000 /MONTH
LABOR COST 62,900 /MONTH
TOTAL DIRECT MONTHLY COST + 130K FOR REHANDLER 672,163 /MONTH
24% OVERHEAD & PROFIT 161,319 /MONTH
TOTAL MONTHLY COST 833,482
TOTAL DAILY COST 27,783

DREDGING COSTS 3,089,440
MOBILIZATION/DEMOBILIZATION
10 DAYS @ 25,000 250,000
TOTAL JOB COST 3,339,440

UNIT COST/CY 3.34

E&D / S&A 9% .30

CONTINGENCIES @ 20% .73

TOTAL UNIT COST 4.37

COST ESTIMATE 1A2-200 BUCKET DREDGE

PLANT:	18 CY BUCKET DREDGE		
CHANNEL SEGMENT:	NORFOLK HARBOR		
DISPOSAL AREA:	DIRECTLY INTO CRANEY ISLAND		
HAUL DISTANCE (MILES):	6		
QUANTITY PAY:	2,000,000 CY	GROSS:	2,400,000 CY
BUCKET TYPE DREDGE CAPACITY:			18 CY
		LOAD FACTOR =	.90
CYCLE TIME (MINUTES):			1.2 MIN.
CYCLES/HR			50 EA
CY/HR			810 CY/HR
EFFICIENCY FACTOR	(24HRS X	75 %)	18 HRS/DAY
CY/DAY			14,580 CY
NUMBER SCOWS PER TOW			2 EA
HAUL	6 MILES @	3.00MPH	2.00 HRS
LOAD & DUMP			14 HRS
RETURN	6 MILES @	3.50MPH	1.71 HRS
TOTAL CYCLE TIME (SCOWS)			17.71 HRS
20	WORK HOURS/DAY /	CYCLE TIME	1.13 LOADS/DAY
2	3000 CY SCOWS @	2,850 CY/LOAD=	5,700 CY/TRIP
SCOWS			
5,700	CY/TRIP X	1.13 LOADS/DAY	6,435 CY/DAY
SCOWS REQ			2 SETS
TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.			186.5 DAYS
LOST TIME	18%		34 DAYS
TOTAL TIME (EFFECTIVE + LOST)			221 DAYS
PLANT COST			301,000 /MONTH
FUEL COST		.90/GAL	133,263 /MONTH
MAINTENANCE AND INSURANCE COST			45,000 /MONTH
LABOR COST			62,900 /MONTH
TOTAL DIRECT MONTHLY COST + 130K FOR REHANDLER			672,163 /MONTH
23% OVERHEAD & PROFIT			154,597 /MONTH
TOTAL MONTHLY COST			826,760
TOTAL DAILY COST			27,559
DREDGING COSTS			6,076,686
MOBILIZATION/DEMOBILIZATION			
	10	DAYS @ 25,000	250,000
TOTAL JOB COST			6,326,686
UNIT COST/CY			3.16
E&D / S&A	9%		.28
CONTINGENCIES @		20%	.69
TOTAL UNIT COST			4.14

COST ESTIMATE 1A2-400 BUCKET DREDGE

PLANT: 18 CY BUCKET DREDGE
CHANNEL SEGMENT: NORFOLK HARBOR
DISPOSAL AREA: DIRECTLY INTO CRANEY ISLAND
HAUL DISTANCE (MILES): 6
QUANTITY PAY: 4,000,000 CY GROSS: 4,800,000 CY
BUCKET TYPE DREDGE CAPACITY: 18 CY
LOAD FACTOR = .90
CYCLE TIME (MINUTES): 1.2 MIN.
CYCLES/HR 50 EA
CY/HR 810 CY/HR
EFFICIENCY FACTOR (24HRS X 75 %) 18 HRS/DAY
CY/DAY 14,580 CY

NUMBER SCOWS PER TOW 2 EA
HAUL 6 MILES @ 3.00MPH 2.00 HRS
LOAD & DUMP 13 HRS
RETURN 6 MILES @ 3.50MPH 1.71 HRS
TOTAL CYCLE TIME (SCOWS) 16.71 HRS
20 WORK HOURS/DAY / CYCLE TIME 1.20 LOADS/DAY
2 3000 CY SCOWS @ 2,850 CY/LOAD= 5,700 CY/TRIP
SCOWS
5,700 CY/TRIP X 1.20 LOADS/DAY 6,821 CY/DAY
SCOWS REQ 2 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD. 351.9 DAYS

LOST TIME 18% 63 DAYS
TOTAL TIME (EFFECTIVE + LOST) 415 DAYS

PLANT COST 301,000 /MONTH
FUEL COST .90/GAL 133,263 /MONTH
MAINTENANCE AND INSURANCE COST 45,000 /MONTH
LABOR COST 62,900 /MONTH
TOTAL DIRECT MONTHLY COST + 130K FOR REHANDLER 672,163 /MONTH
21% OVERHEAD & PROFIT 141,154 /MONTH
TOTAL MONTHLY COST 813,317
TOTAL DAILY COST 27,111

DREDGING COSTS 11,248,174
MOBILIZATION/DEMOBILIZATION
10 DAYS @ 25,000 250,000
TOTAL JOB COST 11,498,174

UNIT COST/CY 2.87

E&D / S&A 9% .26

CONTINGENCIES @ 20% .63

TOTAL UNIT COST 3.76

COST ESTIMATE 1A2-600 BUCKET DREDGE

PLANT:	18 CY BUCKET DREDGE		
CHANNEL SEGMENT:	NORFOLK HARBOR		
DISPOSAL AREA:	DIRECTLY INTO CRANEY ISLAND		
HAUL DISTANCE (MILES):	6		
QUANTITY PAY:	6,000,000 CY GROSS:	7,200,000	CY
BUCKET TYPE DREDGE CAPACITY:		18	CY
	LOAD FACTOR =	.90	
CYCLE TIME (MINUTES):		1.2	MIN.
CYCLES/HR		50	EA
CY/HR		810	CY/HR
EFFICIENCY FACTOR	(24HRS X 75 %)	18	HRS/DAY
CY/DAY		14,580	CY
NUMBER SCOWS PER TOW		2	EA
HAUL 6	MILES @ 3.00MPH	2.00	HRS
LOAD & DUMP		13	HRS
RETURN 6	MILES @ 3.50MPH	1.71	HRS
TOTAL CYCLE TIME (SCOWS)		16.71	HRS
20	WORK HOURS/DAY / CYCLE TIME	1.20	LOADS/DAY
2	3000 CY SCOWS @ 2,850 CY/LOAD=	5,700	CY/TRIP
SCOWS			
5,700	CY/TRIP X 1.20 LOADS/DAY	6,821	CY/DAY
SCOWS REQ		2	SETS
TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.		527.8	DAYS
LOST TIME 17%		90	DAYS
TOTAL TIME (EFFECTIVE + LOST)		618	DAYS
PLANT COST		301,000	/MONTH
FUEL COST	.90/GAL	133,263	/MONTH
MAINTENANCE AND INSURANCE COST		45,000	/MONTH
LABOR COST		62,900	/MONTH
TOTAL DIRECT MONTHLY COST + 130K FOR REHANDLER		672,163	/MONTH
20% OVERHEAD & PROFIT		134,433	/MONTH
TOTAL MONTHLY COST		806,596	
TOTAL DAILY COST		26,887	
DREDGING COSTS		16,610,500	
MOBILIZATION/DEMOBILIZATION			
10	DAYS @ 25,000	250,000	
TOTAL JOB COST		16,860,500	
UNIT COST/CY		2.81	
E&D / S&A 9%		.25	
CONTINGENCIES @	20%	.61	
TOTAL UNIT COST		3.68	

COST ESTIMATE 1B500 BUCKET DREDGE

PLANT:	18 CY BUCKET DREDGE		
CHANNEL SEGMENT:	NORFOLK HARBOR		
DISPOSAL AREA:	DAM NECK		
HAUL DISTANCE (MILES):	37		
QUANTITY PAY:	500,000 CY	GROSS:	600,000 CY
BUCKET TYPE DREDGE CAPACITY:			18 CY
		LOAD FACTOR	= .90
CYCLE TIME (MINUTES):			1.2 MIN.
CYCLES/HR			50 EA
CY/HR			810 CY/HR
EFFICIENCY FACTOR	(24HRS X	65 %)	16 HRS/DAY
CY/DAY			12,960 CY
NUMBER SCOWS PER TOW			2 EA
HAUL	37 MILES @	3.00MPH	12.33 HRS
LOAD & DUMP			8 HRS
RETURN	37 MILES @	3.50MPH	10.57 HRS
TOTAL CYCLE TIME (SCOWS)			30.90 HRS
20	WORK HOURS/DAY /	CYCLE TIME	.65 LOADS/DAY
2	3000 CY SCOWS @	2,850 CY/LOAD=	5,700 CY/TRIP
SCOWS			
5,700	CY/TRIP X	.65 LOADS/DAY	3,689 CY/DAY
SCOWS REQ			4 SETS
TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.			46.3 DAYS
LOST TIME	20%		9 DAYS
TOTAL TIME (EFFECTIVE + LOST)			55 DAYS
PLANT COST			547,000 /MONTH
FUEL COST		.90/GAL	226,547 /MONTH
MAINTENANCE AND INSURANCE COST			45,000 /MONTH
LABOR COST			62,900 /MONTH
TOTAL DIRECT MONTHLY COST			881,447 /MONTH
25% OVERHEAD & PROFIT			220,362 /MONTH
TOTAL MONTHLY COST			1,101,809
TOTAL DAILY COST			36,727
DREDGING COSTS			2,031,001
MOBILIZATION/DEMOBILIZATION			
	10	DAYS @ 25,000	250,000
TOTAL JOB COST			2,281,001
UNIT COST/CY			4.56
E&D / S&A	9%		.41
CONTINGENCIES	@	20%	.99
TOTAL UNIT COST			5.97

COST ESTIMATE 1B750 BUCKET DREDGE

PLANT:	18 CY BUCKET DREDGE		
CHANNEL SEGMENT:	NORFOLK HARBOR		
DISPOSAL AREA:	DAM NECK		
HAUL DISTANCE (MILES):	37		
QUANTITY PAY:	750,000 CY	GROSS:	900,000 CY
BUCKET TYPE DREDGE CAPACITY:			18 CY
		LOAD FACTOR =	.90
CYCLE TIME (MINUTES):			1.2 MIN.
CYCLES/HR			50 EA
CY/HR			810 CY/HR
EFFICIENCY FACTOR	(24HRS X 65 %)		16 HRS/DAY
CY/DAY			12,960 CY
NUMBER SCOWS PER TOW			2 EA
HAUL	37 MILES @ 3.00MPH		12.33 HRS
LOAD & DUMP			8 HRS
RETURN	37 MILES @ 3.50MPH		10.57 HRS
TOTAL CYCLE TIME (SCOWS)			30.90 HRS
20 WORK HOURS/DAY /	CYCLE TIME		.65 LOADS/DAY
2 3000 CY SCOWS @	2,850 CY/LOAD=		5,700 CY/TRIP
SCOWS			
5,700 CY/TRIP X	.65 LOADS/DAY		3,689 CY/DAY
SCOWS REQ			4 SETS
TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.			69.4 DAYS
LOST TIME	19%		13 DAYS
TOTAL TIME (EFFECTIVE + LOST)			82 DAYS
PLANT COST			547,000 /MONTH
FUEL COST	.90/GAL		226,547 /MONTH
MAINTENANCE AND INSURANCE COST			45,000 /MONTH
LABOR COST			62,900 /MONTH
TOTAL DIRECT MONTHLY COST			881,447 /MONTH
24% OVERHEAD & PROFIT			211,547 /MONTH
TOTAL MONTHLY COST			1,092,994
TOTAL DAILY COST			36,433
DREDGING COSTS			3,002,090
MOBILIZATION/DEMOBILIZATION			
	10 DAYS @ 25,000		250,000
TOTAL JOB COST			3,252,090
UNIT COST/CY			4.34
E&D / S&A	9%		.39
CONTINGENCIES	@ 20%		.95
TOTAL UNIT COST			5.67

COST ESTIMATE 1B1000 BUCKET DREDGE

PLANT: 18 CY BUCKET DREDGE
CHANNEL SEGMENT: NORFOLK HARBOR
DISPOSAL AREA: DAM NECK
HAUL DISTANCE (MILES): 37
QUANTITY PAY: 1,000,000 CY GROSS: 1,200,000 CY
BUCKET TYPE DREDGE CAPACITY: 18 CY
LOAD FACTOR = .90
CYCLE TIME (MINUTES): 1.2 MIN.
CYCLES/HR 50 EA
CY/HR 810 CY/HR
EFFICIENCY FACTOR (24HRS X 70 %) 17 HRS/DAY
CY/DAY 13,770 CY

NUMBER SCOWS PER TOW 2 EA
HAUL 37 MILES @ 3.00MPH 12.33 HRS
LOAD & DUMP 8 HRS
RETURN 37 MILES @ 3.50MPH 10.57 HRS
TOTAL CYCLE TIME (SCOWS) 30.90 HRS
20 WORK HOURS/DAY / CYCLE TIME .65 LOADS/DAY
2 3000 CY SCOWS @ 2,850 CY/LOAD= 5,700 CY/TRIP
SCOWS

5,700 CY/TRIP X .65 LOADS/DAY 3,689 CY/DAY
SCOWS REQ 4 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD. 87.1 DAYS

LOST TIME 19% 17 DAYS
TOTAL TIME (EFFECTIVE + LOST) 104 DAYS

PLANT COST 547,000 /MONTH
FUEL COST .90/GAL 226,547 /MONTH
MAINTENANCE AND INSURANCE COST 45,000 /MONTH
LABOR COST 62,900 /MONTH
TOTAL DIRECT MONTHLY COST 881,447 /MONTH
24% OVERHEAD & PROFIT 211,547 /MONTH
TOTAL MONTHLY COST 1,092,994
TOTAL DAILY COST 36,433

DREDGING COSTS 3,792,690
MOBILIZATION/DEMOBILIZATION
10 DAYS @ 25,000 250,000
TOTAL JOB COST 4,042,690

UNIT COST/CY 4.04

E&D / S&A 9% .36

CONTINGENCIES @ 20% .88

TOTAL UNIT COST 5.29

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COST ESTIMATE      1B2000            BUCKET DREDGE

PLANT:              18 CY BUCKET DREDGE
CHANNEL SEGMENT:    NORFOLK HARBOR
DISPOSAL AREA:      DAM NECK
HAUL DISTANCE (MILES):          37
QUANTITY      PAY:    2,000,000  CY  GROSS:        2,400,000 CY
BUCKET TYPE DREDGE CAPACITY:                              18 CY
                                                LOAD FACTOR  =  .90
CYCLE TIME    (MINUTES):                                 1.2 MIN.
CYCLES/HR                                                 50 EA
CY/HR                                                    810 CY/HR


EFFICIENCY FACTOR      (24HRS X        70   %)            17 HRS/DAY
CY/DAY                                                13,770 CY

NUMBER SCOWS PER TOW                                       2 EA
HAUL          37    MILES @       3.00MPH              12.33 HRS
LOAD & DUMP                                                8 HRS
RETURN        37    MILES @       3.50MPH              10.57 HRS
TOTAL CYCLE TIME (SCOWS)                                30.90 HRS
    20   WORK HOURS/DAY /    CYCLE TIME                   .65 LOADS/DAY
    2    3000 CY SCOWS @       2,850 CY/LOAD=          5,700 CY/TRIP
SCOWS
 5,700   CY/TRIP X          .65 LOADS/DAY               3,689 CY/DAY
SCOWS REQ                                                  4 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.              174.3 DAYS

LOST TIME        18%                                      31 DAYS
TOTAL TIME (EFFECTIVE + LOST)                            205 DAYS

PLANT COST                                           547,000 /MONTH
FUEL COST                  .90/GAL                   226,547 /MONTH
MAINTENANCE AND INSURANCE COST                        45,000 /MONTH
LABOR COST                                            62,900 /MONTH
TOTAL DIRECT MONTHLY COST                            881,447 /MONTH
       23% OVERHEAD & PROFIT                         202,733 /MONTH
TOTAL MONTHLY COST                                 1,084,180
TOTAL DAILY COST                                      36,139

DREDGING COSTS                                     7,419,406
MOBILIZATION/DEMOBILIZATION
                        10     DAYS @ 25,000         250,000
TOTAL JOB COST                                     7,669,406

UNIT COST/CY                                            3.83

E&D / S&A         9%                                     .35

CONTINGENCIES    @          20%                         .84

TOTAL UNIT COST                                         5.02
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COST ESTIMATE 1B4000 BUCKET DREDGE

PLANT:	18 CY BUCKET DREDGE		
CHANNEL SEGMENT:	NORFOLK HARBOR		
DISPOSAL AREA:	DAM NECK		
HAUL DISTANCE (MILES):	37		
QUANTITY PAY:	4,000,000 CY	GROSS:	4,800,000 CY
BUCKET TYPE DREDGE CAPACITY:			18 CY
		LOAD FACTOR =	.90
CYCLE TIME (MINUTES):			1.2 MIN.
CYCLES/HR			50 EA
CY/HR			810 CY/HR
EFFICIENCY FACTOR	(24HRS X	70 %)	17 HRS/DAY
CY/DAY			13,770 CY
NUMBER SCOWS PER TOW			2 EA
HAUL	37 MILES @	3.00MPH	12.33 HRS
LOAD & DUMP			8 HRS
RETURN	37 MILES @	3.50MPH	10.57 HRS
TOTAL CYCLE TIME (SCOWS)			30.90 HRS
20	WORK HOURS/DAY /	CYCLE TIME	.65 LOADS/DAY
2	3000 CY SCOWS @	2,850 CY/LOAD=	5,700 CY/TRIP
SCOWS			
5,700	CY/TRIP X	.65 LOADS/DAY	3,689 CY/DAY
SCOWS REQ			4 SETS
TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.			348.6 DAYS
LOST TIME	18%		63 DAYS
TOTAL TIME (EFFECTIVE + LOST)			412 DAYS
PLANT COST			547,000 /MONTH
FUEL COST		.90/GAL	226,547 /MONTH
MAINTENANCE AND INSURANCE COST			45,000 /MONTH
LABOR COST			62,900 /MONTH
TOTAL DIRECT MONTHLY COST			881,447 /MONTH
21% OVERHEAD & PROFIT			185,104 /MONTH
TOTAL MONTHLY COST			1,066,551
TOTAL DAILY COST			35,552
DREDGING COSTS			14,633,081
MOBILIZATION/DEMOBILIZATION			
	10	DAYS @ 25,000	250,000
TOTAL JOB COST			14,883,081
UNIT COST/CY			3.72
E&D / S&A	9%		.33
CONTINGENCIES	@	20%	.81
TOTAL UNIT COST			4.87

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COST ESTIMATE    1B6000          BUCKET DREDGE

PLANT:              18 CY BUCKET DREDGE
CHANNEL SEGMENT:    NORFOLK HARBOR
DISPOSAL AREA:      DAM NECK
HAUL DISTANCE (MILES):          37
QUANTITY      PAY:   6,000,000  CY  GROSS:        7,200,000 CY
BUCKET TYPE DREDGE CAPACITY:                             18 CY
                                                LOAD FACTOR  =  .90
CYCLE TIME    (MINUTES):                                1.2 MIN.
CYCLES/HR                                                50 EA
CY/HR                                                   810 CY/HR
EFFICIENCY FACTOR      (24HRS X        70    %)         17 HRS/DAY
CY/DAY                                               13,770 CY

NUMBER SCOWS PER TOW                                      2 EA
HAUL          37   MILES @      3.00MPH               12.33 HRS
LOAD & DUMP                                               8 HRS
RETURN        37   MILES @      3.50MPH               10.57 HRS
TOTAL CYCLE TIME (SCOWS)                               30.90 HRS
    20    WORK HOURS/DAY /     CYCLE TIME                .65 LOADS/DAY
    2     3000 CY SCOWS @      2,850 CY/LOAD=         5,700 CY/TRIP
SCOWS
 5,700    CY/TRIP X         .65 LOADS/DAY              3,689 CY/DAY
SCOWS REQ                                                 4 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.               522.9 DAYS

LOST TIME        17%                                     89 DAYS
TOTAL TIME (EFFECTIVE + LOST)                           612 DAYS

PLANT COST                                            547,000 /MONTH
FUEL COST                    .90/GAL                  226,547 /MONTH
MAINTENANCE AND INSURANCE COST                         45,000 /MONTH
LABOR COST                                             62,900 /MONTH
TOTAL DIRECT MONTHLY COST                             881,447 /MONTH
       20% OVERHEAD & PROFIT                          176,289 /MONTH
TOTAL MONTHLY COST                                  1,057,736

TOTAL DAILY COST                                       35,258

DREDGING COSTS                                     21,574,291
MOBILIZATION/DEMOBILIZATION
                          10    DAYS @ 25,000        250,000
TOTAL JOB COST                                     21,824,291

UNIT COST/CY                                            3.64

E&D / S&A         9%                                     .33

CONTINGENCIES    @          20%                         .79

TOTAL UNIT COST                                         4.76
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COST ESTIMATE 1C500 BUCKET DREDGE

PLANT:	18 CY BUCKET DREDGE			
CHANNEL SEGMENT:	NORFOLK HARBOR			
DISPOSAL AREA:	NORFOLK			
HAUL DISTANCE (MILES):		45		
QUANTITY PAY:	500,000	CY	GROSS:	600,000 CY
BUCKET TYPE DREDGE CAPACITY:				18 CY
			LOAD FACTOR	= .90
CYCLE TIME (MINUTES):				1.2 MIN.
CYCLES/HR				50 EA
CY/HR				810 CY/HR
EFFICIENCY FACTOR	(24HRS X	65	%)	16 HRS/DAY
CY/DAY				12,960 CY
NUMBER SCOWS PER TOW				2 EA
HAUL	45 MILES @	3.00	MPH	15.00 HRS
LOAD & DUMP				8 HRS
RETURN	45 MILES @	3.50	MPH	12.86 HRS
TOTAL CYCLE TIME (SCOWS)				35.86 HRS
20	WORK HOURS/DAY /	CYCLE TIME		.56 LOADS/DAY
2	3000 CY SCOWS @	2,850 CY/LOAD=		5,700 CY/TRIP
SCOWS				
5,700	CY/TRIP X	.56 LOADS/DAY		3,179 CY/DAY
SCOWS REQ				4 SETS
TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.				47.2 DAYS
LOST TIME	20%			9 DAYS
TOTAL TIME (EFFECTIVE + LOST)				56 DAYS
PLANT COST				547,000 /MONTH
FUEL COST		.90 /GAL		226,547 /MONTH
MAINTENANCE AND INSURANCE COST				45,000 /MONTH
LABOR COST				62,900 /MONTH
TOTAL DIRECT MONTHLY COST				881,447 /MONTH
25% OVERHEAD & PROFIT				220,362 /MONTH
TOTAL MONTHLY COST				1,101,809
TOTAL DAILY COST				36,727
DREDGING COSTS				2,064,056
MOBILIZATION/DEMOBILIZATION				
	10	DAYS @ 25,000		250,000
TOTAL JOB COST				2,314,056
UNIT COST/CY				4.63
E&D / S&A	9 %			.42
CONTINGENCIES	@	20%		1.01
TOTAL UNIT COST				6.05

