Limited Reevaluation Report
Appendix E:
Channel Design

U.S. Army Corps of Engineers
New York District

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NEW YORK AND NEW JERSEY HARBOR DEEPENING PROJECT

CHANNEL DESIGN ENGINEERING APPENDIX

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NEW YORK AND NEW JERSEY HARBOR NAVIGATION STUDY

CHANNEL DESIGN APPENDIX

SECTION I: Background Information – Feasibility Study

Introduction

E1. Section I of this Appendix is from the Channel Design Appendix from the Feasibility Study for the New York and New Jersey Harbor Navigation Study and is provided here for background information. Section II of this Appendix provides the additional information gathered for the Limited Reevaluation Report (LRR) and documents the revisions to the channel design since the completion of the Feasibility Report.

Existing Federal Channels

General

E2. The Harbor's waterways are intensively used navigation channels for both commercial and recreational vessels. The Corps of Engineers presently maintains about 240 miles of navigation channels within the port. Additional channels are also maintained by the Port Authority of New York and New Jersey (PANYNJ), the City of New York, and various commercial interests. **Figure E1** shows the study area and the existing navigation channels within the port. Those channels of interest to this study are described in detail below.

Ambrose Channel

E3. Ambrose Channel is the entrance channel to New York Harbor. From the sea buoy to the Narrows in the Lower Bay, Ambrose Channel extends 10.2 miles at a width of 2000 ft. Two bends in the channel, 27.6 and 23.4 degrees at mile 7.5 and 8.5, respectively, align the channel from its approach course of 296 deg, 58'true into the Narrows. Ambrose Channel is flanked by East Bank Shoal on the east and West Bank and Romer Shoals on the west, all of which are approximately 10 to 15 ft deep. The authorized depth is 45 ft mlw, but actual depths are greater in many locations due to commercial sand mining. Traffic in Ambrose Channel is primarily two-way for deep draft vessels, with occasional overtaking of one vessel by another in the same direction.

Anchorage Channel

E4. Anchorage Channel, 2000 ft in width, is the primary channel in the Upper Bay. It links Ambrose Channel through the Narrows with Kill Van Kull and Port Jersey

Channels and Stapleton Anchorage to the west, the Hudson River and East River Channels to the north and Bay Ridge, Red Hook and Buttermilk Channels and Red Hook Anchorages to the east. Virtually all vessel movements through the Harbor utilize Anchorage Channel. The authorized depth is 45 ft, however the naturally scouring portions in the Narrows have depths of up to 100 ft.

New York and New Jersey Channels

E5. New York and New Jersey Channels is a 31mile long channel between Staten Island, New York and New Jersey. The channel extends from the Anchorage Channel in the Upper Bay to the Chapel Hill Channel in Sandy Hook Bay. This channel is comprised of the Kill Van Kull, Arthur Kill and Raritan Bay Channels, as described in the paragraphs below.

Kill Van Kull

E6. The Kill Van Kull is an 800 ft wide channel (with additional widenings in the bends, 2000 ft at entrance), approximately 5.3 miles in length that links the Upper Bay to the east with Newark Bay and the Arthur Kill to the west. The Kill Van Kull is the segment of the New York and New Jersey Channels along the north shore of Staten Island that separates Staten Island, New York and Bayonne, New Jersey. The channel has 9 bends, which range from 13.6 to 33.7 degrees. At the western limit, vessels entering Newark Bay must negotiate a severe 126 degree bend at Bergen Point. Although authorized to 45 ft mlw, the present depth is 40 ft. Traffic in Kill Van Kull is two-way, however post-panamax vessels will choose optimum locations for passing where both vessels can readily maneuver to the outer portions of the channel. Construction to deepen the channel to 45 ft is currently underway, and is expected to be completed in 2004.

Newark Bay Channels

E7. The Newark Bay Channels are comprised of the Main Channel (South, Middle and North Reaches) plus numerous access channels (South Elizabeth Channel, Elizabeth Channel, Port Newark Pierhead Channel and Port Newark Channel). Together, these channels service over 60 berths at the Port Newark/Elizabeth Marine Terminal on the west shore of Newark Bay. The Main Channel varies in width from 800 ft opposite Port Newark to 2200 ft in the Bergen Point Bend. In addition to providing access into Newark Bay from the Kill Van Kull, the Bergen Point Bend is also used as a turning basin for containerships backing out of the Arthur Kill. A 1550-1830 ft combined channel/maneuvering area opposite Port Elizabeth provides unrestricted access to the Elizabeth Pierhead berths. Access channels vary in width from 290 ft at South Elizabeth to 500 ft at Port Newark. With the exception of the bend at Bergen Point, traffic in the Main Channel is two-way. Although the Bergen Point Bend was originally designed to permit two way (deep + shallow) traffic, current practice indicates that smaller vessels will hold, to allow unrestricted movement for deep draft vessels through the bend. Traffic in the access channels is limited to one way. Construction to deepen Newark Bay Channels from their current depth of 40 ft to 45 ft is currently underway, and scheduled to be completed in 2004.

Arthur Kill

E8. The Arthur Kill is a 13.2. mile segment of the New York and New Jersey Channels along the west side of Staten Island which separates Staten Island, NY from Union and Middlesex Counties, NJ. The reach under consideration for this study extends from Newark Bay, where it connects with the Kill Van Kull and Newark Bay Channels, 2.4 miles to Howland Hook. The existing channel, with a depth of 35 ft, varies in width from 500 to 600 ft. There are two bends in the project reach: a 16 degree bend in the North of Shooters Island Reach, and a 35 degree bend between the North of Shooters Island reach and the Elizabeth port reach. Deep draft traffic in the project reach is essentially one way, however in the straight portion of the North of Shooters Island reach, vessels occasionally may pass in accordance with fair tide rules. Typically, tanker traffic is inbound only, with light tankers departing southbound through Raritan Bay. Containerships departing the Howland Hook Marine Terminal will back out of port, turn at Bergen Point and proceed outbound through Kill Van Kull. Construction to deepen the Arthur Kill to Howland Hook Reach to 41 ft (and 40 ft to GATX) and widening portions to 800 ft is currently underway, and is expected to be completed to Tosco by 2005. The remaining segment from Tosco to GATX may be deferred until GATX is reactivated.

Raritan Bay Channels

E9. The Raritan Bay portion of the New York and New Jersey Channels is a 12.5 mile segment that connects the Arthur Kill at Perth Amboy to the Chapel Hill Channel in the Lower Bay. The 35 ft deep channel, which varies in width from 600 to 800 ft, is outside the limit of this study.

Port Jersey Channel

E10. The existing Port Jersey channel is a non-federal channel, approximately 35 ft deep, which provides access to the Global Marine Terminal and the North East Auto Terminal (NEAT) on the north and the Marine Ocean Terminal at Bayonne (MOTBY) to the south. At the head of the channel there is a 1200 ft diameter turning basin. Within this channel, the Port Authority of New York and New Jersey has constructed a 200 ft wide, 38 ft deep channel to Global Marine Terminal. Deep draft traffic in Port Jersey Channel is one way. Smaller containerships turn in the turning basin; however, larger ships turn in Anchorage Channel and back into port, or back out of port and turn in Anchorage Channel, depending on which side of the ship is needed to face the berth. Construction is currently under way to deepen Port Jersey Channel to 41 ft. The inner channel will be 370 ft wide. The entrance channel will flare out to 1500 ft where it ties into Anchorage Channel. Construction of the 41 ft channel is currently underway. The first 2 contracts are expected to be completed in 2006, the remaining segment, which includes the deepening of a portion of the Jersey Flats, will be included in the consolidation with this project.

The Channel along New Jersey Pierhead Line

E11. The Channel along New Jersey Pierhead Line is a 3 mile long channel connecting the Kill Van Kull with the Anchorage Channel south of Liberty Island. The 20 ft deep channel is 500 ft wide, with additional widening to 800 ft at the bends.

Claremont Channel

E12. Claremont Channel is an existing non-federal channel, approximately 27 ft deep and 300 ft wide, extending west from Anchorage Channel in the Upper Bay. Claremont Channel provides access to the scrap metal facilities at Claremont Terminal.