COST ESTIMATE 1C750 BUCKET DREDGE

PLANT:	18 CY BUCKET DREDGE		
CHANNEL SEGMENT:	NORFOLK HARBOR		
DISPOSAL AREA:	NORFOLK		
HAUL DISTANCE (MILES):	45		
QUANTITY PAY:	750,000 CY	GROSS:	900,000 CY
BUCKET TYPE DREDGE CAPACITY:			18 CY
		LOAD FACTOR =	.90
CYCLE TIME (MINUTES):			1.2 MIN.
CYCLES/HR			50 EA
CY/HR			810 CY/HR
EFFICIENCY FACTOR	(24HRS X	65 %)	16 HRS/DAY
CY/DAY			12,960 CY
NUMBER SCOWS PER TOW			2 EA
HAUL	45 MILES @	3.00 MPH	15.00 HRS
LOAD & DUMP			8 HRS
RETURN	45 MILES @	3.50 MPH	12.86 HRS
TOTAL CYCLE TIME (SCOWS)			35.86 HRS
20	WORK HOURS/DAY /	CYCLE TIME	.56 LOADS/DAY
2	3000 CY SCOWS @	2,850 CY/LOAD=	5,700 CY/TRIP
SCOWS			
5,700	CY/TRIP X	.56 LOADS/DAY	3,179 CY/DAY
SCOWS REQ			4 SETS
TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.			70.8 DAYS
LOST TIME	19%		13 DAYS
TOTAL TIME (EFFECTIVE + LOST)			84 DAYS
PLANT COST			547,000 /MONTH
FUEL COST		.90 /GAL	226,547 /MONTH
MAINTENANCE AND INSURANCE COST			45,000 /MONTH
LABOR COST			62,900 /MONTH
TOTAL DIRECT MONTHLY COST			881,447 /MONTH
24% OVERHEAD & PROFIT			211,547 /MONTH
TOTAL MONTHLY COST			1,092,994
TOTAL DAILY COST			36,433
DREDGING COSTS			3,053,097
MOBILIZATION/DEMOBILIZATION			
	10	DAYS @ 25,000	250,000
TOTAL JOB COST			3,303,097
UNIT COST/CY			4.40
E&D / S&A	9 %		.40
CONTINGENCIES	@	20%	.96
TOTAL UNIT COST			5.76

COST ESTIMATE 1C1000 BUCKET DREDGE

PLANT:	18 CY BUCKET DREDGE		
CHANNEL SEGMENT:	NORFOLK HARBOR		
DISPOSAL AREA:	NORFOLK		
HAUL DISTANCE (MILES):	45		
QUANTITY PAY:	1,000,000 CY	GROSS:	1,200,000 CY
BUCKET TYPE DREDGE CAPACITY:			18 CY
		LOAD FACTOR =	.90
CYCLE TIME (MINUTES):			1.2 MIN.
CYCLES/HR			50 EA
CY/HR			810 CY/HR
EFFICIENCY FACTOR	(24HRS X	70 %)	17 HRS/DAY
CY/DAY			13,770 CY
NUMBER SCOWS PER TOW			2 EA
HAUL	45 MILES @	3.00 MPH	15.00 HRS
LOAD & DUMP			8 HRS
RETURN	45 MILES @	3.50 MPH	12.86 HRS
TOTAL CYCLE TIME (SCOWS)			35.86 HRS
20	WORK HOURS/DAY /	CYCLE TIME	.56 LOADS/DAY
2	3000 CY SCOWS @	2,850 CY/LOAD=	5,700 CY/TRIP
SCOWS			
5,700	CY/TRIP X	.56 LOADS/DAY	3,179 CY/DAY
SCOWS REQ			4 SETS
TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.			94.4 DAYS
LOST TIME	19%		18 DAYS
TOTAL TIME (EFFECTIVE + LOST)			112 DAYS
PLANT COST			547,000 /MONTH
FUEL COST		.90 /GAL	226,547 /MONTH
MAINTENANCE AND INSURANCE COST			45,000 /MONTH
LABOR COST			62,900 /MONTH
TOTAL DIRECT MONTHLY COST			881,447 /MONTH
24% OVERHEAD & PROFIT			211,547 /MONTH
TOTAL MONTHLY COST			1,092,994
TOTAL DAILY COST			36,433
DREDGING COSTS			4,095,085
MOBILIZATION/DEMOBILIZATION			
	10	DAYS @ 25,000	250,000
TOTAL JOB COST			4,345,085
UNIT COST/CY			4.35
E&D / S&A	9 %		.39
CONTINGENCIES	@	20%	.95
TOTAL UNIT COST			5.68

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COST ESTIMATE        1C2000        BUCKET DREDGE

PLANT:              18 CY BUCKET DREDGE
CHANNEL SEGMENT:  NORFOLK HARBOR
DISPOSAL AREA:      NORFOLK
HAUL DISTANCE (MILES):          45
QUANTITY     PAY:   2,000,000  CY   GROSS:      2,400,000 CY
BUCKET TYPE DREDGE CAPACITY:                          18 CY
                                              LOAD FACTOR  =  .90
CYCLE TIME   (MINUTES):                              1.2 MIN.
CYCLES/HR                                             50 EA
CY/HR                                                810 CY/HR


EFFICIENCY FACTOR     (24HRS X        70    %)        17 HRS/DAY
CY/DAY                                            13,770 CY

NUMBER SCOWS PER TOW                                   2 EA
HAUL          45     MILES @    3.00   MPH         15.00 HRS
LOAD & DUMP                                            8 HRS
RETURN        45     MILES @    3.50   MPH         12.86 HRS
TOTAL CYCLE TIME (SCOWS)                            35.86 HRS
    20   WORK HOURS/DAY /    CYCLE TIME               .56 LOADS/DAY
    2    3000 CY SCOWS @      2,850 CY/LOAD=       5,700 CY/TRIP
SCOWS
 5,700   CY/TRIP X        .56 LOADS/DAY            3,179 CY/DAY
SCOWS REQ                                              4 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.          188.7 DAYS

LOST TIME       18%                                   34 DAYS
TOTAL TIME (EFFECTIVE + LOST)                        223 DAYS

PLANT COST                                        547,000 /MONTH
FUEL COST                .90 /GAL                 226,547 /MONTH
MAINTENANCE AND INSURANCE COST                     45,000 /MONTH
LABOR COST                                         62,900 /MONTH
TOTAL DIRECT MONTHLY COST                         881,447 /MONTH
       23% OVERHEAD & PROFIT                      202,733 /MONTH
TOTAL MONTHLY COST                              1,084,180
TOTAL DAILY COST                                   36,139

DREDGING COSTS                                  8,048,230
MOBILIZATION/DEMOBILIZATION
                      10    DAYS @ 25,000        250,000
TOTAL JOB COST                                  8,298,230

UNIT COST/CY                                         4.15

E&D / S&A        9     %                             .37

CONTINGENCIES   @          20%                       .90

TOTAL UNIT COST                                      5.43
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COST ESTIMATE        1C4000        BUCKET DREDGE

PLANT:              18 CY BUCKET DREDGE
CHANNEL SEGMENT:  NORFOLK HARBOR
DISPOSAL AREA:       NORFOLK
HAUL DISTANCE (MILES):          45
QUANTITY     PAY:   4,000,000  CY   GROSS:       4,800,000 CY
BUCKET TYPE DREDGE CAPACITY:                            18 CY
                                              LOAD FACTOR  =  .90
CYCLE TIME   (MINUTES):                               1.2 MIN.
CYCLES/HR                                              50 EA
CY/HR                                                 810 CY/HR
EFFICIENCY FACTOR     (24HRS X        70    %)         17 HRS/DAY
CY/DAY                                             13,770 CY

NUMBER SCOWS PER TOW                                    2 EA
HAUL        45     MILES @    3.00   MPH           15.00 HRS
LOAD & DUMP                                             8 HRS
RETURN      45     MILES @    3.50   MPH           12.86 HRS
TOTAL CYCLE TIME (SCOWS)                             35.86 HRS
    20   WORK HOURS/DAY /    CYCLE TIME               .56 LOADS/DAY
    2    3000 CY SCOWS @     2,850 CY/LOAD=        5,700 CY/TRIP
SCOWS
 5,700   CY/TRIP X        .56 LOADS/DAY             3,179 CY/DAY
SCOWS REQ                                               4 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.            377.4 DAYS

LOST TIME       18%                                    68 DAYS
TOTAL TIME (EFFECTIVE + LOST)                         445 DAYS

PLANT COST                                         547,000 /MONTH
FUEL COST                .90 /GAL                  226,547 /MONTH
MAINTENANCE AND INSURANCE COST                      45,000 /MONTH
LABOR COST                                          62,900 /MONTH
TOTAL DIRECT MONTHLY COST                          881,447 /MONTH
       21% OVERHEAD & PROFIT                       185,104 /MONTH
TOTAL MONTHLY COST                               1,066,551
TOTAL DAILY COST                                    35,552

DREDGING COSTS                                  15,834,729
MOBILIZATION/DEMOBILIZATION
                        10    DAYS @ 25,000        250,000
TOTAL JOB COST                                  16,084,729

UNIT COST/CY                                          4.02

E&D / S&A        9     %                              .36

CONTINGENCIES   @        20%                          .88


TOTAL UNIT COST                                       5.26
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COST ESTIMATE 1C6000 BUCKET DREDGE

PLANT: 18 CY BUCKET DREDGE
CHANNEL SEGMENT: NORFOLK HARBOR
DISPOSAL AREA: NORFOLK
HAUL DISTANCE (MILES): 45
QUANTITY PAY: 6,000,000 CY GROSS: 7,200,000 CY
BUCKET TYPE DREDGE CAPACITY: 18 CY
LOAD FACTOR = .90
CYCLE TIME (MINUTES): 1.2 MIN.
CYCLES/HR 50 EA
CY/HR 810 CY/HR
EFFICIENCY FACTOR (24HRS X 70 %) 17 HRS/DAY
CY/DAY 13,770 CY

NUMBER SCOWS PER TOW 2 EA
HAUL 45 MILES @ 3.00 MPH 15.00 HRS
LOAD & DUMP 8 HRS
RETURN 45 MILES @ 3.50 MPH 12.86 HRS
TOTAL CYCLE TIME (SCOWS) 35.86 HRS
20 WORK HOURS/DAY / CYCLE TIME .56 LOADS/DAY
2 3000 CY SCOWS @ 2,850 CY/LOAD= 5,700 CY/TRIP
SCOWS
5,700 CY/TRIP X .56 LOADS/DAY 3,179 CY/DAY
SCOWS REQ 4 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD. 566.2 DAYS

LOST TIME 17% 96 DAYS
TOTAL TIME (EFFECTIVE + LOST) 662 DAYS

PLANT COST 547,000 /MONTH
FUEL COST .90 /GAL 226,547 /MONTH
MAINTENANCE AND INSURANCE COST 45,000 /MONTH
LABOR COST 62,900 /MONTH
TOTAL DIRECT MONTHLY COST 881,447 /MONTH
20% OVERHEAD & PROFIT 176,289 /MONTH

TOTAL MONTHLY COST 1,057,736
TOTAL DAILY COST 35,258

DREDGING COSTS 23,347,762
MOBILIZATION/DEMOBILIZATION
10 DAYS @ 25,000 250,000
TOTAL JOB COST 23,597,762

UNIT COST/CY 3.93

E&D / S&A 9 % .35

CONTINGENCIES @ 20% .86

TOTAL UNIT COST 5.14

COST ESTIMATE 2A5 BUCKET DREDGE

PLANT: 10 CY BUCKET DREDGE
CHANNEL SEGMENT: NORFOLK HARBOR
DISPOSAL AREA: REHANDLING BASIN AT CRANEY ISLAND
HAUL DISTANCE (MILES): 6
QUANTITY PAY: 5,000 CY GROSS: 6,750 CY
BUCKET TYPE DREDGE CAPACITY: 10 CY
LOAD FACTOR = .90
CYCLE TIME (MINUTES): 1 MIN.
CYCLES/HR 60 EA
CY/HR 540 CY/HR
EFFICIENCY FACTOR (24HRS X 65 %) 16 HRS/DAY
CY/DAY 8,640 CY

NUMBER SCOWS PER TOW 2 EA
HAUL 6 MILES @ 3.00 MPH 2.00 HRS
LOAD & DUMP 12 HRS
RETURN 6 MILES @ 3.50 MPH 1.71 HRS
TOTAL CYCLE TIME (SCOWS) 15.71 HRS
20 WORK HOURS/DAY / CYCLE TIME 1.27 LOADS/DAY
2 3000 CY SCOWS @ 2,850 CY/LOAD= 5,700 CY/TRIP
SCOWS
5,700 CY/TRIP X 1.27 LOADS/DAY 7,255 CY/DAY
SCOWS REQ 1 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD. .9 DAYS

LOST TIME 23% .2 DAYS
TOTAL TIME (EFFECTIVE + LOST) 1.1 DAYS

PLANT COST 158,550 /MONTH
FUEL COST .90 /GAL 76,759 /MONTH
MAINTENANCE AND INSURANCE COST 39,150 /MONTH
LABOR COST 62,900 /MONTH
TOTAL DIRECT MONTHLY COST 337,359 /MONTH
27% OVERHEAD & PROFIT 91,087 /MONTH
TOTAL MONTHLY COST 428,446
TOTAL DAILY COST 14,282

DREDGING COSTS 15,710
MOBILIZATION/DEMOBILIZATION
2 DAYS @ 4,000 8,000
TOTAL JOB COST 23,710

UNIT COST/CY 4.74

E&D / S&A 9 % .43

CONTINGENCIES @ 20% 1.03

TOTAL UNIT COST 6.20

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COST ESTIMATE          2A10          BUCKET DREDGE

PLANT:              10 CY BUCKET DREDGE
CHANNEL SEGMENT:    NORFOLK HARBOR
DISPOSAL AREA:      REHANDLING BASIN AT CRANEY ISLAND
HAUL DISTANCE (MILES):          6
QUANTITY      PAY:       10,000  CY   GROSS:          13,500 CY
BUCKET TYPE DREDGE CAPACITY:                              10 CY
                                                LOAD FACTOR  =  .90
CYCLE TIME    (MINUTES):                                   1 MIN.
CYCLES/HR                                                 60 EA
CY/HR                                                    540 CY/HR
EFFICIENCY FACTOR      (24HRS X        65     %)         16 HRS/DAY
CY/DAY                                                 8,640 CY

NUMBER SCOWS PER TOW                                       2 EA
HAUL          6       MILES @     3.00    MPH           2.00 HRS
LOAD & DUMP                                               12 HRS
RETURN        6       MILES @     3.50    MPH           1.71 HRS
TOTAL CYCLE TIME (SCOWS)                                15.71 HRS
    20    WORK HOURS/DAY /     CYCLE TIME                1.27 LOADS/DAY
    2     3000 CY SCOWS @       2,850 CY/LOAD=         5,700 CY/TRIP
SCOWS
 5,700    CY/TRIP X        1.27 LOADS/DAY                7,255 CY/DAY
SCOWS REQ                                                  1 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.                 1.9 DAYS

LOST TIME        22%                                       .4 DAYS
TOTAL TIME (EFFECTIVE + LOST)                             2.3 DAYS

PLANT COST                                            170,850 /MONTH
FUEL COST                    .90 /GAL                  81,424 /MONTH
MAINTENANCE AND INSURANCE COST                         39,150 /MONTH
LABOR COST                                             62,900 /MONTH
TOTAL DIRECT MONTHLY COST                             354,324 /MONTH
      26% OVERHEAD & PROFIT                            92,124 /MONTH
TOTAL MONTHLY COST                                    446,448

TOTAL DAILY COST                                       14,882

DREDGING COSTS                                         34,228
MOBILIZATION/DEMOBILIZATION
                        2      DAYS @  5,000           10,000
TOTAL JOB COST                                         44,228

UNIT COST/CY                                             4.42

E&D / S&A        9      %                                .40

CONTINGENCIES    @          20%                           .96

TOTAL UNIT COST                                          5.78
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COST ESTIMATE 2A20 BUCKET DREDGE

PLANT:	10 CY BUCKET DREDGE		
CHANNEL SEGMENT:	NORFOLK HARBOR		
DISPOSAL AREA:	REHANDLING BASIN AT CRANEY ISLAND		
HAUL DISTANCE (MILES):	6		
QUANTITY PAY:	20,000 CY	GROSS:	26,000 CY
BUCKET TYPE DREDGE CAPACITY:			10 CY
		LOAD FACTOR	= .90
CYCLE TIME (MINUTES):			1 MIN.
CYCLES/HR			60 EA
CY/HR			540 CY/HR
EFFICIENCY FACTOR	(24HRS X	65 %)	16 HRS/DAY
CY/DAY			8,640 CY
NUMBER SCOWS PER TOW			2 EA
HAUL	6 MILES @	3.00 MPH	2.00 HRS
LOAD & DUMP			12 HRS
RETURN	6 MILES @	3.50 MPH	1.71 HRS
TOTAL CYCLE TIME (SCOWS)			15.71 HRS
20	WORK HOURS/DAY /	CYCLE TIME	1.27 LOADS/DAY
2	3000 CY SCOWS @	2,850 CY/LOAD=	5,700 CY/TRIP
SCOWS			
5,700	CY/TRIP X	1.27 LOADS/DAY	7,255 CY/DAY
SCOWS REQ			1 SETS
TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.			3.6 DAYS
LOST TIME	21%		.8 DAYS
TOTAL TIME (EFFECTIVE + LOST)			4.4 DAYS
PLANT COST			170,850 /MONTH
FUEL COST		.90 /GAL	81,424 /MONTH
MAINTENANCE AND INSURANCE COST			39,150 /MONTH
LABOR COST			62,900 /MONTH
TOTAL DIRECT MONTHLY COST			354,324 /MONTH
26% OVERHEAD & PROFIT			92,124 /MONTH
TOTAL MONTHLY COST			446,448
TOTAL DAILY COST			14,882
DREDGING COSTS			65,479
MOBILIZATION/DEMOBILIZATION			
	2	DAYS @ 7,500	15,000
TOTAL JOB COST			80,479
UNIT COST/CY			4.02
E&D / S&A	9 %		.36
CONTINGENCIES	@	20%	.88
TOTAL UNIT COST			5.26

COST ESTIMATE 2A50 BUCKET DREDGE

PLANT: 10 CY BUCKET DREDGE
CHANNEL SEGMENT: NORFOLK HARBOR
DISPOSAL AREA: REHANDLING BASIN AT CRANEY ISLAND
HAUL DISTANCE (MILES): 6
QUANTITY PAY: 50,000 CY GROSS: 65,000 /CY
BUCKET TYPE DREDGE CAPACITY: 10 CY
LOAD FACTOR = .90
CYCLE TIME (MINUTES): 1 MIN.
CYCLES/HR 60 EA
CY/HR 540 CY/HR

EFFICIENCY FACTOR (24HRS X 65 %) 16 HRS/DAY
CY/DAY 8,640 CY

NUMBER SCOWS PER TOW 2 EA
HAUL 6 MILES @ 3.00 MPH 2.00 HRS
LOAD & DUMP 12 HRS
RETURN 6 MILES @ 3.50 MPH 1.71 HRS
TOTAL CYCLE TIME (SCOWS) 15.71 HRS
20 WORK HOURS/DAY / CYCLE TIME 1.27 LOADS/DAY
2 3000 CY SCOWS @ 2,850 CY/LOAD= 5,700 CY/TRIP
SCOWS
5,700 CY/TRIP X 1.27 LOADS/DAY 7,255 CY/DAY
SCOWS REQ 1 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD. 9 DAYS

LOST TIME 21% 1.9 DAYS
TOTAL TIME (EFFECTIVE + LOST) 10.9 DAYS

PLANT COST 170,850 /MONTH
FUEL COST .90 /GAL 81,424 /MONTH
MAINTENANCE AND INSURANCE COST 39,150 /MONTH
LABOR COST 62,900 /MONTH
TOTAL DIRECT MONTHLY COST 354,324 /MONTH
26% OVERHEAD & PROFIT 92,124 /MONTH
TOTAL MONTHLY COST 446,448
TOTAL DAILY COST 14,882

DREDGING COSTS 162,209
MOBILIZATION/DEMOBILIZATION
3 DAYS @ 10,000 30,000
TOTAL JOB COST 192,209

UNIT COST/CY 3.84

E&D / S&A 9 % .35

CONTINGENCIES @ 20% .84

TOTAL UNIT COST 5.03

COST ESTIMATE 2A75 BUCKET DREDGE

PLANT:	18 CY BUCKET DREDGE		
CHANNEL SEGMENT:	NORFOLK HARBOR		
DISPOSAL AREA:	REHANDLING BASIN AT CRANEY ISLAND		
HAUL DISTANCE (MILES):	6		
QUANTITY PAY:	75,000 CY	GROSS:	93,750 CY
BUCKET TYPE DREDGE CAPACITY:			18 CY
		LOAD FACTOR =	.90
CYCLE TIME (MINUTES):			1.2 MIN.
CYCLES/HR			50 EA
CY/HR			810 CY/HR
EFFICIENCY FACTOR	(24HRS X	65 %)	16 HRS/DAY
CY/DAY			12,960 CY
NUMBER SCOWS PER TOW			2 EA
HAUL	6 MILES @	3.00 MPH	2.00 HRS
LOAD & DUMP			8 HRS
RETURN	6 MILES @	3.50 MPH	1.71 HRS
TOTAL CYCLE TIME (SCOWS)			11.71 HRS
20	WORK HOURS/DAY /	CYCLE TIME	1.71 LOADS/DAY
2	3000 CY SCOWS @	2,850 CY/LOAD=	5,700 CY/TRIP
SCOWS			
5,700	CY/TRIP X	1.71 LOADS/DAY	9,732 CY/DAY
SCOWS REQ			1 SETS
TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.			9.6 DAYS
LOST TIME	20%		1.9 DAYS
TOTAL TIME (EFFECTIVE + LOST)			11.5 DAYS
PLANT COST			178,000 /MONTH
FUEL COST		.90 /GAL	86,621 /MONTH
MAINTENANCE AND INSURANCE COST			45,000 /MONTH
LABOR COST			62,900 /MONTH
TOTAL DIRECT MONTHLY COST			372,521 /MONTH
25% OVERHEAD & PROFIT			93,130 /MONTH
TOTAL MONTHLY COST			465,651
TOTAL DAILY COST			15,522
DREDGING COSTS			178,500
MOBILIZATION/DEMOBILIZATION			
	4	DAYS @ 20,000	80,000
TOTAL JOB COST			258,500
UNIT COST/CY			3.45
E&D / S&A	9 %		.31
CONTINGENCIES	@	20%	.75
TOTAL UNIT COST			4.51