Bay Ridge & Red Hook Channels

E13. Bay Ridge & Red Hook Channels is a 4 mile long channel adjacent to the South Brooklyn waterfront. The Bay Ridge Channel, 40 ft deep, is 1200 ft wide from the Narrows to Bay Ridge Ave (~1 mile), and 1750 ft wide from Bay Ridge Ave to the junction with Red Hook Channel (~2 miles). Red Hook Channel is 1200 ft wide to the junction with Buttermilk Channel (~1 mile). The widths in Bay Ridge Channel are adequate to support vessels perpendicular to the channel maneuvering into the finger piers along the Brooklyn waterfront with sufficient channel available to permit vessels to pass. However, most of these piers are no longer in use and one way traffic would be adequate.

Buttermilk Channel

E14. Buttermilk Channel is a 1000 ft wide channel, 2.3 miles long , that connects Anchorage Channel to the East River through the waterway between Brooklyn and Governors Island. The eastern 500 ft of the channel is 40 ft deep; the western 500 ft is 35 ft deep. Additional widenings at the junctions of the East River and Anchorage Channel at a depth of 35 ft are provided for vessel maneuverability at the bends.

Red Hook Flats Anchorage

E15. Red Hook Flats Anchorages, immediately east of Anchorage Channel in the Upper Bay, are comprised of 3 anchorage areas. Area 21A, a barge anchorage, is restricted to vessels with a draft less than 12 ft. Area 21B, with a depth of 35 ft, is restricted to vessels with a draft less than 34 ft. Area 21C, with a depth of 40 north of the Con Hook Range and 45 ft south of the Con Hook Range, is restricted to vessels over 33 ft in draft.

Stapleton Anchorage

E16. Stapleton Anchorage, immediately west of Anchorage Channel in the Upper Bay, is comprised of 3 anchorage areas. Area 23A is restricted to vessels less than 670 ft in length. Area 23B is restricted to vessels greater than 670 in length. Area 24 is restricted to vessels greater than 800 ft in length and 40 ft in draft. Actual depths in Stapleton range from 40 ft in the north (Area 23A) to over 70 ft near the Verrazano-Narrows Bridge (Area 24). Vessels may anchor in Stapleton Anchorages for no more than 48 hour. Stapleton Anchorage is not a Federal Anchorage, and therefore is not maintained by the Corps.

Gravesend Anchorage

E17. Gravesend Anchorage, located immediately east of Ambrose Channel, just south of the Verrazano-Narrows Bridge in the Lower Bay, is an unrestricted anchorage area with a depth of 47 ft. Being outside of the Upper Bay and subject to a more energetic wave climate, as well as being farther from all port facilities, Gravesend Anchorage has become the anchorage of last resort. It is only used if no anchorage space is available at Red Hook Flats or Stapleton Anchorages in the Upper Bay.

E18. **Table E1** summarizes the baseline data for the existing navigation channels and anchorage areas.

Table E1
Existing Navigation Channels and Anchorage Areas

Channel	Depth (ft mlw)		Width, W/O Proj. (ft)	
	Existing	W/O Project	Channel	Max in Bend/ Entrance
Ambrose	45	Same as exist	2000	2000
Anchorage	45	Same	2000	2000
Kill Van Kull	40	45	800	2000
Newark Bay Main (South & Middle Reach)	40	45	800	2200
NB Port Elizabeth Channels	40	45	290-500	800
NB Port Newark Channels	40	Same	290-500	800
Arthur Kill to Gulfport	35	41/40	500-800	800
AK Gulfport to Perth Amboy	35	Same	500 – 600	800
Bay Ridge and Red Hook	40	Same	1200-1750	1750
Buttermilk	35/40	Same	1000	2100

Table E1 Existing Navigation Channels and Anchorage Areas				
Channel	**Depth (ft mlw)**		**Width, W/O Proj. (ft)**	
	Existing	**W/O Project**	**Channel**	**Max in Bend/ Entrance**
Port Jersey	38	41	370	1500
Claremont	27	Same	300	600
NJ Pierhead	20	Same	500	800
Red Hook Anchorage	35/40/45	Same		
Gravesend Anchorage	47	Same		
Stapleton Anchorage	40-70	Same		

PHYSICAL CONDITIONS

Climate

E19. New York Harbor has a predominantly continental climate of warm summers and cool winters with some maritime influence. This results in frequent short-term meteorological changes. Southeast winds, often in the form of local sea breezes, have a moderating effect on temperature, particularly during the spring and summer months.

E20. General climatic conditions in New York Harbor are described herein from National Weather Service surface observations at nearby Newark Airport. They are based upon 68 years of records as summarized in the NOAA National Climatic Data Center – Local Climatological Data Annual Summary. Predominating winds are from the Southwest. Winds from the Southwest are prevalent from May to December; winds from the Northwest are prevalent from January to April. The average annual wind speed is 10.2 mph, with calm winds occurring 2.9% of the time.

E21. The mean annual temperature is 54.1 degrees F, with the maximum extreme of 105 degrees F occurring in July 1993, and minimum extreme of –8 degrees F occurring in January 1985. Temperatures of 90 degrees F and above occur, on the average, of 23 days/year, while temperatures of 0 degrees or less occur less than 1 day/year. The average relative humidity measures 64%.

E22. The average annual precipitation is about 43 inches/year and is distributed equally throughout the year. The mean average snowfall is 27.4 inches/year. Snowfall of 1 inch or more occurs on about 7 days/year. Occurrences of light freezing rain and drizzle average a total of about 6.9 and 7.2 days/year, respectively. Heavy fog occurs on the average of 16 days/year.

Tides

E23. The tide in New York Harbor is semi-diurnal, with a period of approximately 12.4 hours. In each tidal day of 24.8 hours, two high tides and two low tides occur, with one of the high tides higher than the other. The mean tide range at the Battery is 4.56 ft, the spring tide range is 5.52 ft. The highest observed tide at the Battery was 10.23 ft above mlw, occurring on 9/12/60 (Hurricane Donna). The lowest observed tide level was –4.07 ft mlw, occurring on 2/2/76. The plane of mean low water (mlw) is 1.66 ft below the National Geodetic Vertical Datum (NGVD) 1929; mean lower low water (mlw) is 1.88 ft below NGVD. Tide ranges at various locations through out New York Harbor and their relative time differences, extracted from the NOAA-NOS Tide Tables 1999, are provided in **Table E2** below.

Currents

E24. Tidal currents in New York Harbor are moderate, with average maximum flood currents ranging from 0.6 to 1.8 knots, and average maximum ebb currents ranging from 0.4 to 2.3 knots. At the Narrows, ebb currents are typically stronger than flood currents, with a maximum ebb current of 2.7 knots coinciding with spring tide. At Bergen Point, flood currents are typically

Table E2
Tide Data

Location	**Tide Range (ft)**		**Time Difference (h:mm)**	
	Mean	**Spring**	**High Water**	**Low Water**
The Battery	4.56	5.52	0	0
Ft. Hamilton/ The Narrows	4.7	5.7	-0:26	-0:22
Bayonne Br/ Bergen Point	5.0	6.05	-0:07	+0:05
Port Newark	5.1	6.1	+0:03	+0:21
Sandy Hook	4.66	5.60	-0:28	-0:29

stronger than ebb, with the maximum flood currents of up to 2.6 knots coinciding with spring tide. High water slack tide at the Narrows occurs approximately 1.5 hours after high water at the Battery; high water slack tide at Bergen Point occurs approximately 1 hour before high tide at the Battery. The currents at Ambrose Light are weak, averaging 0.2 knots. Extracted from the NOAA-NOS Tidal Current Tables 1999, tidal currents at various other locations through out New York Harbor and their relative time differences are provided in **Table E3** below.

Salinity

E25. Seasonal salinity variations within the New York Harbor estuary are primarily a function of the variation in the fresh water discharges of the Hudson River (and Passaic and Hackensack Rivers to a lesser extent), with the lower salinity levels in the spring and summer correlating directly with the high spring runoff. The harbor can be considered well mixed with bottom levels slightly higher than surface concentrations. Salinity concentrations can vary by several parts per thousand (ppt) throughout the tidal cycle.

E26. In the Upper Bay, typical salinity concentration of 25 - 28 ppt occur during low flow conditions and drop to 20 – 25 ppt during periods of higher freshwater discharges. Within the Arthur Kill, salinity levels range from a low of 12 ppt to a high of 20 ppt.