COST ESTIMATE 2A100 BUCKET DREDGE

PLANT: 18 CY BUCKET DREDGE
CHANNEL SEGMENT: NORFOLK HARBOR
DISPOSAL AREA: REHANDLING BASIN AT CRANEY ISLAND
HAUL DISTANCE (MILES): 6
QUANTITY PAY: 100,000 CY GROSS: 125,000 CY
BUCKET TYPE DREDGE CAPACITY: 18 CY
LOAD FACTOR = .90
CYCLE TIME (MINUTES): 1.2 MIN.
CYCLES/HR 50 EA
CY/HR 810 CY/HR
EFFICIENCY FACTOR (24HRS X 65 %) 16 HRS/DAY
CY/DAY 12,960 CY

NUMBER SCOWS PER TOW 2 EA
HAUL 6 MILES @ 3.00 MPH 2.00 HRS
LOAD & DUMP 8 HRS
RETURN 6 MILES @ 3.50 MPH 1.71 HRS
TOTAL CYCLE TIME (SCOWS) 11.71 HRS
20 WORK HOURS/DAY / CYCLE TIME 1.71 LOADS/DAY
2 3000 CY SCOWS @ 2,850 CY/LOAD= 5,700 CY/TRIP
SCOWS
5,700 CY/TRIP X 1.71 LOADS/DAY 9,732 CY/DAY
SCOWS REQ 1 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD. 12.8 DAYS

LOST TIME 20% 2.6 DAYS
TOTAL TIME (EFFECTIVE + LOST) 15.4 DAYS

PLANT COST 178,000 /MONTH
FUEL COST .90 /GAL 86,621 /MONTH
MAINTENANCE AND INSURANCE COST 45,000 /MONTH
LABOR COST 62,900 /MONTH
TOTAL DIRECT MONTHLY COST 372,521 /MONTH
25% OVERHEAD & PROFIT 93,130 /MONTH

TOTAL MONTHLY COST 465,651
TOTAL DAILY COST 15,522

DREDGING COSTS 239,034
MOBILIZATION/DEMOBILIZATION
4 DAYS @ 20,000 80,000
TOTAL JOB COST 319,034

UNIT COST/CY 3.19

E&D / S&A 9 % .29

CONTINGENCIES @ 20% .70

TOTAL UNIT COST 4.17

COST ESTIMATE 2A250 BUCKET DREDGE

PLANT: 18 CY BUCKET DREDGE
CHANNEL SEGMENT: NORFOLK HARBOR
DISPOSAL AREA: REHANDLING BASIN AT CRANEY ISLAND
HAUL DISTANCE (MILES): 6
QUANTITY PAY: 250,000 CY GROSS: 312,500 CY
BUCKET TYPE DREDGE CAPACITY: 18 CY
LOAD FACTOR = .90
CYCLE TIME (MINUTES): 1.2 MIN.
CYCLES/HR 50 EA
CY/HR 810 CY/HR
EFFICIENCY FACTOR (24HRS X 65 %) 16 HRS/DAY
CY/DAY 12,960 CY

NUMBER SCOWS PER TOW 2 EA
HAUL 6 MILES @ 3.00 MPH 2.00 HRS
LOAD & DUMP 8 HRS
RETURN 6 MILES @ 3.50 MPH 1.71 HRS
TOTAL CYCLE TIME (SCOWS) 11.71 HRS
20 WORK HOURS/DAY / CYCLE TIME 1.71 LOADS/DAY
2 3000 CY SCOWS @ 2,850 CY/LOAD= 5,700 CY/TRIP
SCOWS
5,700 CY/TRIP X 1.71 LOADS/DAY 9,732 CY/DAY

SCOWS REQ 1 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD. 32.1 DAYS

LOST TIME 20% 6.4 DAYS
TOTAL TIME (EFFECTIVE + LOST) 38.5 DAYS

PLANT COST 178,000 /MONTH
FUEL COST .90 /GAL 86,621 /MONTH
MAINTENANCE AND INSURANCE COST 45,000 /MONTH
LABOR COST 62,900 /MONTH
TOTAL DIRECT MONTHLY COST 372,521 /MONTH
25% OVERHEAD & PROFIT 93,130 /MONTH
TOTAL MONTHLY COST 465,651
TOTAL DAILY COST 15,522

DREDGING COSTS 597,585
MOBILIZATION/DEMOBILIZATION
6 DAYS @ 25,000 150,000
TOTAL JOB COST 747,585

UNIT COST/CY 2.99

E&D / S&A 9 % .27

CONTINGENCIES @ 20% .65

TOTAL UNIT COST 3.91

COST ESTIMATE 2A500 BUCKET DREDGE

PLANT: 18 CY BUCKET DREDGE
CHANNEL SEGMENT: NORFOLK HARBOR
DISPOSAL AREA: REHANDLING BASIN AT CRANEY ISLAND
HAUL DISTANCE (MILES): 6
QUANTITY PAY: 500,000 CY GROSS: 625,000 CY
BUCKET TYPE DREDGE CAPACITY: 18 CY
LOAD FACTOR = .90
CYCLE TIME (MINUTES): 1.2 MIN.
CYCLES/HR 50 EA

CY/HR 810 CY/HR
EFFICIENCY FACTOR (24HRS X 65 %) 16 HRS/DAY
CY/DAY 12,960 CY

NUMBER SCOWS PER TOW 2 EA
HAUL 6 MILES @ 3.00 MPH 2.00 HRS
LOAD & DUMP 8 HRS
RETURN 6 MILES @ 3.50 MPH 1.71 HRS
TOTAL CYCLE TIME (SCOWS) 11.71 HRS
20 WORK HOURS/DAY / CYCLE TIME 1.71 LOADS/DAY
2 3000 CY SCOWS @ 2,850 CY/LOAD= 5,700 CY/TRIP
SCOWS
5,700 CY/TRIP X 1.71 LOADS/DAY 9,732 CY/DAY
SCOWS REQ 1 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD. 64.2 DAYS

LOST TIME 20% 12.8 DAYS
TOTAL TIME (EFFECTIVE + LOST) 77 DAYS

PLANT COST 178,000 /MONTH
FUEL COST .90 /GAL 86,621 /MONTH
MAINTENANCE AND INSURANCE COST 45,000 /MONTH
LABOR COST 62,900 /MONTH
TOTAL DIRECT MONTHLY COST 372,521 /MONTH
25% OVERHEAD & PROFIT 93,130 /MONTH
TOTAL MONTHLY COST 465,651
TOTAL DAILY COST 15,522

DREDGING COSTS 1,195,171
MOBILIZATION/DEMOBILIZATION
10 DAYS @ 25,000 250,000
TOTAL JOB COST 1,445,171

UNIT COST/CY 2.89

E&D / S&A 9 % .26

CONTINGENCIES @ 20% .63

TOTAL UNIT COST 3.78

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COST ESTIMATE        2A1000        BUCKET DREDGE

PLANT:              18 CY BUCKET DREDGE
CHANNEL SEGMENT:    NORFOLK HARBOR
DISPOSAL AREA:      REHANDLING BASIN AT CRANEY ISLAND
HAUL DISTANCE (MILES):          6
QUANTITY     PAY:   1,000,000  CY   GROSS:      1,250,000 CY
BUCKET TYPE DREDGE CAPACITY:                          18 CY
                                          LOAD FACTOR  =  .90
CYCLE TIME   (MINUTES):                             1.2 MIN.
CYCLES/HR                                            50 EA
CY/HR                                               810 CY/HR
EFFICIENCY FACTOR     (24HRS X        70    %)      17 HRS/DAY
CY/DAY                                           13,770 CY

NUMBER SCOWS PER TOW                                  2 EA
HAUL          6      MILES @    3.00   MPH        2.00 HRS
LOAD & DUMP                                          8 HRS
RETURN        6      MILES @    3.50   MPH        1.71 HRS
TOTAL CYCLE TIME (SCOWS)                         11.71 HRS
    20   WORK HOURS/DAY /    CYCLE TIME           1.71 LOADS/DAY
    2    3000 CY SCOWS @      2,850 CY/LOAD=      5,700 CY/TRIP
SCOWS
 5,700   CY/TRIP X        1.71 LOADS/DAY          9,732 CY/DAY
SCOWS REQ                                             1 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.        128.4 DAYS

LOST TIME       19%                               24.4 DAYS
TOTAL TIME (EFFECTIVE + LOST)                    152.8 DAYS

PLANT COST                                      178,000 /MONTH
FUEL COST                  .90 /GAL              86,621 /MONTH
MAINTENANCE AND INSURANCE COST                   45,000 /MONTH
LABOR COST                                       62,900 /MONTH
TOTAL DIRECT MONTHLY COST                       372,521 /MONTH
     24% OVERHEAD & PROFIT                       89,405 /MONTH
TOTAL MONTHLY COST                              461,926
TOTAL DAILY COST                                 15,398

DREDGING COSTS                                2,352,743
MOBILIZATION/DEMOBILIZATION
                        10    DAYS @ 25,000     250,000
TOTAL JOB COST                                2,602,743

UNIT COST/CY                                       2.60

E&D / S&A        9     %                           .23


CONTINGENCIES   @          20%                     .57

TOTAL UNIT COST                                    3.40
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COST ESTIMATE 2A3000 BUCKET DREDGE

PLANT: 18 CY BUCKET DREDGE
CHANNEL SEGMENT: NORFOLK HARBOR
DISPOSAL AREA: REHANDLING BASIN AT CRANEY ISLAND
HAUL DISTANCE (MILES): 6
QUANTITY PAY: 3,000,000 CY GROSS: 3,750,000 CY
BUCKET TYPE DREDGE CAPACITY: 18 CY
LOAD FACTOR = .90
CYCLE TIME (MINUTES): 1.2 MIN.
CYCLES/HR 50 EA
CY/HR 810 CY/HR
EFFICIENCY FACTOR (24HRS X 70 %) 17 HRS/DAY
CY/DAY 13,770 CY

NUMBER SCOWS PER TOW 2 EA
HAUL 6 MILES @ 3.00 MPH 2.00 HRS
LOAD & DUMP .8 HRS
RETURN 6 MILES @ 3.50 MPH 1.71 HRS
TOTAL CYCLE TIME (SCOWS) 11.71 HRS
20 WORK HOURS/DAY / CYCLE TIME 1.71 LOADS/DAY
2 3000 CY SCOWS @ 2,850 CY/LOAD= 5,700 CY/TRIP
SCOWS
5,700 CY/TRIP X 1.71 LOADS/DAY 9,732 CY/DAY
SCOWS REQ 1 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD. 385.3 DAYS

LOST TIME 18% 69.4 DAYS
TOTAL TIME (EFFECTIVE + LOST) 454.7 DAYS

PLANT COST 178,000 /MONTH
FUEL COST .90 /GAL 86,621 /MONTH
MAINTENANCE AND INSURANCE COST 45,000 /MONTH
LABOR COST 62,900 /MONTH
TOTAL DIRECT MONTHLY COST 372,521 /MONTH
22% OVERHEAD & PROFIT 81,955 /MONTH

TOTAL MONTHLY COST 454,476
TOTAL DAILY COST 15,149

DREDGING COSTS 6,888,340
MOBILIZATION/DEMOBILIZATION
10 DAYS @ 25,000 250,000
TOTAL JOB COST 7,138,340

UNIT COST/CY 2.38

E&D / S&A 9 % .21

CONTINGENCIES @ 20% .52

TOTAL UNIT COST 3.11

COST ESTIMATE 2B5 BUCKET DREDGE

PLANT: 10 CY BUCKET DREDGE
CHANNEL SEGMENT: NORFOLK HARBOR
DISPOSAL AREA: INTO CRANEY ISLAND BY BARGE REHANDLER
HAUL DISTANCE (MILES): 6
QUANTITY PAY: 5,000 CY GROSS: 6,750 CY
BUCKET TYPE DREDGE CAPACITY: 10 CY
LOAD FACTOR = .90
CYCLE TIME (MINUTES): 1 MIN.
CYCLES/HR 60 EA
CY/HR 540 CY/HR
EFFICIENCY FACTOR (24HRS X 65 %) 16 HRS/DAY
CY/DAY 8,640 CY

NUMBER SCOWS PER TOW 2 EA
HAUL 6 MILES @ 3.00 MPH 2.00 HRS
LOAD & DUMP 19 HRS
RETURN 6 MILES @ 3.50 MPH 1.71 HRS
TOTAL CYCLE TIME (SCOWS) 22.71 HRS
20 WORK HOURS/DAY / CYCLE TIME .88 LOADS/DAY
2 3000 CY SCOWS @ 2,850 CY/LOAD= 5,700 CY/TRIP
SCOWS
5,700 CY/TRIP X .88 LOADS/DAY 5,019 CY/DAY
SCOWS REQ 2 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD. .8 DAYS

LOST TIME 23% .2 DAYS
TOTAL TIME (EFFECTIVE + LOST) 1 DAYS

PLANT COST 293,850 /MONTH
FUEL COST .90 /GAL 128,066 /MONTH
MAINTENANCE AND INSURANCE COST 39,150 /MONTH
LABOR COST 62,900 /MONTH
TOTAL DIRECT MONTHLY COST (+130K FOR REHANDLER) 653,966 /MONTH
27% OVERHEAD & PROFIT 176,571 /MONTH
TOTAL MONTHLY COST 830,537
TOTAL DAILY COST 27,685

DREDGING COSTS 27,685
MOBILIZATION/DEMOBILIZATION
2 DAYS @ 4,000 8,000
TOTAL JOB COST 35,685

UNIT COST/CY 7.14

E&D / S&A 9 % .64

CONTINGENCIES @ 20% 1.56

TOTAL UNIT COST 9.34

COST ESTIMATE 2B10 BUCKET DREDGE

PLANT:	10 CY BUCKET DREDGE		
CHANNEL SEGMENT:	NORFOLK HARBOR		
DISPOSAL AREA:	INTO CRANEY ISLAND BY BARGE REHANDLER		
HAUL DISTANCE (MILES):	6		
QUANTITY PAY:	10,000 CY	GROSS:	13,500 CY
BUCKET TYPE DREDGE CAPACITY:			10 CY
		LOAD FACTOR =	.90
CYCLE TIME (MINUTES):			1 MIN.
CYCLES/HR			60 EA
CY/HR			540 CY/HR
EFFICIENCY FACTOR	(24HRS X 65 %)		16 HRS/DAY
CY/DAY			8,640 CY
NUMBER SCOWS PER TOW			2 EA
HAUL	6 MILES @ 3.00 MPH		2.00 HRS
LOAD & DUMP			19 HRS
RETURN	6 MILES @ 3.50 MPH		1.71 HRS
TOTAL CYCLE TIME (SCOWS)			22.71 HRS
20	WORK HOURS/DAY / CYCLE TIME		.88 LOADS/DAY
2	3000 CY SCOWS @ 2,850 CY/LOAD=		5,700 CY/TRIP
SCOWS			
5,700	CY/TRIP X .88 LOADS/DAY		5,019 CY/DAY
SCOWS REQ			2 SETS
TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.			1.6 DAYS
LOST TIME	22%		.4 DAYS
TOTAL TIME (EFFECTIVE + LOST)			2 DAYS
PLANT COST			293,850 /MONTH
FUEL COST	.90 /GAL		128,066 /MONTH
MAINTENANCE AND INSURANCE COST			39,150 /MONTH
LABOR COST			62,900 /MONTH
TOTAL DIRECT MONTHLY COST (+130K FOR REHANDLER)			653,966 /MONTH
26% OVERHEAD & PROFIT			170,031 /MONTH
TOTAL MONTHLY COST			823,997
TOTAL DAILY COST			27,467
DREDGING COSTS			54,933
MOBILIZATION/DEMOBILIZATION			
	2 DAYS @ 5,000		10,000
TOTAL JOB COST			64,933
UNIT COST/CY			6.49
E&D / S&A	9 %		.58
CONTINGENCIES	@ 20%		1.42
TOTAL UNIT COST			8.49

COST ESTIMATE 2820 BUCKET DREDGE

PLANT: 10 CY BUCKET DREDGE
CHANNEL SEGMENT: NORFOLK HARBOR
DISPOSAL AREA: INTO CRANEY ISLAND BY BARGE REHANDLER
HAUL DISTANCE (MILES): 6
QUANTITY PAY: 20,000 CY GROSS: 26,000 CY
BUCKET TYPE DREDGE CAPACITY: 10 CY
LOAD FACTOR = .90
CYCLE TIME (MINUTES): 1 MIN.
CYCLES/HR 60 EA
CY/HR 540 CY/HR
EFFICIENCY FACTOR (24HRS X 65 %) 16 HRS/DAY
CY/DAY 8,640 CY

NUMBER SCOWS PER TOW 2 EA
HAUL 6 MILES @ 3.00 MPH 2.00 HRS
LOAD & DUMP .19 HRS
RETURN 6 MILES @ 3.50 MPH 1.71 HRS
TOTAL CYCLE TIME (SCOWS) 22.71 HRS
20 WORK HOURS/DAY / CYCLE TIME .88 LOADS/DAY
2 3000 CY SCOWS @ 2,850 CY/LOAD= 5,700 CY/TRIP
SCOWS
5,700 CY/TRIP X .88 LOADS/DAY 5,019 CY/DAY
SCOWS REQ 2 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD. 3 DAYS

LOST TIME 21% .6 DAYS
TOTAL TIME (EFFECTIVE + LOST) 3.6 DAYS

PLANT COST 293,850 /MONTH
FUEL COST .90 /GAL 128,066 /MONTH
MAINTENANCE AND INSURANCE COST 39,150 /MONTH
LABOR COST 62,900 /MONTH
TOTAL DIRECT MONTHLY COST (+130K FOR REHANDLER) 653,966 /MONTH
26% OVERHEAD & PROFIT 170,031 /MONTH
TOTAL MONTHLY COST 823,997
TOTAL DAILY COST 27,467

DREDGING COSTS 98,880
MOBILIZATION/DEMOBILIZATION
2 DAYS @ 7,500 15,000
TOTAL JOB COST 113,880

UNIT COST/CY 5.69

E&D / S&A 9 % .51

CONTINGENCIES @ 20% 1.24

TOTAL UNIT COST 7.45

COST ESTIMATE 2B50 BUCKET DREDGE

PLANT: 10 CY BUCKET DREDGE
CHANNEL SEGMENT: NORFOLK HARBOR
DISPOSAL AREA: INTO CRANEY ISLAND BY BARGE REHANDLER
HAUL DISTANCE (MILES): 6
QUANTITY PAY: 50,000 CY GROSS: 65,000 CY
BUCKET TYPE DREDGE CAPACITY: 10 CY
LOAD FACTOR = .90
CYCLE TIME (MINUTES): 1 MIN.
CYCLES/HR 60 EA
CY/HR 540 CY/HR

EFFICIENCY FACTOR (24HRS X 65 %) 16 HRS/DAY
CY/DAY 8,640 CY

NUMBER SCOWS PER TOW 2 EA
HAUL 6 MILES @ 3.00 MPH 2.00 HRS
LOAD & DUMP 18 HRS
RETURN 6 MILES @ 3.50 MPH 1.71 HRS
TOTAL CYCLE TIME (SCOWS) 21.71 HRS
20 WORK HOURS/DAY / CYCLE TIME .92 LOADS/DAY
2 3000 CY SCOWS @ 2,850 CY/LOAD= 5,700 CY/TRIP
SCOWS
5,700 CY/TRIP X .92 LOADS/DAY 5,250 CY/DAY
SCOWS REQ 2 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD. 7.5 DAYS

LOST TIME 21% 1.6 DAYS
TOTAL TIME (EFFECTIVE + LOST) 9.1 DAYS

PLANT COST 293,850 /MONTH
FUEL COST .90 /GAL 128,066 /MONTH
MAINTENANCE AND INSURANCE COST 39,150 /MONTH
LABOR COST 62,900 /MONTH
TOTAL DIRECT MONTHLY COST (+130K FOR REHANDLER) 653,966 /MONTH
26% OVERHEAD & PROFIT 170,031 /MONTH
TOTAL MONTHLY COST 823,997
TOTAL DAILY COST 27,467

DREDGING COSTS 249,946
MOBILIZATION/DEMOBILIZATION
3 DAYS @ 10,000 30,000
TOTAL JOB COST 279,946

UNIT COST/CY 5.60

E&D / S&A 9 % .50

CONTINGENCIES @ 20% 1.22

TOTAL UNIT COST 7.32

COST ESTIMATE 2B75 BUCKET DREDGE

PLANT: 18 CY BUCKET DREDGE
CHANNEL SEGMENT: NORFOLK HARBOR
DISPOSAL AREA: INTO CRANEY ISLAND BY BARGE REHANDLER
HAUL DISTANCE (MILES): 6
QUANTITY PAY: 75,000 CY GROSS: 93,750 CY
BUCKET TYPE DREDGE CAPACITY: 18 CY
LOAD FACTOR = .90
CYCLE TIME (MINUTES): 1.2 MIN.
CYCLES/HR 50 EA
CY/HR 810 CY/HR
EFFICIENCY FACTOR (24HRS X 65 %) 16 HRS/DAY
CY/DAY 12,960 CY

NUMBER SCOWS PER TOW 2 EA
HAUL 6 MILES @ 3.00 MPH 2.00 HRS
LOAD & DUMP .14 HRS
RETURN 6 MILES @ 3.50 MPH 1.71 HRS
TOTAL CYCLE TIME (SCOWS) 17.71 HRS
20 WORK HOURS/DAY / CYCLE TIME 1.13 LOADS/DAY
2 3000 CY SCOWS @ 2,850 CY/LOAD= 5,700 CY/TRIP
SCOWS
5,700 CY/TRIP X 1.13 LOADS/DAY 6,435 CY/DAY
SCOWS REQ 2 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD. 7.3 DAYS