Table E3
Current Data

Location	Ave Max Current (knots)		Time Difference (h:mm)	
	Flood	Ebb	Flood	Ebb
Ambrose Chan. @ Transect	1.6	1.7	-1:10	-0:07
The Narrows	1.7	2.0	0	0
Anchorage Chan. Near Red Hook	1.3	2.3	1:06	0:52
Bergen Point @ Bayonne Bridge	1.8	1.4	-2:13	-1:44
Kill Van Kull @ Con. Hook	1.3	1.9	-2:08	-1:43
Arthur Kill @ Elizabethport	1.4	1.1	-0:09	+0:04
NewarkBay @ South Reach	0.7	0.7	-1:45	-1:06

Sedimentation

Sources

E27. Sedimentation within Ambrose Channel is caused primarily by offshore wave energy, which produces the westward littoral transport of sand along the south shore of Long Island as well as the northward littoral transport along the New Jersey shore and Sandy Hook. This wave energy also results in the movement of sand across the East Bank Shoal on the east side of Ambrose Channel and Romer Shoal south west of Ambrose Channel, which deposits into Ambrose Channel.

E28. Estuarine sediments within New York Harbor have a variety of sources. For the interior channels within the New York Harbor estuary, the primary sources of sediment are the Hudson, Passaic and Hackensack Rivers as well as other tributary rivers, and wastewater discharges from combined sewer outfalls (CSO's) and storm sewers. To a lesser extent, the resuspension of bottom sediments and local runoff contribute sediment as well.

Rates

E29. Sedimentation rates were developed from the New York District navigation channel maintenance dredging records. The dredging records include dates, pay quantities dredged, and locations for both maintenance dredging and new work construction for most of the channels within the Port. Typically, the time period for the analyses began with the most recent new work construction, since any shoaling rates prior to that time would not be applicable to the current channel configuration. The average maintenance rate was determined by dividing the total volume of maintenance material removed by the number of years between the last maintenance operation and the last new work construction. Historically, the pay yardage (the material within the channel prism plus paid overdepth) was recorded rather than gross yardage (total material removed). (Most recent records include both pay and gross volumes). Utilizing the gross yardage in the analyses would better predict the actual sedimentation rate. However, the pay yardage was used since it is more suited for determining the cost of the channel maintenance, and with that, the increased channel maintenance cost due to the channel deepening.

E30. Ambrose Channel was last improved in 1952. Between 1952 and 1984, 20 separate maintenance operations were performed, resulting in an average annual maintenance rate of approximately 400,000 cy/yr. Since 1984, sand mining within or adjacent to Ambrose Channel has eliminated the need for maintenance dredging. Currently there are approximately 371,000 CY of maintenance material within the channel prism.

E31. Anchorage Channel was last improved in 1953. Between 1953 and 1973, 4 separate maintenance operations resulted in an average maintenance rate of 22,000 cy/yr. for that time period. Anchorage channel has not required maintenance dredging since

1973. Currently there are approximately 12,000 CY of maintenance material within the channel prism.

E32. Kill Van Kull was last improved in 1994 when it was deepened to 40 ft. Since that time, no maintenance dredging has been performed. However, in 1997, a reprofiling operation leveled approximately 4,000 CY. (Reprofiling consists of dragging a heavy beam over the channel bottom to eliminate high shoals).

E33. Newark Bay was last improved in 1990, when it was deepened to 40 ft. Since that time, two maintenance operations have occurred. In 1997, 205,000 CY were removed from the South Elizabeth and Elizabeth Pierhead Channels, and in 1998, 416,000 CY were removed from the Elizabethport Channel. This results in an average shoaling rate of 78,000 cy/yr.

E34. Arthur Kill (N. Shooters Is to Gulfport) was last improved in 1962. The Shooters Island Dike was rehabilitated in 1964. Since that time, there have been 6 maintenance operations in the North of Shooters Island Reach, resulting in an average shoaling rate of 82,000 cy/yr. The Elizabethport and Gulfport reach was maintained in 1984 and then most recently in 1999, resulting in an average shoaling rate of approximately 5000 cy/yr.

E35. Bay Ridge and Red Hook Channels were last improved in the 1940's. Since 1960, there have been 27 maintenance operations, resulting in an average annual maintenance rate of approximately 520,000 cy/yr.