LOST TIME 20% 1.5 DAYS
TOTAL TIME (EFFECTIVE + LOST) 8.8 DAYS

PLANT COST 301,000 /MONTH
FUEL COST .90 /GAL 133,263 /MONTH
MAINTENANCE AND INSURANCE COST 45,000 /MONTH
LABOR COST 62,900 /MONTH
TOTAL DIRECT MONTHLY COST (+130K FOR REHANDLER) 672,163 /MONTH
25% OVERHEAD & PROFIT 168,041 /MONTH
TOTAL MONTHLY COST 840,204
TOTAL DAILY COST 28,007

DREDGING COSTS 246,460
MOBILIZATION/DEMOBILIZATION
4 DAYS @ 20,000 80,000
TOTAL JOB COST 326,460

UNIT COST/CY 4.35

E&D / S&A 9 % .39

CONTINGENCIES @ 20% .95

TOTAL UNIT COST 5.69

COST ESTIMATE 2B100 BUCKET DREDGE

PLANT: 18 CY BUCKET DREDGE
CHANNEL SEGMENT: NORFOLK HARBOR
DISPOSAL AREA: INTO CRANEY ISLAND BY BARGE REHANDLER
HAUL DISTANCE (MILES): 6
QUANTITY PAY: 100,000 CY GROSS: 125,000 CY
BUCKET TYPE DREDGE CAPACITY: 18 CY
LOAD FACTOR = .90
CYCLE TIME (MINUTES): 1.2 MIN.
CYCLES/HR 50 EA
CY/HR 810 CY/HR
EFFICIENCY FACTOR (24HRS X 65 %) 16 HRS/DAY
CY/DAY 12,960 CY

NUMBER SCOWS PER TOW 2 EA
HAUL 6 MILES @ 3.00 MPH 2.00 HRS
LOAD & DUMP .14 HRS
RETURN 6 MILES @ 3.50 MPH 1.71 HRS
TOTAL CYCLE TIME (SCOWS) 17.71 HRS
20 WORK HOURS/DAY / CYCLE TIME 1.13 LOADS/DAY
2 3000 CY SCOWS @ 2,850 CY/LOAD= 5,700 CY/TRIP
SCOWS
5,700 CY/TRIP X 1.13 LOADS/DAY 6,435 CY/DAY
SCOWS REQ 2 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD. 9.7 DAYS

LOST TIME 20% 1.9 DAYS
TOTAL TIME (EFFECTIVE + LOST) 11.6 DAYS

PLANT COST 301,000 /MONTH
FUEL COST .90 /GAL 133,263 /MONTH
MAINTENANCE AND INSURANCE COST 45,000 /MONTH
LABOR COST 62,900 /MONTH
TOTAL DIRECT MONTHLY COST (+130K FOR REHANDLER) 672,163 /MONTH
25% OVERHEAD & PROFIT 168,041 /MONTH

TOTAL MONTHLY COST 840,204
TOTAL DAILY COST 28,007

DREDGING COSTS 324,879
MOBILIZATION/DEMOBILIZATION
4 DAYS @ 20,000 80,000
TOTAL JOB COST 404,879

UNIT COST/CY 4.05

E&D / S&A 9 % .36

CONTINGENCIES @ 20% .88

TOTAL UNIT COST 5.30

COST ESTIMATE 2B250 BUCKET DREDGE

PLANT: 18 CY BUCKET DREDGE
CHANNEL SEGMENT: NORFOLK HARBOR
DISPOSAL AREA: INTO CRANEY ISLAND BY BARGE REHANDLER
HAUL DISTANCE (MILES): 6
QUANTITY PAY: 250,000 CY GROSS: 312,500 CY
BUCKET TYPE DREDGE CAPACITY: 18 CY
LOAD FACTOR = .90
CYCLE TIME (MINUTES): 1.2 MIN.
CYCLES/HR 50 EA
CY/HR 810 CY/HR
EFFICIENCY FACTOR (24HRS X 65 %) 16 HRS/DAY
CY/DAY 12,960 CY

NUMBER SCOWS PER TOW 2 EA
HAUL 6 MILES @ 3.00 MPH 2.00 HRS
LOAD & DUMP .14 HRS
RETURN 6 MILES @ 3.50 MPH 1.71 HRS
TOTAL CYCLE TIME (SCOWS) 17.71 HRS
20 WORK HOURS/DAY / CYCLE TIME 1.13 LOADS/DAY
2 3000 CY SCOWS @ 2,850 CY/LOAD= 5,700 CY/TRIP
SCOWS
5,700 CY/TRIP X 1.13 LOADS/DAY 6,435 CY/DAY

SCOWS REQ 2 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD. 24.3 DAYS

LOST TIME 20% 4.9 DAYS
TOTAL TIME (EFFECTIVE + LOST) 29.2 DAYS

PLANT COST 301,000 /MONTH
FUEL COST .90 /GAL 133,263 /MONTH
MAINTENANCE AND INSURANCE COST 45,000 /MONTH
LABOR COST 62,900 /MONTH
TOTAL DIRECT MONTHLY COST (+130K FOR REHANDLER) 672,163 /MONTH
25% OVERHEAD & PROFIT 168,041 /MONTH
TOTAL MONTHLY COST 840,204
TOTAL DAILY COST 28,007

DREDGING COSTS 817,799
MOBILIZATION/DEMOBILIZATION
6 DAYS @ 25,000 150,000
TOTAL JOB COST 967,799

UNIT COST/CY 3.87

E&D / S&A 9 % .35

CONTINGENCIES @ 20% .84

TOTAL UNIT COST 5.06

COST ESTIMATE 2B500 BUCKET DREDGE

PLANT: 18 CY BUCKET DREDGE
CHANNEL SEGMENT: NORFOLK HARBOR
DISPOSAL AREA: INTO CRANEY ISLAND BY BARGE REHANDLER
HAUL DISTANCE (MILES): 6
QUANTITY PAY: 500,000 CY GROSS: 625,000 CY
BUCKET TYPE DREDGE CAPACITY: 18 CY
LOAD FACTOR = .90
CYCLE TIME (MINUTES): 1.2 MIN.
CYCLES/HR 50 EA

CY/HR 810 CY/HR
EFFICIENCY FACTOR (24HRS X 65 %) 16 HRS/DAY
CY/DAY 12,960 CY

NUMBER SCOWS PER TOW 2 EA
HAUL 6 MILES @ 3.00 MPH 2.00 HRS
LOAD & DUMP .14 HRS
RETURN 6 MILES @ 3.50 MPH 1.71 HRS
TOTAL CYCLE TIME (SCOWS) 17.71 HRS
20 WORK HOURS/DAY / CYCLE TIME 1.13 LOADS/DAY
2 3000 CY SCOWS @ 2,850 CY/LOAD= 5,700 CY/TRIP
SCOWS
5,700 CY/TRIP X 1.13 LOADS/DAY 6,435 CY/DAY
SCOWS REQ 2 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD. 48.6 DAYS

LOST TIME 20% 9.7 DAYS
TOTAL TIME (EFFECTIVE + LOST) 58.3 DAYS

PLANT COST 301,000 /MONTH
FUEL COST .90 /GAL 133,263 /MONTH
MAINTENANCE AND INSURANCE COST 45,000 /MONTH
LABOR COST 62,900 /MONTH
TOTAL DIRECT MONTHLY COST (+130K FOR REHANDLER) 672,163 /MONTH
25% OVERHEAD & PROFIT 168,041 /MONTH
TOTAL MONTHLY COST 840,204
TOTAL DAILY COST 28,007

DREDGING COSTS 1,632,796
MOBILIZATION/DEMOBILIZATION
10 DAYS @ 25,000 250,000
TOTAL JOB COST 1,882,796

UNIT COST/CY 3.77

E&D / S&A 9 % .34

CONTINGENCIES @ 20% .82

TOTAL UNIT COST 4.93

COST ESTIMATE 2B1000 BUCKET DREDGE

PLANT: 18 CY BUCKET DREDGE
CHANNEL SEGMENT: NORFOLK HARBOR
DISPOSAL AREA: INTO CRANEY ISLAND BY BARGE REHANDLER
HAUL DISTANCE (MILES): 6
QUANTITY PAY: 1,000,000 CY GROSS: 1,250,000 CY
BUCKET TYPE DREDGE CAPACITY: 18 CY
LOAD FACTOR = .90
CYCLE TIME (MINUTES): 1.2 MIN.
CYCLES/HR 50 EA
CY/HR 810 CY/HR
EFFICIENCY FACTOR (24HRS X 70 %) 17 HRS/DAY
CY/DAY 13,770 CY

NUMBER SCOWS PER TOW 2 EA
HAUL 6 MILES @ 3.00 MPH 2.00 HRS
LOAD & DUMP .14 HRS
RETURN 6 MILES @ 3.50 MPH 1.71 HRS
TOTAL CYCLE TIME (SCOWS) 17.71 HRS
20 WORK HOURS/DAY / CYCLE TIME 1.13 LOADS/DAY
2 3000 CY SCOWS @ 2,850 CY/LOAD= 5,700 CY/TRIP
SCOWS
5,700 CY/TRIP X 1.13 LOADS/DAY 6,435 CY/DAY
SCOWS REQ 2 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD. 97.1 DAYS

LOST TIME 19% 18.4 DAYS
TOTAL TIME (EFFECTIVE + LOST) 115.5 DAYS

PLANT COST 301,000 /MONTH
FUEL COST .90 /GAL 133,263 /MONTH
MAINTENANCE AND INSURANCE COST 45,000 /MONTH
LABOR COST 62,900 /MONTH
TOTAL DIRECT MONTHLY COST (+130K FOR REHANDLER) 672,163 /MONTH
24% OVERHEAD & PROFIT 161,319 /MONTH
TOTAL MONTHLY COST 833,482
TOTAL DAILY COST 27,783

DREDGING COSTS 3,208,906
MOBILIZATION/DEMOBILIZATION
10 DAYS @ 25,000 250,000
TOTAL JOB COST 3,458,906

UNIT COST/CY 3.46

E&D / S&A 9 % .31

CONTINGENCIES @ 20% .75

TOTAL UNIT COST 4.52

COST ESTIMATE 2B3000 BUCKET DREDGE

PLANT: 18 CY BUCKET DREDGE
CHANNEL SEGMENT: NORFOLK HARBOR
DISPOSAL AREA: INTO CRANEY ISLAND BY BARGE REHANDLER
HAUL DISTANCE (MILES): 6
QUANTITY PAY: 3,000,000 CY GROSS: 3,750,000 CY
BUCKET TYPE DREDGE CAPACITY: 18 CY
LOAD FACTOR = .90
CYCLE TIME (MINUTES): 1.2 MIN.
CYCLES/HR 50 EA
CY/HR 810 CY/HR
EFFICIENCY FACTOR (24HRS X 70 %) 17 HRS/DAY
CY/DAY 13,770 CY

NUMBER SCOWS PER TOW 2 EA
HAUL 6 MILES @ 3.00 MPH 2.00 HRS
LOAD & DUMP 14 HRS
RETURN 6 MILES @ 3.50 MPH 1.71 HRS
TOTAL CYCLE TIME (SCOWS) 17.71 HRS
20 WORK HOURS/DAY / CYCLE TIME 1.13 LOADS/DAY
2 3000 CY SCOWS @ 2,850 CY/LOAD= 5,700 CY/TRIP
SCOWS
5,700 CY/TRIP X 1.13 LOADS/DAY 6,435 CY/DAY
SCOWS REQ 2 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD. 291.4 DAYS

LOST TIME 18% 52.5 DAYS
TOTAL TIME (EFFECTIVE + LOST) 343.9 DAYS

PLANT COST 301,000 /MONTH
FUEL COST .90 /GAL 133, 63 /MONTH
MAINTENANCE AND INSURANCE COST 45,000 /MONTH
LABOR COST 62,900 /MONTH
TOTAL DIRECT MONTHLY COST (+130K FOR REHANDLER) 672,163 /MONTH
22% OVERHEAD & PROFIT 147,876 /MONTH

TOTAL MONTHLY COST 820,039
TOTAL DAILY COST 27,335

DREDGING COSTS 9,400,380
MOBILIZATION/DEMOBILIZATION
10 DAYS @ 25,000 250,000
TOTAL JOB COST 9,650,380

UNIT COST/CY 3.22

E&D / S&A 9 % .29

CONTINGENCIES @ 20% .70

TOTAL UNIT COST 4.21

COST ESTIMATE 2C5 BUCKET DREDGE

PLANT:	10 CY BUCKET DREDGE		
CHANNEL SEGMENT:	NORFOLK HARBOR		
DISPOSAL AREA:	DAM NECK		
HAUL DISTANCE (MILES):	37		
QUANTITY PAY:	5,000 CY	GROSS:	6,750 CY
BUCKET TYPE DREDGE CAPACITY:			10 CY
		LOAD FACTOR =	.90
CYCLE TIME (MINUTES):			1 MIN.
CYCLES/HR			60 EA
CY/HR			540 CY/HR
EFFICIENCY FACTOR	(24HRS X	65 %)	16 HRS/DAY
CY/DAY			8,640 CY
NUMBER SCOWS PER TOW			2 EA
HAUL	37 MILES @	3.00 MPH	12.33 HRS
LOAD & DUMP			12 HRS
RETURN	37 MILES @	3.50 MPH	10.57 HRS
TOTAL CYCLE TIME (SCOWS)			34.90 HRS
20	WORK HOURS/DAY /	CYCLE TIME	.57 LOADS/DAY
2	3000 CY SCOWS @	2,850 CY/LOAD=	5,700 CY/TRIP
SCOWS			
5,700	CY/TRIP X	.57 LOADS/DAY	3,266 CY/DAY
SCOWS REQ			3 SETS
TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.			.8 DAYS
LOST TIME	23%		.2 DAYS
TOTAL TIME (EFFECTIVE + LOST)			1 DAYS
PLANT COST			416,850 /MONTH
FUEL COST		.90 /GAL	174,708 /MONTH
MAINTENANCE AND INSURANCE COST			39,150 /MONTH
LABOR COST			62,900 /MONTH
TOTAL DIRECT MONTHLY COST			693,608 /MONTH
27% OVERHEAD & PROFIT			187,274 /MONTH
TOTAL MONTHLY COST			880,882
TOTAL DAILY COST			29,363
DREDGING COSTS			29,363
MOBILIZATION/DEMOBILIZATION			
	2	DAYS @ 4,000	8,000
TOTAL JOB COST			37,363
UNIT COST/CY			7.47
E&D / S&A	9 %		.67
CONTINGENCIES	@	20%	1.63
TOTAL UNIT COST			9.77

COST ESTIMATE 2C10 BUCKET DREDGE

PLANT:	10 CY BUCKET DREDGE		
CHANNEL SEGMENT:	NORFOLK HARBOR		
DISPOSAL AREA:	DAM NECK		
HAUL DISTANCE (MILES):	37		
QUANTITY PAY:	10,000 CY	GROSS:	13,500 CY
BUCKET TYPE DREDGE CAPACITY:			10 CY
		LOAD FACTOR =	.90
CYCLE TIME (MINUTES):			1 MIN.
CYCLES/HR			60 EA
CY/HR			540 CY/HR
EFFICIENCY FACTOR	(24HRS X	65 %)	16 HRS/DAY
CY/DAY			8,640 CY
NUMBER SCOWS PER TOW			2 EA
HAUL	37 MILES @	3.00 MPH	12.33 HRS
LOAD & DUMP			12 HRS
RETURN	37 MILES @	3.50 MPH	10.57 HRS
TOTAL CYCLE TIME (SCOWS)			34.90 HRS
20	WORK HOURS/DAY /	CYCLE TIME	.57 LOADS/DAY
2	3000 CY SCOWS @	2,850 CY/LOAD=	5,700 CY/TRIP
SCOWS			
5,700	CY/TRIP X	.57 LOADS/DAY	3,266 CY/DAY
SCOWS REQ			3 SETS
TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.			1.6 DAYS
LOST TIME	22%		.4 DAYS
TOTAL TIME (EFFECTIVE + LOST)			2 DAYS
PLANT COST			416,850 /MONTH
FUEL COST		.90 /GAL	174,708 /MONTH
MAINTENANCE AND INSURANCE COST			39,150 /MONTH
LABOR COST			62,900 /MONTH
TOTAL DIRECT MONTHLY COST			693,608 /MONTH
26% OVERHEAD & PROFIT			180,338 /MONTH
TOTAL MONTHLY COST			873,946
TOTAL DAILY COST			29,132
DREDGING COSTS			58,263
MOBILIZATION/DEMOBILIZATION			
	2	DAYS @ 5,000	10,000
TOTAL JOB COST			68,263
UNIT COST/CY			6.83
E&D / S&A	9 %		.61
CONTINGENCIES @		20%	1.49
TOTAL UNIT COST			8.93

COST ESTIMATE 2C20 BUCKET DREDGE

PLANT:	10 CY BUCKET DREDGE		
CHANNEL SEGMENT:	NORFOLK HARBOR		
DISPOSAL AREA:	DAM NECK		
HAUL DISTANCE (MILES):	37		
QUANTITY PAY:	20,000 CY	GROSS:	26,000 CY
BUCKET TYPE DREDGE CAPACITY:			10 CY
		LOAD FACTOR =	.90
CYCLE TIME (MINUTES):			1 MIN.
CYCLES/HR			60 EA
CY/HR			540 CY/HR
EFFICIENCY FACTOR	(24HRS X	65 %)	16 HRS/DAY
CY/DAY			8,640 CY
NUMBER SCOWS PER TOW			2 EA
HAUL	37 MILES @	3.00 MPH	12.33 HRS
LOAD & DUMP			12 HRS
RETURN	37 MILES @	3.50 MPH	10.57 HRS
TOTAL CYCLE TIME (SCOWS)			34.90 HRS
20	WORK HOURS/DAY /	CYCLE TIME	.57 LOADS/DAY
2	3000 CY SCOWS @	2,850 CY/LOAD=	5,700 CY/TRIP
SCOWS			
5,700	CY/TRIP X	.57 LOADS/DAY	3,266 CY/DAY
SCOWS REQ			3 SETS
TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD			3 DAYS
LOST TIME	21%		.6 DAYS
TOTAL TIME (EFFECTIVE + LOST)			3.6 DAYS
PLANT COST			416,850 /MONTH
FUEL COST		.90 /GAL	174,708 /MONTH
MAINTENANCE AND INSURANCE COST			39,150 /MONTH
LABOR COST			62,900 /MONTH
TOTAL DIRECT MONTHLY COST			693,608 /MONTH
26% OVERHEAD & PROFIT			180,338 /MONTH
TOTAL MONTHLY COST			873,946
TOTAL DAILY COST			29,132
DREDGING COSTS			104,873
MOBILIZATION/DEMOBILIZATION			
2	DAYS @	7,500	15,000
TOTAL JOB COST			119,873
UNIT COST/CY			5.99
E&D / S&A	9 %		.54
CONTINGENCIES @		20%	1.31
TOTAL UNIT COST			7.84

COST ESTIMATE 2C50 BUCKET DREDGE

PLANT:	10 CY BUCKET DREDGE		
CHANNEL SEGMENT:	NORFOLK HARBOR		
DISPOSAL AREA:	DAM NECK		
HAUL DISTANCE (MILES):	37		
QUANTITY PAY:	50,000 CY	GROSS:	65,000 CY
BUCKET TYPE DREDGE CAPACITY:			10 CY
		LOAD FACTOR =	.90
CYCLE TIME (MINUTES):			1 MIN.
CYCLES/HR			60 EA
CY/HR			540 CY/HR
EFFICIENCY FACTOR	(24HRS X	65 %)	16 HRS/DAY
CY/DAY			8,640 CY
NUMBER SCOWS PER TOW			2 EA
HAUL	37 MILES @	3.00 MPH	12.33 HRS
LOAD & DUMP			12 HRS
RETURN	37 MILES @	3.50 MPH	10.57 HRS
TOTAL CYCLE TIME (SCOWS)			34.90 HRS
20	WORK HOURS/DAY /	CYCLE TIME	.57 LOADS/DAY
2	3000 CY SCOWS @	2,850 CY/LOAD=	5,700 CY/TRIP
SCOWS			
5,700	CY/TRIP X	.57 LOADS/DAY	3,266 CY/DAY
SCOWS REQ			3 SETS
TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.			7.5 DAYS
LOST TIME	21%		1.6 DAYS
TOTAL TIME (EFFECTIVE + LOST)			9.1 DAYS
PLANT COST			416,850 /MONTH
FUEL COST		.90 /GAL	174,708 /MONTH
MAINTENANCE AND INSURANCE COST			39,150 /MONTH
LABOR COST			62,900 /MONTH
TOTAL DIRECT MONTHLY COST			693,608 /MONTH
26% OVERHEAD & PROFIT			180,338 /MONTH
TOTAL MONTHLY COST			873,946
TOTAL DAILY COST			29,132
DREDGING COSTS			265,097
MOBILIZATION/DEMOBILIZATION			
	3	DAYS @ 10,000	30,000
TOTAL JOB COST			295,097
UNIT COST/CY			5.90
E&D / S&A	9 %		.53
CONTINGENCIES	@	20%	1.29
TOTAL UNIT COST			7.72

.

COST ESTIMATE 2C75 BUCKET DREDGE

PLANT:	18 CY BUCKET DREDGE		
CHANNEL SEGMENT:	NORFOLK HARBOR		
DISPOSAL AREA:	DAM NECK		
HAUL DISTANCE (MILES):	37		
QUANTITY PAY:	75,000 CY	GROSS:	93,750 CY
BUCKET TYPE DREDGE CAPACITY:			18 CY
		LOAD FACTOR =	.90
CYCLE TIME (MINUTES):			1.2 MIN.
CYCLES/HR			50 EA
CY/HR			810 CY/HR
EFFICIENCY FACTOR	(24HRS X	65 %)	16 HRS/DAY
CY/DAY			12,960 CY
NUMBER SCOWS PER TOW			2 EA
HAUL	37 MILES @	3.00 MPH	12.33 HRS
LOAD & DUMP			8 HRS
RETURN	37 MILES @	3.50 MPH	10.57 HRS
TOTAL CYCLE TIME (SCOWS)			30.90 HRS
20	WORK HOURS/DAY /	CYCLE TIME	.65 LOADS/DAY
2	3000 CY SCOWS @	2,850 CY/LOAD=	5,700 CY/TRIP
SCOWS			
5,700	CY/TRIP X	.65 LOADS/DAY	3,689 CY/DAY
SCOWS REQ			4 SETS
TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.			7.2 DAYS
LOST TIME	20%		1.4 DAYS
TOTAL TIME (EFFECTIVE + LOST)			8.6 DAYS
PLANT COST			547,000 /MONTH
FUEL COST	.90 /GAL		226,547 /MONTH
MAINTENANCE AND INSURANCE COST			45,000 /MONTH
LABOR COST			62,900 /MONTH
TOTAL DIRECT MONTHLY COST			881,447 /MONTH
25% OVERHEAD & PROFIT			220,362 /MONTH
TOTAL MONTHLY COST			1,101,809
TOTAL DAILY COST			36,727
DREDGING COSTS			315,852
MOBILIZATION/DEMOBILIZATION			
4	DAYS @ 20,000		80,000
TOTAL JOB COST			395,852
UNIT COST/CY			5.28
E&D / S&A	9 %		.48
CONTINGENCIES	@ 20%		1.15
TOTAL UNIT COST			6.90

```
COST ESTIMATE        2C100          BUCKET DREDGE

PLANT:              18 CY BUCKET DREDGE
CHANNEL SEGMENT:  NORFOLK HARBOR
DISPOSAL AREA:       DAM NECK
HAUL DISTANCE (MILES):          37
QUANTITY     PAY:     100,000  CY   GROSS:          125,000 CY
BUCKET TYPE DREDGE CAPACITY:                              18 CY
                                                LOAD FACTOR  =  .90
CYCLE TIME   (MINUTES):                                 1.2 MIN.
CYCLES/HR                                                50 EA
CY/HR                                                   810 CY/HR
EFFICIENCY FACTOR     (24HRS X        65    %)          16 HRS/DAY
CY/DAY                                               12,960 CY

NUMBER SCOWS PER TOW                                      2 EA
HAUL         37     MILES @    3.00   MPH             12.33 HRS
LOAD & DUMP                                               8 HRS
RETURN       37     MILES @    3.50   MPH             10.57 HRS
TOTAL CYCLE TIME (SCOWS)                                30.90 HRS
   20   WORK HOURS/DAY /    CYCLE TIME                   .65 LOADS/DAY
    2   3000 CY SCOWS @      2,850 CY/LOAD=            5,700 CY/TRIP
SCOWS
 5,700   CY/TRIP X          .65 LOADS/DAY               3,689 CY/DAY
SCOWS REQ                                                 4 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.                 9.6 DAYS

LOST TIME       20%                                       1.9 DAYS
TOTAL TIME (EFFECTIVE + LOST)                            11.5 DAYS

PLANT COST                                             547,000 /MONTH
FUEL COST                  .90 /GAL                    226,547 /MONTH
MAINTENANCE AND INSURANCE COST                          45,000 /MONTH
LABOR COST                                              62,900 /MONTH
TOTAL DIRECT MONTHLY COST                              881,447 /MONTH
     25% OVERHEAD & PROFIT                             220,362 /MONTH

TOTAL MONTHLY COST                                   1,101,809
TOTAL DAILY COST                                        36,727

DREDGING COSTS                                         422,360
MOBILIZATION/DEMOBILIZATION
                        4     DAYS @ 20,000             80,000
TOTAL JOB COST                                         502,360

UNIT COST/CY                                              5.02

E&D / S&A        9     %                                  .45

CONTINGENCIES   @          20%                            1.10

TOTAL UNIT COST                                           6.57
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COST ESTIMATE 2C250 BUCKET DREDGE

PLANT:	18 CY BUCKET DREDGE		
CHANNEL SEGMENT:	NORFOLK HARBOR		
DISPOSAL AREA:	DAM NECK		
HAUL DISTANCE (MILES):	37		
QUANTITY PAY:	250,000 CY	GROSS:	312,500 CY
BUCKET TYPE DREDGE CAPACITY:			18 CY
		LOAD FACTOR =	.90
CYCLE TIME (MINUTES):			1.2 MIN.
CYCLES/HR			50 EA
CY/HR			810 CY/HR
EFFICIENCY FACTOR	(24HRS X	65 %)	16 HRS/DAY
CY/DAY			12,960 CY
NUMBER SCOWS PER TOW			2 EA
HAUL	37 MILES @	3.00 MPH	12.33 HRS
LOAD & DUMP			8 HRS
RETURN	37 MILES @	3.50 MPH	10.57 HRS
TOTAL CYCLE TIME (SCOWS)			30.90 HRS
20	WORK HOURS/DAY /	CYCLE TIME	.65 LOADS/DAY
2	3000 CY SCOWS @	2,850 CY/LOAD=	5,700 CY/TRIP
SCOWS			
5,700	CY/TRIP X	.65 LOADS/DAY	3,689 CY/DAY
SCOWS REQ			4 SETS
TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.			24.1 DAYS
LOST TIME	20%		4.8 DAYS
TOTAL TIME (EFFECTIVE + LOST)			28.9 DAYS
PLANT COST			547,000 /MONTH
FUEL COST		.90 /GAL	226,547 /MONTH
MAINTENANCE AND INSURANCE COST			45,000 /MONTH
LABOR COST			62,900 /MONTH
TOTAL DIRECT MONTHLY COST			881,447 /MONTH
25% OVERHEAD & PROFIT			220,362 /MONTH
TOTAL MONTHLY COST			1,101,809
TOTAL DAILY COST			36,727
DREDGING COSTS			1,061,409
MOBILIZATION/DEMOBILIZATION			
6	DAYS @ 25,000		150,000
TOTAL JOB COST			1,211,409
UNIT COST/CY			4.85
E&D / S&A	9 %		.44
CONTINGENCIES	@ 20%		1.06
TOTAL UNIT COST			6.34

COST ESTIMATE 2C500 BUCKET DREDGE

PLANT: 18 CY BUCKET DREDGE
CHANNEL SEGMENT: NORFOLK HARBOR
DISPOSAL AREA: DAM NECK
HAUL DISTANCE (MILES): 37
QUANTITY PAY: 500,000 CY GROSS: 625,000 CY
BUCKET TYPE DREDGE CAPACITY: 18 CY
LOAD FACTOR = .90
CYCLE TIME (MINUTES): 1.2 MIN.
CYCLES/HR 50 EA

CY/HR 810 CY/HR
EFFICIENCY FACTOR (24HRS X 65 %) 16 HRS/DAY
CY/DAY 12,960 CY

NUMBER SCOWS PER TOW 2 EA
HAUL 37 MILES @ 3.00 MPH 12.33 HRS
LOAD & DUMP 8 HRS
RETURN 37 MILES @ 3.50 MPH 10.57 HRS
TOTAL CYCLE TIME (SCOWS) 30.90 HRS
20 WORK HOURS/DAY / CYCLE TIME .65 LOADS/DAY
2 3000 CY SCOWS @ 2,850 CY/LOAD= 5,700 CY/TRIP
SCOWS
5,700 CY/TRIP X .65 LOADS/DAY 3,689 CY/DAY
SCOWS REQ 4 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD. 48.2 DAYS

LOST TIME 20% 9.6 DAYS
TOTAL TIME (EFFECTIVE + LOST) 57.8 DAYS

PLANT COST 547,000 /MONTH
FUEL COST .90 /GAL 226,547 /MONTH
MAINTENANCE AND INSURANCE COST 45,000 /MONTH
LABOR COST 62,900 /MONTH
TOTAL DIRECT MONTHLY COST 881,447 /MONTH
25% OVERHEAD & PROFIT 220,362 /MONTH
TOTAL MONTHLY COST 1,101,809
TOTAL DAILY COST 36,727

DREDGING COSTS 2,122,819
MOBILIZATION/DEMOBILIZATION
10 DAYS @ 25,000 250,000
TOTAL JOB COST 2,372,819

UNIT COST/CY 4.75

E&D / S&A 9 % .43

CONTINGENCIES @ 20% 1.03

TOTAL UNIT COST 6.21

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COST ESTIMATE        2C1000        BUCKET DREDGE

PLANT:              18 CY BUCKET DREDGE
CHANNEL SEGMENT:  NORFOLK HARBOR
DISPOSAL AREA:       DAM NECK
HAUL DISTANCE (MILES):          37
QUANTITY     PAY:   1,000,000  CY   GROSS:      1,250,000 CY
BUCKET TYPE DREDGE CAPACITY:                           18 CY
                                            LOAD FACTOR  =  .90
CYCLE TIME   (MINUTES):                               1.2 MIN.
CYCLES/HR                                              50 EA
CY/HR                                                 810 CY/HR
EFFICIENCY FACTOR     (24HRS X        70    %)        17 HRS/DAY
CY/DAY                                             13,770 CY

NUMBER SCOWS PER TOW                                    2 EA
HAUL          37     MILES @    3.00   MPH          12.33 HRS
LOAD & DUMP                                             8 HRS
RETURN        37     MILES @    3.50   MPH          10.57 HRS
TOTAL CYCLE TIME (SCOWS)                            30.90 HRS
    20   WORK HOURS/DAY /    CYCLE TIME               .65 LOADS/DAY
    2    3000 CY SCOWS @      2,850 CY/LOAD=        5,700 CY/TRIP
SCOWS
 5,700   CY/TRIP X        .65 LOADS/DAY             3,689 CY/DAY
SCOWS REQ                                               4 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.              90.8 DAYS

LOST TIME       19%                                    17.3 DAYS
TOTAL TIME (EFFECTIVE + LOST)                         108.1 DAYS

PLANT COST                                          547,000 /MONTH
FUEL COST                .90 /GAL                   226,547 /MONTH
MAINTENANCE AND INSURANCE COST                       45,000 /MONTH
LABOR COST                                           62,900 /MONTH
TOTAL DIRECT MONTHLY COST                           881,447 /MONTH
    24% OVERHEAD & PROFIT                           211,547 /MONTH
TOTAL MONTHLY COST                                1,092,994
TOTAL DAILY COST                                     36,433

DREDGING COSTS                                    3,938,422
MOBILIZATION/DEMOBILIZATION
                        10    DAYS @ 25,000         250,000
TOTAL JOB COST                                    4,188,422

UNIT COST/CY                                           4.19

E&D / S&A        9     %                               .38


CONTINGENCIES   @          20%                         .91

TOTAL UNIT COST                                        5.48
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COST ESTIMATE 2C3000 BUCKET DREDGE

PLANT: 18 CY BUCKET DREDGE
CHANNEL SEGMENT: NORFOLK HARBOR
DISPOSAL AREA: DAM NECK
HAUL DISTANCE (MILES): 37
QUANTITY PAY: 3,000,000 CY GROSS: 3,750,000 CY
BUCKET TYPE DREDGE CAPACITY: 18 CY
LOAD FACTOR = .90
CYCLE TIME (MINUTES): 1.2 MIN.
CYCLES/HR 50 EA
CY/HR 810 CY/HR
EFFICIENCY FACTOR (24HRS X 70 %) 17 HRS/DAY
CY/DAY 13,770 CY

NUMBER SCOWS PER TOW 2 EA
HAUL 37 MILES @ 3.00 MPH 12.33 HRS
LOAD & DUMP 8 HRS
RETURN 37 MILES @ 3.50 MPH 10.57 HRS
TOTAL CYCLE TIME (SCOWS) 30.90 HRS
20 WORK HOURS/DAY / CYCLE TIME .65 LOADS/DAY
2 3000 CY SCOWS @ 2,850 CY/LOAD= 5,700 CY/TRIP
SCOWS
5,700 CY/TRIP X .65 LOADS/DAY 3,689 CY/DAY
SCOWS REQ 4 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD. 272.3 DAYS

LOST TIME 18% 49 DAYS
TOTAL TIME (EFFECTIVE + LOST) 321.3 DAYS

PLANT COST 547,000 /MONTH
FUEL COST .90 /GAL 226,547 /MONTH
MAINTENANCE AND INSURANCE COST 45,000 /MONTH
LABOR COST 62,900 /MONTH
TOTAL DIRECT MONTHLY COST 881,447 /MONTH
22% OVERHEAD & PROFIT 193,918 /MONTH

TOTAL MONTHLY COST 1,075,365
TOTAL DAILY COST 35,846

DREDGING COSTS 11,517,160
MOBILIZATION/DEMOBILIZATION
10 DAYS @ 25,000 250,000
TOTAL JOB COST 11,767,160

UNIT COST/CY 3.92

E&D / S&A 9 % .35

CONTINGENCIES @ 20% .86

TOTAL UNIT COST 5.13

COST ESTIMATE 2D5 BUCKET DREDGE

PLANT: 10 CY BUCKET DREDGE
CHANNEL SEGMENT: NORFOLK HARBOR
DISPOSAL AREA: NORFOLK
HAUL DISTANCE (MILES): 45
QUANTITY PAY: 5,000 CY GROSS: 6,750 CY
BUCKET TYPE DREDGE CAPACITY: 10 CY
LOAD FACTOR = .90
CYCLE TIME (MINUTES): 1 MIN.
CYCLES/HR 60 EA
CY/HR 540 CY/HR
EFFICIENCY FACTOR (24HRS X 65 %) 16 HRS/DAY
CY/DAY 8,640 CY

NUMBER SCOWS PER TOW 2 EA
HAUL 45 MILES @ 3.00 MPH 15.00 HRS
LOAD & DUMP 12 HRS
RETURN 45 MILES @ 3.50 MPH 12.86 HRS
TOTAL CYCLE TIME (SCOWS) 39.86 HRS
20 WORK HOURS/DAY / CYCLE TIME .50 LOADS/DAY
2 3000 CY SCOWS @ 2,850 CY/LOAD= 5,700 CY/TRIP
SCOWS
5,700 CY/TRIP X .50 LOADS/DAY 2,860 CY/DAY
SCOWS REQ 3 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD. .8 DAYS

LOST TIME 23% .3 DAYS
TOTAL TIME (EFFECTIVE + LOST) 1.1 DAYS

PLANT COST 416,850 /MONTH
FUEL COST .90 /GAL 174,708 /MONTH
MAINTENANCE AND INSURANCE COST 39,150 /MONTH
LABOR COST 62,900 /MONTH
TOTAL DIRECT MONTHLY COST 693,608 /MONTH
27% OVERHEAD & PROFIT 187,274 /MONTH
TOTAL MONTHLY COST 880,882
TOTAL DAILY COST 29,363

DREDGING COSTS 32,299
MOBILIZATION/DEMOBILIZATION
2 DAYS @ 4,000 8,000
TOTAL JOB COST 40,299

UNIT COST/CY 8.06

E&D / S&A 9 % .73

CONTINGENCIES @ 20% 1.76

TOTAL UNIT COST 10.54

COST ESTIMATE 2D10 BUCKET DREDGE

PLANT:	10 CY BUCKET DREDGE		
CHANNEL SEGMENT:	NORFOLK HARBOR		
DISPOSAL AREA:	NORFOLK		
HAUL DISTANCE (MILES):	45		
QUANTITY PAY:	10,000 CY	GROSS:	13,500 CY
BUCKET TYPE DREDGE CAPACITY:			10 CY
		LOAD FACTOR	= .90
CYCLE TIME (MINUTES):			1 MIN.
CYCLES/HR			60 EA
CY/HR			540 CY/HR
EFFICIENCY FACTOR	(24HRS X	65 %)	16 HRS/DAY
CY/DAY			8,640 CY

NUMBER SCOWS PER TOW					2 EA
HAUL	45	MILES @	3.00	MPH	15.00 HRS
LOAD & DUMP					12 HRS
RETURN	45	MILES @	3.50	MPH	12.86 HRS
TOTAL CYCLE TIME (SCOWS)					39.86 HRS
20	WORK HOURS/DAY /		CYCLE TIME		.50 LOADS/DAY
2	3000 CY SCOWS @		2,850 CY/LOAD=		5,700 CY/TRIP
SCOWS					
5,700	CY/TRIP X	.50 LOADS/DAY			2,860 CY/DAY
SCOWS REQ					3 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.	1.6 DAYS
LOST TIME 22%	.5 DAYS
TOTAL TIME (EFFECTIVE + LOST)	2.1 DAYS
PLANT COST	416,850 /MONTH
FUEL COST .90 /GAL	174,708 /MONTH
MAINTENANCE AND INSURANCE COST	39,150 /MONTH
LABOR COST	62,900 /MONTH
TOTAL DIRECT MONTHLY COST	693,608 /MONTH
26% OVERHEAD & PROFIT	180,338 /MONTH
TOTAL MONTHLY COST	873,946
TOTAL DAILY COST	29,132
DREDGING COSTS	61,176
MOBILIZATION/DEMOBILIZATION 2 DAYS @ 5,000	10,000
TOTAL JOB COST	71,176
UNIT COST/CY	7.12
E&D / S&A 9 %	.64
CONTINGENCIES @ 20%	1.55
TOTAL UNIT COST	9.31

COST ESTIMATE 2D20 BUCKET DREDGE

PLANT:	10 CY BUCKET DREDGE				
CHANNEL SEGMENT:	NORFOLK HARBOR				
DISPOSAL AREA:	NORFOLK				
HAUL DISTANCE (MILES):		45			
QUANTITY PAY:	20,000 CY	GROSS:		26,000	CY
BUCKET TYPE DREDGE CAPACITY:				10	CY
			LOAD FACTOR	=	.90
CYCLE TIME (MINUTES):				1	MIN.
CYCLES/HR				60	EA
CY/HR				540	CY/HR
EFFICIENCY FACTOR	(24HRS X	65	%)	16	HRS/DAY
CY/DAY				8,640	CY
NUMBER SCOWS PER TOW				2	EA
HAUL	45 MILES @	3.00	MPH	15.00	HRS
LOAD & DUMP				12	HRS
RETURN	45 MILES @	3.50	MPH	12.86	HRS
TOTAL CYCLE TIME (SCOWS)				39.86	HRS
20	WORK HOURS/DAY /	CYCLE TIME		.50	LOADS/DAY
2	3000 CY SCOWS @	2,850 CY/LOAD=		5,700	CY/TRIP
SCOWS					
5,700	CY/TRIP X	.50 LOADS/DAY		2,860	CY/DAY
SCOWS REQ				3	SETS
TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.				3	DAYS
LOST TIME	21%			.8	DAYS
TOTAL TIME (EFFECTIVE + LOST)				3.8	DAYS
PLANT COST				416,850	/MONTH
FUEL COST		.90 /GAL		174,708	/MONTH
MAINTENANCE AND INSURANCE COST				39,150	/MONTH
LABOR COST				62,900	/MONTH
TOTAL DIRECT MONTHLY COST				693,608	/MONTH
26% OVERHEAD & PROFIT				180,338	/MONTH
TOTAL MONTHLY COST				873,946	
TOTAL DAILY COST				29,132	
DREDGING COSTS				110,700	
MOBILIZATION/DEMOBILIZATION					
2	DAYS @	7,500		15,000	
TOTAL JOB COST				125,700	
UNIT COST/CY				6.28	
E&D / S&A	9 %			.57	
CONTINGENCIES	@	20%		1.37	
TOTAL UNIT COST				8.22	

COST ESTIMATE 2D50 BUCKET DREDGE

PLANT: 10 CY BUCKET DREDGE
CHANNEL SEGMENT: NORFOLK HARBOR
DISPOSAL AREA: NORFOLK
HAUL DISTANCE (MILES): 45
QUANTITY PAY: 50,000 CY GROSS: 65,000 CY
BUCKET TYPE DREDGE CAPACITY: 10 CY
LOAD FACTOR = .90
CYCLE TIME (MINUTES): 1 MIN.
CYCLES/HR 60 EA
CY/HR 540 CY/HR

EFFICIENCY FACTOR (24HRS X 65 %) 16 HRS/DAY
CY/DAY 8,640 CY

NUMBER SCOWS PER TOW 2 EA
HAUL 45 MILES @ 3.00 MPH 15.00 HRS
LOAD & DUMP 12 HRS
RETURN 45 MILES @ 3.50 MPH 12.86 HRS
TOTAL CYCLE TIME (SCOWS) 39.86 HRS
20 WORK HOURS/DAY / CYCLE TIME .50 LOADS/DAY
2 3000 CY SCOWS @ 2,850 CY/LOAD= 5,700 CY/TRIP
SCOWS
5,700 CY/TRIP X .50 LOADS/DAY 2,860 CY/DAY
SCOWS REQ 3 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD. 7.6 DAYS

LOST TIME 21% 1.8 DAYS
TOTAL TIME (EFFECTIVE + LOST) 9.4 DAYS

PLANT COST 416,850 /MONTH
FUEL COST .90 /GAL 174,708 /MONTH
MAINTENANCE AND INSURANCE COST 39,150 /MONTH
LABOR COST 62,900 /MONTH
TOTAL DIRECT MONTHLY COST 693,608 /MONTH
26% OVERHEAD & PROFIT 180,338 /MONTH
TOTAL MONTHLY COST 873,946
TOTAL DAILY COST 29,132

DREDGING COSTS 273,836
MOBILIZATION/DEMOBILIZATION
3 DAYS @ 10,000 30,000
TOTAL JOB COST 303,836

UNIT COST/CY 6.08

E&D / S&A 9 % .55

CONTINGENCIES @ 20% 1.32

TOTAL UNIT COST 7.95

COST ESTIMATE 2D75 BUCKET DREDGE

PLANT:	18 CY BUCKET DREDGE		
CHANNEL SEGMENT:	NORFOLK HARBOR		
DISPOSAL AREA:	NORFOLK		
HAUL DISTANCE (MILES):	45		
QUANTITY PAY:	75,000 CY	GROSS:	93,750 CY
BUCKET TYPE DREDGE CAPACITY:			18 CY
		LOAD FACTOR =	.90
CYCLE TIME (MINUTES):			1.2 MIN.
CYCLES/HR			50 EA
CY/HR			810 CY/HR
EFFICIENCY FACTOR	(24HRS X	65 %)	16 HRS/DAY
CY/DAY			12,960 CY

NUMBER SCOWS PER TOW					2 EA
HAUL	45	MILES @	3.00	MPH	15.00 HRS
LOAD & DUMP					8 HRS
RETURN	45	MILES @	3.50	MPH	12.86 HRS
TOTAL CYCLE TIME (SCOWS)					35.86 HRS
20	WORK HOURS/DAY /		CYCLE TIME		.56 LOADS/DAY
2	3000 CY SCOWS @		2,850 CY/LOAD=		5,700 CY/TRIP
SCOWS					
5,700	CY/TRIP X	.56 LOADS/DAY			3,179 CY/DAY
SCOWS REQ					4 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.			7.4 DAYS
LOST TIME	20%		1.5 DAYS
TOTAL TIME (EFFECTIVE + LOST)			8.9 DAYS
PLANT COST			547,000 /MONTH
FUEL COST		.90 /GAL	226,547 /MONTH
MAINTENANCE AND INSURANCE COST			45,000 /MONTH
LABOR COST			62,900 /MONTH
TOTAL DIRECT MONTHLY COST			881,447 /MONTH
25% OVERHEAD & PROFIT			220,362 /MONTH
TOTAL MONTHLY COST			1,101,809
TOTAL DAILY COST			36,727
DREDGING COSTS			326,870
MOBILIZATION/DEMOBILIZATION			
	4	DAYS @ 20,000	80,000
TOTAL JOB COST			406,870
UNIT COST/CY			5.42
E&D / S&A	9	%	.49
CONTINGENCIES	@	20%	1.18
TOTAL UNIT COST			7.10

COST ESTIMATE 2D100 BUCKET DREDGE

PLANT:	18 CY BUCKET DREDGE		
CHANNEL SEGMENT:	NORFOLK HARBOR		
DISPOSAL AREA:	NORFOLK		
HAUL DISTANCE (MILES):	45		
QUANTITY BAY:	100,000 CY	GROSS:	125,000 CY
BUCKET TYPE DREDGE CAPACITY:			18 CY
		LOAD FACTOR =	.90
CYCLE TIME (MINUTES):			1.2 MIN.
CYCLES/HR			50 EA
CY/HR			810 CY/HR
EFFICIENCY FACTOR	(24HRS X	65 %)	16 HRS/DAY
CY/DAY			12,960 CY

NUMBER SCOWS PER TOW					2 EA
HAUL	45	MILES @	3.00	MPH	15.00 HRS
LOAD & DUMP					8 HRS
RETURN	45	MILES @	3.50	MPH	12.86 HRS
TOTAL CYCLE TIME (SCOWS)					35.86 HRS
20	WORK HOURS/DAY /		CYCLE TIME		.56 LOADS/DAY
2	3000 CY SCOWS @		2,850 CY/LOAD=		5,700 CY/TRIP
SCOWS					
5,700	CY/TRIP X	.56 LOADS/DAY			3,179 CY/DAY
SCOWS REQ					4 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.	9.8 DAYS
LOST TIME 20%	2 DAYS
TOTAL TIME (EFFECTIVE + LOST)	11.8 DAYS

PLANT COST		547,000 /MONTH
FUEL COST	.90 /GAL	226,547 /MONTH
MAINTENANCE AND INSURANCE COST		45,000 /MONTH
LABOR COST		62,900 /MONTH
TOTAL DIRECT MONTHLY COST		881,447 /MONTH
25% OVERHEAD & PROFIT		220,362 /MONTH
TOTAL MONTHLY COST		1,101,809
TOTAL DAILY COST		36,727
DREDGING COSTS		433,378
MOBILIZATION/DEMOBILIZATION		
4	DAYS @ 20,000	80,000
TOTAL JOB COST		513,378
UNIT COST/CY		5.13
E&D / S&A 9 %		.46
CONTINGENCIES @	20%	1.12
TOTAL UNIT COST		6.71

COST ESTIMATE 2D250 BUCKET DREDGE

PLANT:	18 CY BUCKET DREDGE		
CHANNEL SEGMENT:	NORFOLK HARBOR		
DISPOSAL AREA:	NORFOLK		
HAUL DISTANCE (MILES):	45		
QUANTITY PAY:	250,000 CY	GROSS:	312,500 CY
BUCKET TYPE DREDGE CAPACITY:			18 CY
		LOAD FACTOR =	.90
CYCLE TIME (MINUTES):			1.2 MIN.
CYCLES/HR			50 EA
CY/HR			810 CY/HR
EFFICIENCY FACTOR	(24HRS X	65 %)	16 HRS/DAY
CY/DAY			12,960 CY
NUMBER SCOWS PER TOW			2 EA
HAUL	45 MILES @	3.00 MPH	15.00 HRS
LOAD & DUMP			8 HRS
RETURN	45 MILES @	3.50 MPH	12.86 HRS
TOTAL CYCLE TIME (SCOWS)			35.86 HRS
20	WORK HOURS/DAY /	CYCLE TIME	.56 LOADS/DAY
2	3000 CY SCOWS @	2,850 CY/LOAD=	5,700 CY/TRIP
SCOWS			
5,700	CY/TRIP X	.56 LOADS/DAY	3,179 CY/DAY
SCOWS REQ			4 SETS
TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.			24.6 DAYS
LOST TIME	20%		4.9 DAYS
TOTAL TIME (EFFECTIVE + LOST)			29.5 DAYS
PLANT COST			547,000 /MONTH
FUEL COST		.90 /GAL	226,547 /MONTH
MAINTENANCE AND INSURANCE COST			45,000 /MONTH
LABOR COST			62,900 /MONTH
TOTAL DIRECT MONTHLY COST			881,447 /MONTH
25% OVERHEAD & PROFIT			220,362 /MONTH
TOTAL MONTHLY COST			1,101,809
TOTAL DAILY COST			36,727
DREDGING COSTS			1,083,446
MOBILIZATION/DEMOBILIZATION			
	6	DAYS @ 25,000	150,000
TOTAL JOB COST			1,233,446
UNIT COST/CY			4.93
E&D / S&A	9 %		.44
CONTINGENCIES	@	20%	1.08
TOTAL UNIT COST			6.45

COST ESTIMATE 2D500 BUCKET DREDGE

PLANT:	18 CY BUCKET DREDGE		
CHANNEL SEGMENT:	NORFOLK HARBOR		
DISPOSAL AREA:	NORFOLK		
HAUL DISTANCE (MILES):	45		
QUANTITY PAY:	500,000 CY	GROSS:	625,000 CY
BUCKET TYPE DREDGE CAPACITY:			18 CY
		LOAD FACTOR =	.90
CYCLE TIME (MINUTES):			1.2 MIN.
CYCLES/HR			50 EA
CY/HR			810 CY/HR
EFFICIENCY FACTOR	(24HRS X	65 %)	16 HRS/DAY
CY/DAY			12,960 CY
NUMBER SCOWS PER TOW			2 EA
HAUL	45 MILES @	3.00 MPH	15.00 HRS
LOAD & DUMP			8 HRS
RETURN	45 MILES @	3.50 MPH	12.86 HRS
TOTAL CYCLE TIME (SCOWS)			35.86 HRS
20	WORK HOURS/DAY /	CYCLE TIME	.56 LOADS/DAY
2	3000 CY SCOWS @	2,850 CY/LOAD=	5,700 CY/TRIP
SCOWS			
5,700	CY/TRIP X	.56 LOADS/DAY	3,179 CY/DAY
SCOWS REQ			4 SETS
TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.			49.1 DAYS
LOST TIME	20%		9.8 DAYS
TOTAL TIME (EFFECTIVE + LOST)			58.9 DAYS
PLANT COST			547,000 /MONTH
FUEL COST		.90 /GAL	226,547 /MONTH
MAINTENANCE AND INSURANCE COST			45,000 /MONTH
LABOR COST			62,900 /MONTH
TOTAL DIRECT MONTHLY COST			881,447 /MONTH
25% OVERHEAD & PROFIT			220,362 /MONTH
TOTAL MONTHLY COST			1,101,809
TOTAL DAILY COST			36,727
DREDGING COSTS			2,163,219
MOBILIZATION/DEMOBILIZATION	10	DAYS @ 25,000	250,000
TOTAL JOB COST			2,413,219
UNIT COST/CY			4.83
E&D / S&A	9 %		.43
CONTINGENCIES @		20%	1.05
TOTAL UNIT COST			6.31

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.
COST ESTIMATE        2D1000        BUCKET DREDGE

PLANT:              18 CY BUCKET DREDGE
CHANNEL SEGMENT:    NORFOLK HARBOR
DISPOSAL AREA:      NORFOLK
HAUL DISTANCE (MILES):          45
QUANTITY     PAY:   1,000,000  CY   GROSS:     1,250,000 CY
BUCKET TYPE DREDGE CAPACITY:                          18 CY
                                          LOAD FACTOR  =  .90
CYCLE TIME   (MINUTES):                            1.2 MIN.
CYCLES/HR                                           50 EA
CY/HR                                              810 CY/HR
EFFICIENCY FACTOR     (24HRS X        70    %)     17 HRS/DAY
CY/DAY                                          13,770 CY

NUMBER SCOWS PER TOW                                 2 EA
HAUL         45     MILES @    3.00   MPH       15.00 HRS
LOAD & DUMP                                          8 HRS
RETURN       45     MILES @    3.50   MPH       12.86 HRS
TOTAL CYCLE TIME (SCOWS)                         35.86 HRS
    20   WORK HOURS/DAY /    CYCLE TIME            .56 LOADS/DAY
    2    3000 CY SCOWS @      2,850 CY/LOAD=     5,700 CY/TRIP
SCOWS
 5,700   CY/TRIP X        .56 LOADS/DAY         3,179 CY/DAY
SCOWS REQ                                            4 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.         98.3 DAYS

LOST TIME        19%                              18.7 DAYS
TOTAL TIME (EFFECTIVE + LOST)                      117 DAYS

PLANT COST                                       547,000 /MONTH
FUEL COST                .90 /GAL                226,547 /MONTH
MAINTENANCE AND INSURANCE COST                    45,000 /MONTH
LABOR COST                                        62,900 /MONTH
TOTAL DIRECT MONTHLY COST                        881,447 /MONTH
      24% OVERHEAD & PROFIT                      211,547 /MONTH
TOTAL MONTHLY COST                             1,092,994
TOTAL DAILY COST                                  36,433

DREDGING COSTS                                 4,262,677
MOBILIZATION/DEMOBILIZATION
                        10    DAYS @ 25,000      250,000
TOTAL JOB COST                                 4,512,677

UNIT COST/CY                                        4.51

E&D / S&A        9     %                            .41


CONTINGENCIES    @          20%                     .98

TOTAL UNIT COST                                     5.90
```

COST ESTIMATE 2D3000 BUCKET DREDGE

PLANT: 18 CY BUCKET DREDGE
CHANNEL SEGMENT: NORFOLK HARBOR
DISPOSAL AREA: NORFOLK
HAUL DISTANCE (MILES): 45
QUANTITY PAY: 3,000,000 CY GROSS: 3,750,000 CY
BUCKET TYPE DREDGE CAPACITY: 18 CY
LOAD FACTOR = .90
CYCLE TIME (MINUTES): 1.2 MIN.
CYCLES/HR 50 EA
CY/HR 810 CY/HR
EFFICIENCY FACTOR (24HRS X 70 %) 17 HRS/DAY
CY/DAY 13,770 CY

NUMBER SCOWS PER TOW 2 EA
HAUL 45 MILES @ 3.00 MPH 15.00 HRS
LOAD & DUMP 8 HRS
RETURN 45 MILES @ 3.50 MPH 12.86 HRS
TOTAL CYCLE TIME (SCOWS) 35.86 HRS
20 WORK HOURS/DAY / CYCLE TIME .56 LOADS/DAY
2 3000 CY SCOWS @ 2,850 CY/LOAD= 5,700 CY/TRIP
SCOWS
5,700 CY/TRIP X .56 LOADS/DAY 3,179 CY/DAY
SCOWS REQ 4 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD. 294.9 DAYS

LOST TIME 18% 53.1 DAYS
TOTAL TIME (EFFECTIVE + LOST) 348 DAYS

PLANT COST 547,000 /MONTH
FUEL COST .90 /GAL 226,547 /MONTH
MAINTENANCE AND INSURANCE COST 45,000 /MONTH
LABOR COST 62,900 /MONTH
TOTAL DIRECT MONTHLY COST 881,447 /MONTH
22% OVERHEAD & PROFIT 193,918 /MONTH

TOTAL MONTHLY COST 1,075,365
TOTAL DAILY COST 35,846

DREDGING COSTS 12,474,235
MOBILIZATION/DEMOBILIZATION
10 DAYS @ 25,000 250,000
TOTAL JOB COST 12,724,235

UNIT COST/CY 4.24

E&D / S&A 9 % .38

CONTINGENCIES @ 20% .92

TOTAL UNIT COST 5.55

ATTACHMENT 5

EMPTYING CRANEY ISLAND

Prepared by:

Rich and Associates

8 February 1989

TABLE OF CONTENTS

DISCUSSION 1

LAND DISPOSAL..... 2-3

OCEAN DISPOSAL..... 4-5

RECOMMENDATIONS..... 6

ALTERNATIVES EVALUATED..... 7

SUMMARY OF COSTS..... 8

OCEAN HAUL TO DAM NECK OCEAN DISPOSAL AREA..... 9

OCEAN HAUL TO NORFOLK OCEAN DISPOSAL AREA 10

SCOW LOADING FACILITY..... 11

MOBILIZATION/DEMOBILIZATION.....12-13

SCHEME 1, OPTION A..... 14

SCHEME 1, OPTION B..... 15

SCHEME 1, OPTION C..... 16

SCHEME 1, OPTION D..... 17

SCHEME 1, OPTION E..... 18

SCHEME 2, OPTION A..... 19

SCHEME 2, OPTION B..... 20

SCHEME 3, OPTION A.....21-25

SCHEME 4, OPTION A..... 26

SCHEME 4, OPTION B..... 27

SCHEME 1, OPTION B TWO SHIFTS..... 28

APPENDIX A.....29-30

CRANEY ISLAND

The purpose of this report is to evaluate possible options of extending the life of Craney Island. Several options were discussed, those considered highly unfeasible and those covered by other studies have not been priced.

Three major options appear available; expansion, compaction of existing material and removal of existing material. Expansion both latterly and vertically are being considered by other studies . Compaction is currently taking place by natural occurences aided by the current management plan.

Emptying is considered under this study. Both land and ocean disposal were investigated.

Some of the material is suitable for use as fills for construction projects. In the Tidewater area several borrow pits are currently operating and are capable of handling the immediate needs. With the expansion of this area the demand for borrow material will increase. Establishment of new pits will be severely limited by environmental and social concerns. It is likely that any new pits established will be located well outside the currently built up area. Increased hauling cost will make some of the existing marginal materials increasingly attractive from a cost standpoint. Use of these new pits will significantly increase hauling costs. Some of the existing material in Craney Island is currently suitable for borrow, some is marginal but becomes suitable using special compaction techniques. For nonstructural fills, these marginal materials are currently suitable. When hauling costs increase to where they exceed special compaction costs, then these marginal materials become cost effective. Use of material from Craney Island as commercial borrow was discussed with four local contractors. All were in agreement that existing borrow pits are limited in life and the establishment of new pits will be at sites well distant from the local built up area.

Segregation of material suitable for use as borrow could result in slightly increased dredging costs. These increased costs should be more than offset by sale of usable material and increase in the life

of the disposal area.

Establishing a portion of Craney Island Disposal Area as a commercial borrow pit is an option that should be investigated. The terms should be such that the material is conveniently available to contractors. Rate of removal must also be acceptable to the government.

It is understood that only a small percent of the existing material in Craney Island is suitable and would not have a material effect on the storage requirement. Also, any new work to be dredged to attain a 55-foot depth in the Newport News Channel and very little of that to be dredged in the Norfolk Harbor Channel is suitable. Also practically all material resulting from channel maintenance operations is basically silt and clay. It is understood that any plan developed for the disposal of dredged material will take into account the future beneficial uses of the material disposed in Craney Island as the opportunitites present themselves and where feasible.

OCEAN DISPOSAL

Several alternative methods of ocean disposal have been evaluated. Disposal in both the Dam Neck Ocean Disposal area and the Norfolk Ocean Disposal area have been priced. Options within these disposal sites evaluate varying methods of transporting material to scows. Material must have dried to such an extent that land equipment can operate. Scows can be loaded hydraulically, however, this greatly reduces the effective yardage removed per load resulting in increased costs. The more sandy materials become more efficient to move by this method. No costs were developed for this approach.

Contract costs for each option are divided into four parts.

1. Costs for loading and hauling material to scows including loading on scows.
2. Costs to haul material to ocean disposal sites.
3. Mobilization and demobilization costs.
4. Costs to construct a mooring facility for scows distributed over a 10 year production.

To each of these total contract costs, E&D/S&A of 9% and Contingencies of 20% have been included.

Options 1, 2, and 4 are limited to materials dry enough so that land equipment can be operated. Current estimates are that this is approximately 20% of the total volume.

Option 3, Bucket Dredging, an remove any type of material; however, the risk of breaching the levee is encountered. Costs for a bulkhead on each side of the breach is included in the unit cost shown. These costs are based upon steel sheet piling extending down to an elevation of -120'. Staggered tie backs at 5' OC, 250' and 300' back from the bulkhead are included. No design calculations have been made. Existing material is highly unstable to depths of 110 feet. If this option is given consideration, a more detailed study should be made.

The schemes considered are presented in the following tabulation. Schemes 1, 2, and 3 do not create noise that would disturb adjacent residential neighborhoods. Schemes 1 and 2 could be expanded to a two shift operation with a little variation in unit cost. Inefficiencies in a night shift and lighting costs are offset by lower scow loading facility cost. Scheme 3 considers an effective 20 hour day operation. Scheme 4 requires an acceptable disposal site and also requires truck traffic thru existing residential neighborhoods. The use of a two shift operation is unlikely.

Recommendations:

Removal of material by all methods evaluated is expensive considering that these are costs added to the original dredging costs. From a cost standpoint several options appear to deserve consideration.

1. Direct ocean disposal of large volumes of material. This may be confined to material unsuitable for borrow.

2. Removal of material from Craney Island by mechanical means to an ocean disposal site.

3. Use as borrow of the more suitable materials.

CRANEY ISLAND
ALTERNATIVES EVALUATED
FILE: AE

SCHEME 1. MECHANICAL HAUL TO SCOW, OCEAN DISPOSAL

OPTION	LOAD AT PIT	LAND HAUL	LOAD AT SCOW	OCEAN HAUL
A	FRONT END LOADER-5-1/2 cy	TRUCK 25 CY	CLAMSHELL	SCOW
B	FRONT END LOADER-12 cy	TRUCK 25 CY	CLAMSHELL	SCOW
C	SCRAPER	SCRAPER	CLAMSHELL	SCOW
D	FRONT END LOADER-12 cy	TRUCK 25 CY	CONVEYOR	SCOW
E	SCRAPER	SCRAPER	CONVEYOR	SCOW

SCHEME 2. CONVEYOR TO SCOW, OCEAN DISPOSAL

OPTION	LOAD AT PIT	LAND HAUL	LOAD AT SCOW	OCEAN HAUL
A	DOZER	CONVEYOR	CONVEYOR	SCOW
B	SCRAPER	CONVEYOR	CONVEYOR	SCOW

SCHEME 3. BUCKET DREDGE, SCOW OCEAN DISPOSAL

OPTION	OCEAN DISPOSAL AREA	LOAD AT PIT	OCEAN HAUL
A	DAM NECK	BUCKET DREDGE	SCOW
B	NORFOLK	BUCKET DREDGE	SCOW

SCHEME 4. TRUCK HAUL TO LAND DISPOSAL

OPTION	DISTANCE	LOAD AT PIT	LAND HAUL
A	20 MILE HAUL	FRONT END LOADER	TRUCK 10 CY
B	10 MILE HAUL	FRONT END LOADER	TRUCK 10 CY

SCHEME 1. MECHANICAL HAUL TO SCOW, OCEAN DISPOSAL

OPTION	LOAD AT PIT	LAND HAUL	LOAD AT SCOW	OCEAN HAUL
B-2	B USING 2 SHIFTS			

CRANEY ISLAND
SUMMARY OF COSTS
FILE: SUM

SCHEME	OPTION	DISPOSAL DAM NECK	DISPOSAL NORFOLK	VOLUME/YEAR DAM NECK	VOLUME/YEAR NORFOLK
1.	MECHANICAL HAUL TO SCOW OCEAN DISPOSAL				
	A	7.61	8.04	1,436,400 CY	1,333,800 CY
	B	7.03	7.47	1,436,400 CY	1,333,800 CY
	C	7.12	7.55	1,436,400 CY	1,333,800 CY
	D	7.02	7.45	1,436,400 CY	1,333,800 CY
	E	7.10	7.54	1,436,400 CY	1,333,800 CY
1.	MECHANICAL HAUL TO SCOW OCEAN DISPOSAL USING NIGHT SHIFT FOR LAND.				
	B	7.02	7.45	2,872,800 CY	2,666,000 CY
2.	CONVEYOR TO SCOW OCEAN DISPOSAL				
	A	7.26	7.69	1,436,400 CY	1,333,800 CY
	B	7.42	7.85	1,436,400 CY	1,333,800 CY
3.	BUCKET DREDGE OCEAN DISPOSAL				
	A	5.26	5.67	4,268,700 CY	3,941,900 CY
4.	TRUCK HAUL LAND DISPOSAL				
	A	20 MILE HAUL	9.44		715,400 CY
	B	10 MILE HAUL	5.40		715,400 CY

CRANEY ISLAND
SCHEME 1 - OPTION A.1
FILE: PAGE1

SCHEME 1 - OPTION A.1
DAM NECK OCEAN DISPOSAL AREA SCOW CAPACITY: 3000 CY GROSS
2850 CY NET

LOADING @ 363 CY/HR = 7.85 USING 2 CREWS X 2 BARGES = 7.85 HRS

SCOW HAUL 37 MILES @ 3.00 MPH	12.33	HRS
DUMP	1.00	HRS
RETURN 37 MILES @ 3.50 MPH	10.57	HRS
	31.75	HRS

USING 2 SETS SCOWS, LOAD 1 SET/DAY

	LOAD	SET 1 DEPART	SET 1 RETURN	SET 2 DEPART	SET 2 RETURN
MONDAY	SET 1	4 PM			
TUESDAY	SET 2		4 PM	4PM	
WEDNESDAY	SET 1	4 PM			4 PM
THURSDAY	SET 2		4 PM	4 PM	
FRIDAY	SET 1	4 PM			4 PM
SATURDAY	SET 2		4 PM	4 PM	
SUNDAY		4 PM			4 PM

2 SETS OF SCOWS WILL KEEP LOADING EQUIPMENT OPERATING 6 DAYS A WEEK,
8 TO 9 HOURS A DAY
6 LOADS @ 2850 X 2 = 34,200 CY/WEEK
ALLOW FOR BAD WEATHER 3-1/2 WEEKS/MO USING 3-1/2 WEEKS/MO X 12 MO/YR =
42 WEEKS = 1,436,400 CY/YEAR

MONTHLY COSTS

SCOW 2 @ 1,500/MO X 2 SETS	6,000
TUGS 4,000/DAY X 2 X 30 DAYS	240,000
FUEL 1750 X .85 X 504 X .067 X 0.90	45,200
24 HRS/TRIP X 6 TRIPS/WK X 3-1/2 WKS = 504 HRS	
MAINTENANCE AND INSURANCE	25,000
LABOR W/TUGS ALLOW SUPERINTENDENT	7,000
TOTAL DIRECT	323,200
OH & P 22%	71,100
	394,300

HAULING TO OCEAN DISPOSAL CAPACITY/MO = 3.5 X 34,200 = 119,700 CY/MO

$394,300 / 119,700 CY/MO 3.29 / CY

CRANEY ISLAND
SCHEME 1 - OPTION A.2
FILE: PAGE2

SCHEME 1 - OPTION A.2
NORFOLK OCEAN DISPOSAL AREA SCOW CAPACITY: 3000 CY GROSS
2850 CY NET

LOADING @ 363 CY/HR = 7.85 USING 2 CREWS X 2 BARGES = 7.85 HRS

SCOW HAUL 45 MILES @ 3.00 MPH	15.00	HRS
DUMP	1.00	HRS
RETURN 45 MILES @ 3.50 MPH	12.86	HRS
	36.71	HRS

USING 2 SETS SCOWS, LOAD 1 SET/DAY 5 DAYS

	LOAD	SET 1 DEPART	SET 1 RETURN	SET 2 DEPART	SET 2 RETURN
MONDAY	SET 1	4 PM			
TUESDAY	SET 2		9 PM	4PM	
WEDNESDAY	SET 1	4 PM			9 PM
THURSDAY	SET 2		9 PM	4 PM	
FRIDAY	SET 1	4 PM			9 PM
SATURDAY	SET 2		9 PM	4 PM	
SUNDAY		4 PM			9 PM

2 SETS OF SCOWS WILL KEEP LOADING EQUIPMENT OPERATING 6 DAYS A WEEK,
8 TO 9 HOURS A DAY
6 LOADS @ 2850 X 2 = 34,200 CY/WEEK
ALLOW FOR BAD WEATHER 3-1/4 WEEKS/MO USING 3-1/4 WEEKS/MO X 12 MO/YR =
39 WEEKS = 1,333,800 CY/YEAR

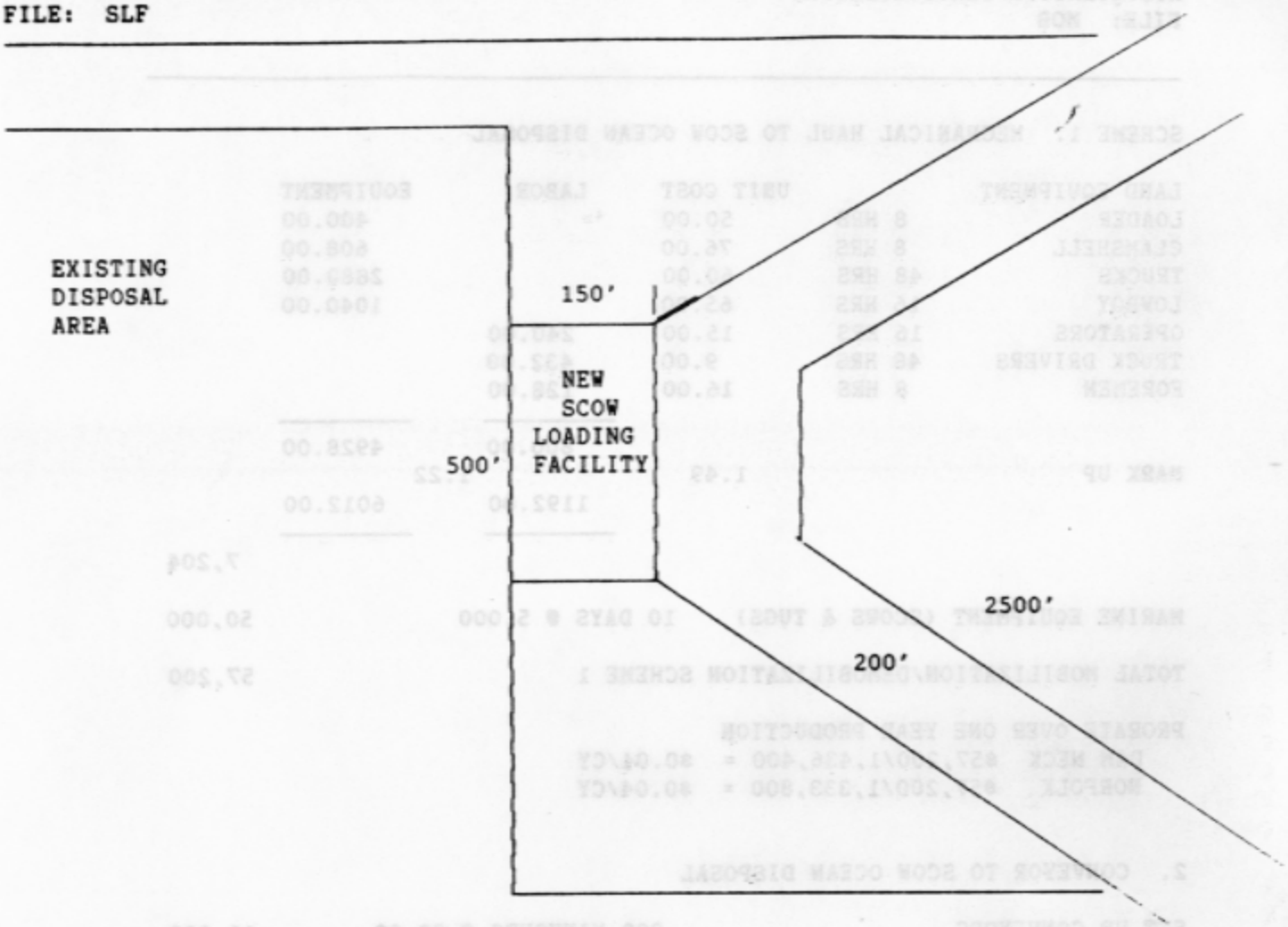
MONTHLY COSTS

SCOW 2 @ 1,500/MO X 2 SETS	6,000
TUGS 4,000/DAY X 2 X 30 DAYS	240,000
FUEL 1750 X .85 X 565 X .067 X 0.90	50,700
29 HRS/TRIP X 6 TRIPS/WK X 3-1/4 WKS = 565 HRS	
MAINTENANCE AND INSURANCE	25,000
LABOR W/TUGS ALLOW SUPERINTENDENT	7,000
TOTAL DIRECT	328,700
OH & P 22%	72,300
	401,000

HAULING TO OCEAN DISPOSAL CAPACITY/MO = 3.25 X 34,200 = 111,150 CY/MO

$401,000 / 111,150 CY/MO 3.61 / CY

CRANEY ISLAND
SCOW LOADING FACILITY
FILE: SLF



BULKHEAD - 50' X [500 +150(2)]=40,000 SF	@$ 30.00=	1200000.00
FILL - 15' X 150 X 500 / 27 = 41,666 CY USE 45,000 CY	@ 3.00=	135000.00
FENDER - 500 LF	@ 150.00=	75000.00
DREDGE - 200'[2500(2) + 200](0 + 15)(1/2) = 7,800,000 = 288,900 CY USE 300,000 CY	@ 2.00=	600000.00
SURFACE - 250 X 500 X 1/9 = 13,888 USE 14,000 SY	@ 2.00=	28000.00
(SELECT MATERIAL FROM CRANEY ISLAND)		
		2038000.00
	USE	$2,100,000

WITH 10 YEAR LIFE =	210,000 /YR
MAINTENANCE	25,000 /YR
	235,000 /YR

SCHEME 1 - OPTION A - DAM NECK 1,436,400 CY/YR = $0.165/CY USE $0.17

SCHEME 1 - OPTION A - NORFOLK 1,333,800 CY/YR = $0.176/CY USE $0.18

CRANEY ISLAND
MOBILIZATION/DEMOBILIZATION
FILE: MOB

SCHEME 1. MECHANICAL HAUL TO SCOW OCEAN DISPOSAL

LAND EQUIPMENT		UNIT COST	LABOR	EQUIPMENT	
LOADER	8 HRS	50.00		400.00	
CLAMSHELL	8 HRS	76.00		608.00	
TRUCKS	48 HRS	60.00		2880.00	
LOWBOY	16 HRS	65.00		1040.00	
OPERATORS	16 HRS	15.00	240.00		
TRUCK DRIVERS	48 HRS	9.00	432.00		
FOREMEN	8 HRS	16.00	128.00		
			800.00	4928.00	
MARK UP		1.49	1.22		
			1192.00	6012.00	
					7,204

MARINE EQUIPMENT (SCOWS & TUGS) 10 DAYS @ 5,000 50,000

TOTAL MOBILIZATION/DEMOBILIZATION SCHEME 1 57,200

PRORATE OVER ONE YEAR PRODUCTION
DAM NECK $57,200/1,436,400 = $0.04/CY
NORFOLK $57,200/1,333,800 = $0.04/CY

2. CONVEYOR TO SCOW OCEAN DISPOSAL

SET UP CONVEYORS	800 MANHOURS @ 20.00	16,000
TRANSPORT CONVEYORS		5,000
MOVE CONVEYORS DURING OPERATIONS	1,200 MANHOURS @ 20.00	24,000
REMOVE CONVEYORS	600 MANHOURS @ 20.00	12,000
MATERIALS FOR SUPPORT	ALLOWANCE	10,000
MARINE EQUIPMENT	10 DAYS @ 5,000.00	50,000

TOTAL MOBILIZATION/DEMOBILIZATION SCHEME 2 117,000

PRORATE OVER ONE YEAR PRODUCTION
DAM NECK $117,000/1,436,400 = $0.08/CY
NORFOLK $117,000/1,333,800 = $0.09/CY

SCHEME 3. BUCKET DREDGE OCEAN DISPOSAL

MARINE EQUIPMENT (DREDGE,SCOWS,TUGS) 10 DAYS @ 25,000 250,000

PRORATE OVER ONE YEAR PRODUCTION

CRANEY ISLAND
MOBILIZATION/DEMOBILIZATION
FILE: MOB2

SCHEME 4. TRUCK HAUL LAND DISPOSAL

OPTION A

LAND EQUIPMENT		UNIT COST	LABOR	EQUIPMENT
LOADER	8 HRS	50.00		400.00
TRUCKS @4 HRS	220 HRS	29.00		6380.00
DOZER	8 HRS	34.00		280.00
LOWBOY	16 HRS	65.00		1040.00
OPERATORS	16 HRS	15.00	240.00	
TRUCK DRIVERS	220 HRS	9.00	1980.00	
FOREMAN	8 HRS	16.00	128.00	
			2348.00	8100.00
MARK UP		1.49	3500.00 1.22	9880.00

TOTAL MOBILIZATION/DEMOBILIZATION SCHEME 4 OPTION A 13380.00

PRORATE OVER ONE YEAR PRODUCTION $13,380/715,390 CY = $0.01 / CY

OPTION B

LAND EQUIPMENT		UNIT COST	LABOR	EQUIPMENT
LOADER	8 HRS	50.00		400.00
TRUCKS @4 HRS	116 HRS	29.00		3364.00
DOZER	8 HRS	34.00		280.00
LOWBOY	16 HRS	65.00		1040.00
OPERATORS	16 HRS	15.00	240.00	
TRUCK DRIVERS	116 HRS	9.00	1044.00	
FOREMAN	8 HRS	16.00	128.00	
			1412.00	5084.00
MARK UP		1.49	2104.00 1.22	6202.00

TOTAL MOBILIZATION/DEMOBILIZATION SCHEME 4 OPTION B 8306.00

PRORATE OVER ONE YEAR PRODUCTION $ 8,306/715,390 CY = $0.01 / CY

CRANEY ISLAND
SCHEME 1 - OPTION A
FILE: 1A

SCHEME 1 - MECHANICAL HAUL TO SCOW OCEAN DISPOSAL

OPTION A: HAUL TO MOORING FACILITY

LOAD WITH FRONT END LOADER - 5 1/2 CY	50.00 /HR
HAUL WITH OFF HIGHWAY TRUCK - 25 CY TRUCK	60.00 /HR
LOAD TO BARGE SCOW - 5 CY CLAMSHELL & BUCKET	76.00 /HR

25 CY TRUCK = 22 CY EFFECTIVE (15% SWELL)

LOAD @ 40 SEC/CYCLE 25 CY TRUCK/5 CY CYCLE = 5 CYCLE X 40 SEC = 200 SEC = (2.22 MIN/TRUCK)
55 MIN HOUR/ 3.33 MIN/TRUCK X 22 CY/TRUCK = 363 CY/HOUR 2 SETS = 726 CY/HR

HAUL - 1 1/2 MILE EA WAY @ 15 MPH = 6 MIN	12.00	MIN
LOAD	3.33	MIN
WAIT	.50	MIN
DUMP	1.00	MIN
	16.83	MIN

55 MIN HOUR / 16.83 = 3.3 LOADS/HOUR
3.3 LOADS/HOUR X 22 CY/HR 72.6 CY/HR/TRUCK
363 CY/HR / 72.6 CY/HR/TRUCK = 5.0 TRUCKS USE 6 TRUCKS

		UNIT COST	LABOR	EQUIPMENT
WATER TRUCK	1 EA	15.00		15.00
GRADER	1 EA	19.00		19.00
LOADER	1 EA	50.00		50.00
TRUCK	6 EA	60.00		360.00
CLAMSHELL 5-1/2 CY	1 EA	76.00		76.00
OPERATORS	3 EA	15.00	45.00	
TRUCK DRIVER	7 EA	9.00	63.00	
LABORER	2 EA	8.00	16.00	
FOREMAN	1 EA	16.00	16.00	
			140.00	520.00
INS TAX 22%, OH 12%, PROFIT 8%, BOND 1%		1.49	209.00	
OH 12%, PROFIT 8%, BOND 1%		1.22		634.00

843.00 /HR

$843.00 / 363 CY/HR = $2.32 cy

	DAM NECK	NORFOLK
HAUL - LAND	2.32	2.32
HAUL - OCEAN DISPOSAL	3.29	3.61
MOBILIZATION/DEMOBILIZATION	.04	.04
SCOW LOADING FACILITY	.17	.18
	5.82	6.15
E&D / S&A 9%	.52	.55
CONTINGENCY 20%	1.27	1.34
TOTAL ESTIMATED UNIT COST	7.61	8.04

CRANEY ISLAND
SCHEME 1 - OPTION B
FILE: 1B

SCHEME 1 - MECHANICAL HAUL TO SCOW OCEAN DISPOSAL

OPTION B: HAUL TO MOORING FACILITY

USE 12 CY FRONT END LOADER $122.00/HR
LOAD 55 SEC. CYCLE 25 CY TRUCK/12 CY CYCLE=2.08 CYCLE X 55 SEC=
USE 2 - 55 SEC CYCLES = 110 SEC = 1.83 MIN
55 MIN HR/1.83 MIN TRUCK X 22 CY TRUCK = 661 CY/HR

HAUL	1-1/2 MILE @15 MPH =6 MIN X 2	12.00	MIN
LOAD		1.80	MIN
WAIT		.50	MIN
DUMP		1.00	MIN
		15.30	MIN

55 MIN. HR/15.3=3.6 LOADS/HR X 22 CY LOAD= 79.2 CY HR TRUCK
661 CY HR / 79.2 CY HR TRUCK = 8.35 TRUCKS USE 9

		UNIT COST	LABOR	EQUIPMENT
WATER TRUCK	1 EA	15.00		15.00
GRADER	1 EA	19.00		19.00
LOADER	1 EA	122.00		122.00
TRUCK	9 EA	60.00		540.00
CLAMSHELL 12 CY	1 EA	110.00		110.00
OPERATORS	3 EA	15.00	45.00	
TRUCK DRIVER	10 EA	9.00	90.00	
LABORER	3 EA	8.00	24.00	
FOREMAN	1 EA	16.00	16.00	
			175.00	806.00
MARK UP		1.49	261.00	
MARK UP		1.22		983.00
				1244.00 /HR

$1244.00 / 661 CY/HR = $1.88 cy

	DAM NECK	NORFOLK
HAUL - LAND	1.88	1.88
HAUL - OCEAN DISPOSAL	3.29	3.61
MOBILIZATION/DEMOBILIZATION	.04	.04
SCOW LOADING FACILITY	.17	.18
	5.38	5.71
E&D / S&A 9%	.48	.51
CONTINGENCY 20%	1.17	1.24
TOTAL ESTIMATED UNIT COST	7.03	7.47

CRANEY ISLAND
SCHEME 1 - OPTION C
FILE: 1C

SCHEME 1 - MECHANICAL HAUL TO SCOW OCEAN DISPOSAL

OPTION C: HAUL TO MOORING FACILITY

USE SCRAPPERS 21-31 CY (25 CY EFFECTIVE) @ 91.00/HR

LOAD	2.00 MIN
HAUL 1-1/2 MILES	12.00 MIN
WAIT	.50 MIN
DUMP	1.00 MIN
	15.5 MIN 15.5 MIN 55 MIN HR=3.55 TRIPS/HR
	3.55 X 25 = 88.8 CY /HR

CLAMSHELL 12 CY X 55 CYCLES HR = 660 CY/HR 660 / 88.8 = 7.43
USE 8 SCRAPERS

		UNIT COST	LABOR	EQUIPMENT	
SCRAPERS	8 EA	91.00		728.00	
CLAMSHELL 12 CY	1 EA	110.00		110.00	
OPERATORS	9 EA	15.00	135.00		
LABORERS	3 EA	8.00	24.00		
FOREMAN	1 EA	16.00	16.00		
			175.00	838.00	
MARK UP		1.49	261.00		
MARK UP		1.22		1072.00	=1283/HR

$1283.00 / 660 CY HR = $1.94 CY

	DAM NECK	NORFOLK
HAUL - LAND	1.94	1.94
HAUL - OCEAN DISPOSAL	3.29	3.61
MOBILIZATION/DEMOBILIZATION	.04	.04
SCOW LOADING FACILITY	.17	.18
	5.44	5.77
E&D / S&A 9%	.49	.52
CONTINGENCIES 20%	1.19	1.26
TOTAL ESTIMATED UNIT COST	7.12	7.55

CRANEY ISLAND
SCHEME 1 - OPTION D
FILE: 1D

SCHEME 1 - MECHANICAL HAUL TO SCOW OCEAN DISPOSAL

OPTION D: LOAD SCOW BY CONVEYOR
SAME AS OPTION B EXCEPT LOAD SCOW BY CONVEYOR

		UNIT COST	LABOR	EQUIPMENT	
WATER TRUCK	1 EA	15.00		15.00	
GRADER	1 EA	19.00		19.00	
LOADER	1 EA	122.00		122.00	
TRUCK	9 EA	60.00		540.00	
CONVEYOR 100 LF W/ACCESSORIES 1260 T/HR	1 EA	30.00		30.00	
OPERATORS	4 EA	15.00	60.00		
LABORERS	3 EA	8.00	24.00		
FOREMAN	1 EA	16.00	16.00		
TRUCK DRIVER	10 EA	9.00	90.00		
DOZER D-6	1 EA	50.00		50.00	
			190.00	776.00	
MARK UP		1.49	283.00		
MARK UP		1.22		947.00	=$1230

$1230.00 / 661 CY HR = $1.86 CY

	DAM NECK	NORFOLK
HAUL - LAND	1.86	1.86
HAUL - OCEAN DISPOSAL	3.29	3.61
MOBILIZATION/DEMOBILIZATION	.05	.05
SCOW LOADING FACILITY	.17	.18
	5.37	5.70
E&D / S&A 9%	.48	.51
CONTINGENCIES 20%	1.17	1.24
TOTAL ESTIMATED UNIT COST	7.02	7.45

CRANEY ISLAND
SCHEME 1 - OPTION E
FILE: 1E

SCHEME 1 - MECHANICAL HAUL TO SCOW OCEAN DISPOSAL

OPTION E: LOAD SCOW BY CONVEYOR
SAME AS OPTION C EXCEPT LOAD SCOW BY CONVEYOR

		UNIT COST	LABOR	EQUIPMENT	
SCRAPER	8 EA	91.00		728.00	
CONVEYOR 100 LF W/ACCESSORIES 1260 T/HR	1 EA	30.00		30.00	
OPERATORS	10 EA	15.00	150.00		
LABORERS	3 EA	8.00	24.00		
FOREMAN	1 EA	16.00	16.00		
DOZER D-6	1 EA	50.00		50.00	
			190.00	808.00	
MARK UP		1.49	283.00		
MARK UP		1.22		986.00	=$1269

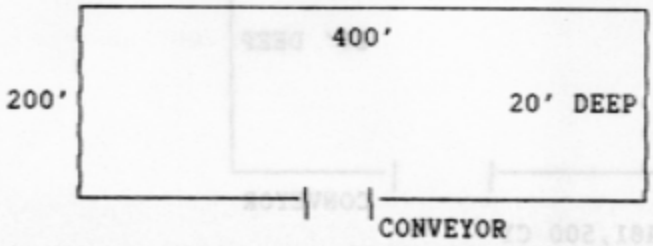
$1269.00 / 660 CY HR = $1.92 CY

	DAM NECK	NORFOLK
HAUL - LAND	1.92	1.92
HAUL - OCEAN DISPOSAL	3.29	3.61
MOBILIZATION/DEMOBILIZATION	.05	.05
SCOW LOADING FACILITY	.17	.18
	5.43	5.76
E&D / S&A 9%	.49	.52
CONTINGENCIES 20%	1.18	1.26
TOTAL ESTIMATED UNIT COST	7.10	7.54

CRANEY ISLAND
SCHEME 2 - OPTION A
FILE: 2A

OPTION 2 - A: CONVEYOR LOAD BY DOZER

200 LF EFFECTIVE PUSH DISTANCE - 100' AVE



200' X 400'X 20'/ 27 = 59,250 CY PRODUCTION 800 CY HR X 8 = 6400 CY DAY
SCOW 119,700 CY MO MOVE EVERY 2 WEEKS
ASSUME EXTENDING 200' FOR 1200' = 6 TIMES 6 X 59,250 = 355,500 CY
MAJOR MOVE EACH 3 MONTHS. MOVES TO BE MADE ON WEEKENDS. NO REDUCTION IN HAULING CAPACITY. SET UP INCLUDED IN MOBILIZATION/DEMOBILIZATION.

FOR ONE MONTH PRODUCTION 119,700 CY
8 HRS DAY X 6 DAY WK X 3-1/2 WKS = 168 HRS

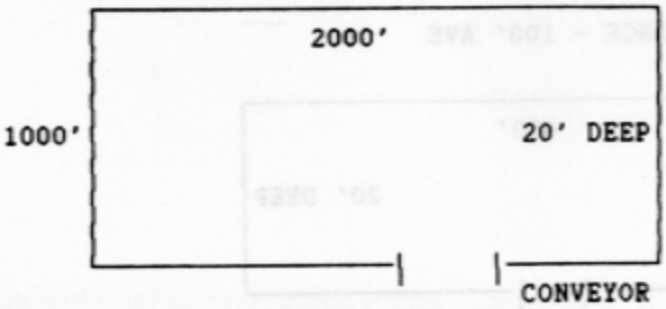
		UNIT COST	LABOR	EQUIPMENT
CONVEYOR 48" X 50'= 1260 T/HR				
4000' = 80 PCS @ 12.00 EA	168 HRS	960.00		161,280
LOADING HOPPER AT SOURCE	168 HRS	4.00		672
DOZER D-6 (2 EA)	336 HRS	50.00		16,800
LABORERS (4 EA)	672 HRS	8.00	5,376	
OPERATORS (2 EA)	336 HRS	15.00	5,040	
FOREMAN	168 HRS	16.00	2,688	
MOVE CONVEYOR & HOPPER				
CRANE	16 HRS	70.00		1,120
LABORERS	40 HRS	8.00	320	
LOADER	8 HRS	50.00		400
OPERATOR	16 HRS	15.00	240	
			13,664	180,272
MARK UP		1.49	20,360	
MARK UP		1.22		219,930 =$240,2

$240,290 / 119,700 CY = $2.01 CY

	DAM NECK	NORFOLK
HAUL - LAND	2.01	2.01
HAUL - OCEAN DISPOSAL	3.29	3.61
MOBILIZATION/DEMOBILIZATION	.08	.08
SCOW LOADING FACILITY	.17	.18
	5.55	5.88
E&D / S&A 9%	.50	.53
CONTINGENCIES 20%	1.21	1.28
TOTAL ESTIMATED UNIT COST	7.26	7.69

CRANEY ISLAND
SCHEME 2 - OPTION B
FILE: 2B

OPTION 2 - B: CONVEYOR LOAD BY SCRAPER
SCRAPER HAUL 1000'



1000' X 2000' X20/ 27 = 1,481,500 CY

FOR ONE YEAR PRODUCTION USE CONVEYOR 3000'

SCRAPER PRODUCTION	LOAD	2 MIN
	HAUL 500'	2 MIN
	DUMP	1 MIN
		5 MIN

55 MIN HR / 5 MIN = 11 CYCLES X 25 CY = 275 CY/HR/SCRAPER
725 / 275 = 2.63 3 REQUIRED
USE D-6 DOZER PUSHING TO HOPPER

FOR ONE MONTHS PRODUCTION SCOW CAPACITY 119,700 CY
8 HRS DAY X 6 DAYS WK X 3-1/2 WEEKS = 168 HRS

		UNIT COST	LABOR	EQUIPMENT	
CONVEYOR 48" X 50'= 910 T/HR					
3000' = 60 PCS @ 12.00 EA	168 HRS	720.00		120,960	
LOADING HOPPER AT SOURCE	168 HRS	4.00		672	
SCRAPERS (3 EA)	504 HRS	91.00		45,864	
DOZER D-6 (2 EA)	336 HRS	50.00		16,800	
LABORERS (4 EA)	672 HRS	8.00	5,376		
OPERATORS (5 EA)	840 HRS	15.00	12,600		
FOREMAN	168 HRS	16.00	2,688		
			20,664	184,296	
MARK UP		1.49	30,789		
MARK UP		1.22		224,841	=$255,630

$255,630 / 119,700 CY = $2.13 CY

		DAM NECK	NORFOLK
HAUL - LAND		2.13	2.13
HAUL - OCEAN DISPOSAL		3.29	3.61
MOBILIZATION/DEMOBILIZATION		.08	.08
SCOW LOADING FACILITY		.17	.18
		5.67	6.00
E&D / S&A	9%	.51	.54
CONTINGENCIES	20%	1.24	1.31
TOTAL ESTIMATED UNIT COST		7.42	7.85

COST ESTIMATE BUCKET DREDGE

PLANT:	18 CY BUCKET DREDGE		
CHANNEL SEGMENT:	CRANEY ISLAND		
DISPOSAL AREA:	DAM NECK		
HAUL DISTANCE (MILES):	37		
QUANTITY PAY:	4,000,000 CY	GROSS:	4,400,000 CY
BUCKET TYPE DREDGE CAPACITY:			18 CY
		LOAD FACTOR =	.90
CYCLE TIME (MINUTES):			1.2 MIN.
CYCLES/HR			50 EA
CY/HR			810 CY/HR
EFFICIENCY FACTOR	(24HRS X 70 %)		17 HRS/DAY
CY/DAY			13,770 CY
NUMBER SCOWS PER TOW			2 EA
HAUL	37 MILES @ 3.00 MPH		12.33 HRS
LOAD & DUMP			8 HRS
RETURN	37 MILES @ 3.50 MPH		10.57 HRS
TOTAL CYCLE TIME (SCOWS)			30.90 HRS
20 WORK HOURS/DAY /	CYCLE TIME		.65 LOADS/DAY
2 3000 CY SCOWS @	2,850 CY/LOAD=		5,700 CY/TRIP
SCOWS			
5,700 CY/TRIP X	.65 LOADS/DAY		3,689 CY/DAY
SCOWS REQ			4 SETS
TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD.			320 DAYS
LOST TIME (18%)			58 DAYS
TOTAL TIME (EFFECTIVE + LOST)			378 DAYS
PLANT COST			547,000 /MONTH
FUEL COST	.90 /GAL		226,547 /MONTH
MAINTENANCE AND INSURANCE COST			45,000 /MONTH
LABOR COST			62,900 /MONTH
TOTAL DIRECT MONTHLY COST			881,447 /MONTH
21% OVERHEAD & PROFIT			185,104 /MONTH
TOTAL MONTHLY COST			1,066,551
TOTAL DAILY COST			35,552
DREDGING COSTS			13,438,544
MOBILIZATION/DEMOBILIZATION			
10	DAYS @ 25,000		250,000
TOTAL JOB COST			13,688,544
UNIT COST/CY			3.42
E&D / S&A (9%)			.31
CONTINGENCIES @	20%		.75
TOTAL UNIT COST DREDGING			4.48
BREACH LEVEE			.78
			5.26

COST ESTIMATE BUCKET DREDGE

PLANT: 18 CY BUCKET DREDGE
CHANNEL SEGMENT: CRANEY ISLAND
DISPOSAL AREA: NORFOLK
HAUL DISTANCE (MILES): 45
QUANTITY PAY: 4,000,000 CY GROSS: 4,400,000 CY
BUCKET TYPE DREDGE CAPACITY: 18 CY
LOAD FACTOR = .90
CYCLE TIME (MINUTES): 1.2 MIN.
CYCLES/HR 50 EA
CY/HR 810 CY/HR
EFFICIENCY FACTOR (24HRS X 70 %) 17 HRS/DAY
CY/DAY 13,770 CY

NUMBER SCOWS PER TOW 2 EA
HAUL 45 MILES @ 3.00 MPH 15.00 HRS
LOAD & DUMP 8 HRS
RETURN 45 MILES @ 3.50 MPH 12.86 HRS
TOTAL CYCLE TIME (SCOWS) 35.86 HRS
20 WORK HOURS/DAY / CYCLE TIME .56 LOADS/DAY
2 3000 CY SCOWS @ 2,850 CY/LOAD= 5,700 CY/TRIP
SCOWS
5,700 CY/TRIP X .56 LOADS/DAY 3,179 CY/DAY
SCOWS REQ 4 SETS

TOT EFFECTIVE TIME=GROSS QTY/DREDGE PROD. 346 DAYS

LOST TIME (18%) 62 DAYS
TOTAL TIME (EFFECTIVE + LOST) 408 DAYS

PLANT COST 547,000 /MONTH
FUEL COST .90 /GAL 226,547 /MONTH
MAINTENANCE AND INSURANCE COST 45,000 /MONTH
LABOR COST 62,900 /MONTH
TOTAL DIRECT MONTHLY COST 881,447 /MONTH
21% OVERHEAD & PROFIT 185,104 /MONTH
TOTAL MONTHLY COST 1,066,551
TOTAL DAILY COST 35,552

DREDGING COSTS 14,505,095
MOBILIZATION/DEMOBILIZATION
10 DAYS @ 25,000 250,000
TOTAL JOB COST 14,755,095

UNIT COST/CY 3.69

E&D / S&A (9%) .33

CONTINGENCIES @ 20% .80

TOTAL UNIT COST DREDGING 4.82

BREACH LEVEE .85

TOTAL UNIT COST 5.67

CRANEY ISALND
BREACH LEVEE
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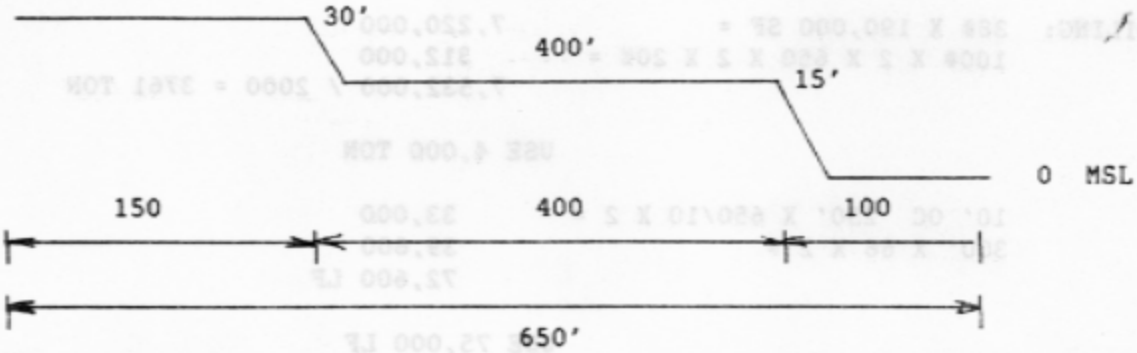


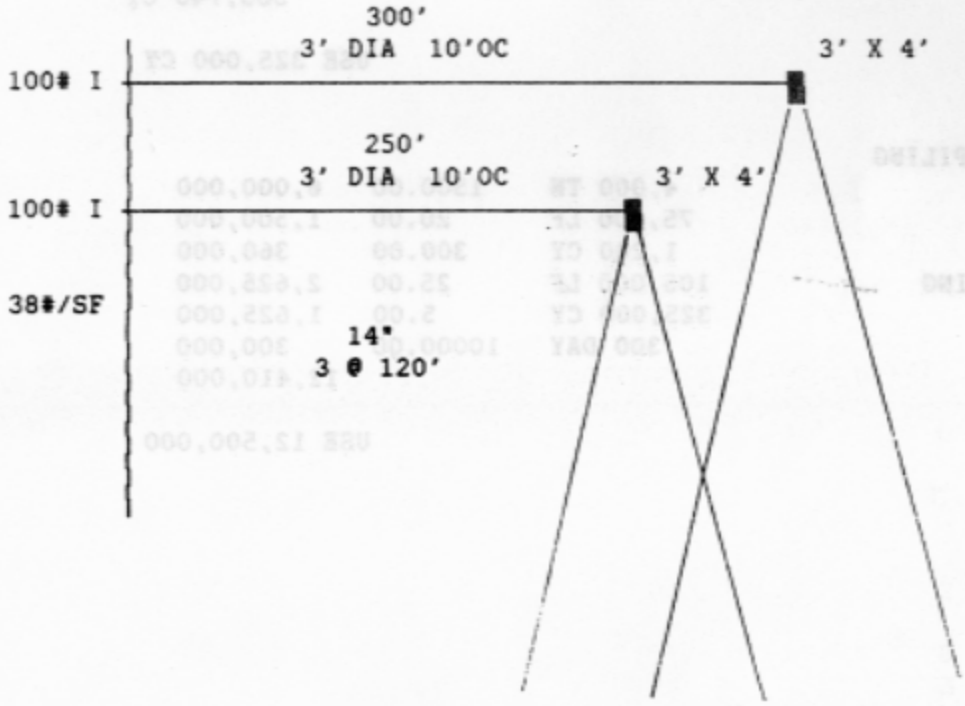
SHEET PILE LGTH:

150' 140' 130'
- 110 TOP SAND

- 120 BOTTOM SHEET PILING

AREA: 150 X 150 = 22,500
400 X 140 = 56,000
100 X 130 = 13,000

91,500 SF X 2 SIDES = 183,000 USE 190,000 SF



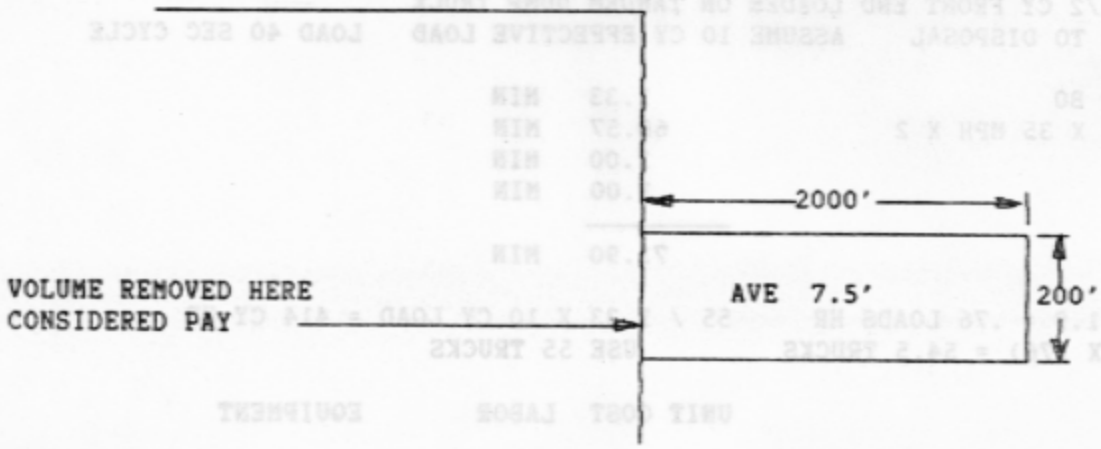
CRANEY ISLAND
BREACH LEVEE
FILE: BL2

STEEL SHEET PILING:	38# X 190,000 SF =	7,220,000
	100# X 2 X 650 X 2 X 20% =	312,000
		7,532,000 / 2000 = 3761 TON
		USE 4,000 TON
TIE RODS:	10' OC 250' X 650/10 X 2 =	33,000
	300' X 66 X 2 =	39,600
		72,600 LF
		USE 75,000 LF
24# @ 0.80 = 19.20		USE 20.00 LF
CONCRETE:	3' X 4' X 650 X 2 X 2 =	1,155 CY
		USE 1,200 CY
EXCAVATE (LAND):		
TIE BACK	15' X 350' X 650 X 2 =	6,825,000
SHEET PILING	50' X 20' X 700' X 2 =	1,400,000
		8,225,000 CF
		305,740 CY
		USE 325,000 CY

STEEL SHEET PILING & WALES	4,000 TN	1500.00	6,000,000
TIE RODS	75,000 LF	20.00	1,500,000
CONCRETE	1,200 CY	300.00	360,000
TIE BACK PILING	105,000 LF	25.00	2,625,000
EXCAVATION	325,000 CY	5.00	1,625,000
DEWATERING	300 DAY	10000.00	300,000
			12,410,000
			USE 12,500,000

CRANEY ISLAND
BREACH LEVEE
FILE: DAC

DREDGE ACCESS CHANNEL:



2000 X 200 X 7.5 = 3,000,000 / 27 = 111,111 CY
115,000 CY @ 2.00 = $230,000

DREDGE	250,000
BULKHEAD	12,500,000
	12,750,000

ASSUME REMOVAL FOR 5 YEARS / CELL 5 YEARS = 2,550,000 / YR

DAM NECK $2,550,000 / 4,268,700 CY/YR = $ 0.60/CY

NORFOLK $2,550,000 / 3,944,900 CY/YR = $ 0.65/CY

WITH 9% E&D / S&A AND 20% CONTINGENCIES

DAM NECK	$ 0.78
NORFOLK	$ 0.85

CRANEY ISLAND
SCHEME 4 - OPTION A
FILE: 4A

SCHEME 4 - OPTION A: TRUCK HAUL, LAND DISPOSAL

LOAD WITH 5 1/2 CY FRONT END LOADER ON TANDEM DUMP TRUCK
HAUL 20 MILES TO DISPOSAL ASSUME 10 CY EFFECTIVE LOAD LOAD 40 SEC CYCLE

LOAD 40 X 2 = 80	1.33	MIN
HAUL 20 MILES X 35 MPH X 2	68.57	MIN
DUMP	1.00	MIN
WAIT	1.00	MIN
	71.90	MIN

55 MIN HR / 71.9 = .76 LOADS HR 55 / 1.33 X 10 CY LOAD = 414 CY HR
414 CY / (10 X .76) = 54.5 TRUCKS USE 55 TRUCKS

		UNIT COST	LABOR		EQUIPMENT	
WATER TRUCK	1 EA	15.00			15	
GRADER	1 EA	19.00			19	
FRONT END LOADER (5 1/2 CY)	1 EA	50.00			50	
TRUCKS	55 EA	29.00			1595	
DOZER D-6 (SPREADING)	1 EA	34.00			34	
OPERATORS	3 EA	15.00	45			
TRUCK DRIVERS	56 EA	9.00	504			
LABORERS	4 EA	8.00	32			
FOREMAN	1 EA	16.00	16			
			597		1713	
MARK UP		1.49	889	1.22	2090	=$2980

$2980 / 414 CY = $7.20 CY

414 CY HR X 8 HRS X 4 1/2 DAYS X 48 WKS = 715,390 CY YR

		DAM NECK
HAUL - LAND		7.20
MOBILIZATION/DEMOBILIZATION		.02
		7.22
E&D / S&A	9%	.65
CONTINGENCY	20%	1.57
		9.44

CRANEY ISLAND
SCHEME 4 - OPTION B
FILE: 4B

SCHEME 4 - OPTION B: TRUCK HAUL, LAND DISPOSAL

LOAD WITH 5 1/2 CY FRONT END LOADER ON TANDEM DUMP TRUCK
HAUL 10 MILES TO DISPOSAL ASSUME 10 CY EFFECTIVE LOAD LOAD 40 SEC CYCLE

LOAD 40 X 2 = 80	1.33	MIN
HAUL 10 MILES X 35 MPH X 2	34.28	MIN
DUMP	1.00	MIN
WAIT	1.00	MIN
	37.61	MIN

55 MIN HR / 37.61= 1.46 LOADS HR 55 / 1.33 X 10 CY LOAD = 414 CY HR
414 CY / (10 X 1.46) = 28.36 TRUCKS USE 29 TRUCKS

		UNIT COST	LABOR		EQUIPMENT
WATER TRUCK	1 EA	15.00			15
GRADER	1 EA	19.00			19
FRONT END LOADER (5 1/2 CY)	1 EA	50.00			50
TRUCKS	29 EA	29.00			841
DOZER D-6 (SPREADING)	1 EA	34.00			34
OPERATORS	3 EA	15.00	45		
TRUCK DRIVERS	30 EA	9.00	270		
LABORERS	4 EA	8.00	32		
FOREMAN	1 EA	16.00	16		
			363		959
MARK UP		1.49	541	1.22	1170 =$1711

$1711 / 414 CY = $4.13 CY

414 CY HR X 8 HRS X 4 1/2 DAYS X 48 WKS = 715,390 CY YR

		NORFOLK
HAUL - LAND		4.13
MOBILIZATION/DEMOBILIZATION		.02
		4.15
E&D / S&A	9%	.37
CONTINGENCY	20%	.90
		5.42

CRANEY ISLAND
SCHEME 1 - OPTION B - 2S
FILE: 2S

SCHEME 1 - MECHANICAL HAUL TO SCOW OCEAN DISPOSAL

OPTION B: HAUL TO MOORING FACILITY
USING 2 (TWO) SHIFTS

NIGHT OPERATION:
LIGHTING: USE 20 200W HPS, FIXTURE AND POLE W/DISTRIBUTION 1500 EA
POWER: 20 LIGHTS X 10 HRS X 200W/1000 = 40 KW/DAY, 40 KW @$.06 =$24.00 DAY
USE: $30.00 DAY

LIGHTS	20 @ $1,500.00	$30,000.00
POWER	$30.00 X 6 X 45	$8,000.00
MAINTENANCE		$5,000.00
LIGHTS TOTAL COST PER YEAR		$43,000.00

DAM NECK 43,000 / 1,436,400 = $0.03 / CY

NORFOLK 43,000 / 1,333,800 = $0.03 / CY

ASSUME NIGHT OPERATION LAND HAUL 5% LESS EFFICIENT

($1.88/ CY + 1.88/CY X 1.05) 2 =
($1.88 + 1.97) 2 = $1.93

	DAM NECK	NORFOLK
LIGHTING	.03	.03
HAUL LAND	1.93	1.93
HAUL OCEAN	3.29	3.61
MOB/DEMOB	.04	.04
SCOW LOADING FAC 50%	.08	.09
	5.37	5.70
E&D / S&A 9%	.48	.51
CONTINGENCY	1.17	1.24
	7.02	7.45

Appendix A

The Great Lakes Report describes variations in materials and working conditions as well as listing optional dredging methods. In the general terms provided these appear to be a good summary of the variables involved.

When comparing pricing it is necessary to compare prices based upon the same assumptions or to make adjustments to compensate for the differences. Great Lakes calls their prices "budget". To them this may be at contract level. They have priced a 100,000 cy project for both maintenance and new work. New work is apparently priced based upon a much harder material than maintenance. Prices in the Norfolk harbor study are based upon new work material being such that production is the same as maintenance. A pay to gross ratio of 1.25 for maintenance and 1.2 for new work accounts for the lower price.

Variation in production is shown below. As mentioned above, Great Lakes uses a much lower production for new work. 8 cy etc. indicates bucket size assumed, high and low indicated Great Lakes's pricing range.

	NEW		MAINTENANCE	
HIGH	GREAT LAKES	NORFOLK HARBOR	GREAT LAKES	NORFOLK HARBOR
8 CY			8,000 CY	
4 CY	5,000 CY			
10 CY				8,640 CY
18 CY		12,960-13,770 CY		12,960-13,770 CY

LOW	GREAT LAKES	NORFOLK HARBOR	GREAT LAKES	NORFOLK HARBOR
21 CY			13,500 CY	
12 CY			5,000-8,000 CY	
10 CY				8,640 CY
18 CY		12,960-13,770 CY		12,960-13,770 CY

Comparing Great Lakes costs with the Norfolk Harbor costs adding 9% E&D and 20% contingencies to Great Lakes pricing.

	Great Lakes		Norfolk Harbor
	High	Low	Dam Neck
	(37 miles)	(37 miles)	(37 miles)
Maintenance	7.63	5.45	6.57
New Work *	10.14	6.29	5.97

*Great Lakes based upon 100,000 cy project, Norfolk Harbor upon 500,000 cy pricing.

Depending upon the assumptions made either set of prices appear to be reasonable. Another unknown, bidding climate, could impact upon pricing as much as the production assumption.