E36. Port Jersey Channel is not a Federal Channel. A 200 ft wide channel was deepened to 38 ft by the locals in 1998. The base condition of Port Jersey Channel is assumed to be the 41 ft channel as proposed in the 1992 GDM. Prior to the last deepening, sedimentation rates for the 35 ft channel were calculated to be .15 in/yr. The GDM predicted a sedimentation rate of .21 in/yr. for the 41 ft channel, which would result in a maintenance rate of approximately 58,000 cy/yr.

E37. Claremont Channel is not a Federal Channel. No historic dredging records are available. The 1992 GDM predicted a sedimentation rate of .16 in/yr. for the existing channel, which would result in a maintenance rate of approximately 25,000 cy/yr.

E38. NJ Pierhead Channel was last improved in 1961. The channel was maintained in 1964 and 1973, resulting in an average maintenance rate of 40,000 cy/yr. for that time period. The NJ Pierhead Channel has not been maintained since 1973.

E39. Bay Ridge Flats Anchorage was last improved in 1975. Since that time, there have been 8 maintenance operations resulting in an average maintenance rate of 145,000 cy/yr.

E40. Gravesend Anchorage was last improved in 1984. Since that time, there have been 4 maintenance operations resulting in an average maintenance rate of 28,000 cy/yr.

E41. **Table E4** contains a summary of maintenance requirements for the various channels within the Port. Greater confidence should be placed on the maintenance rates for those channels where long term dredging records over multiple dredging operations at the existing depths are available, such as Ambrose Channel, Bay Ridge Channel, Red Hook Flats Anchorage. The long term averages tends to eliminate the fluctuation in computed maintenance rates resulting from the inconsistencies in spatial extent and overdepth dredging in each maintenance operation. Short term rates developed from one or two maintenance operations will not be as accurate as long term rates for many reasons. A single maintenance operation that removes material from only a portion of the channel will not include material that may have shoaled in the remainder of the channel but is still below project depth. Also, the volume of overdepth material a dredging contractor removes may vary, resulting in different post maintenance and post new construction depths. Statistically, longer periods of record and more data are always preferred when developing long term trends.

E42. As can be seen in the summary table, the short term rates for the Kill Van Kull and Newark Bay do not agree well with the published information from the GDM. This may be due to the fact that portions of the Kill Van Kull and Newark Bay channels were constructed in rock or hard material that provided an additional 2 ft of safety clearance (down to –42 MLW). These channels would only require maintenance if they shoaled in above project depth (-40 MLW), allowing two ft of accumulation. In the short time frame since the new work construction was completed, this accumulated material tends to underestimate maintenance rates. The last column in the above table represents the best estimate of the without project (base) conditions shoaling rates based upon available data. Long term shoaling rates are utilized wherever available. For those channels recently improved, or channels where the base conditions are different from existing conditions, previously published data projected for the improved conditions or base conditions are used.

Table E4 Existing Maintenance Requirements						
Channel	**Last Improv.**	**Last Maint'd**	**Average Mainten. Interval (years)**	**Average Mainten. Rate (Existin) (cy/yr.)**	**Previous Published Rate (Adj to Base) (cy/yr.)**	**Use (Base) (cy/yr.)**
Ambrose	1951	1984	1.7 yrs	400,000		400,000
Anchorage	1953	1973	6.7	0		0 (1)
K V K Con Hook	1994	1997	3.0	1300	20,800	28,000
K V K Bergen Pt	1994	(1)			4,000	4000
Newark Bay Main	1990	1997	3.0		211,000	211,000
NB Port Elizabeth	1990	2001	7.5	78,000	121,700	121,700
NB Port Newark	1990	2002			226,200	226,200
AK N.Shooters Is	1962	1999	5.7	82,000	154,000	115000 (3)
AK Eliz. – Gulf	1964	1999	14	5,000	0	7000 (3)
Bay Ridge (+ RH)	1940	1992	1.2	520,000		520,000
Port Jersey	1998	1984	10 (4)		58,000	58,000
Claremont			12.5 (4)		25,000	25,000
NJ Pierhead	1961	1973	6.0	40,000		40,000
Red Hook Anch.	1975	1992	2.1	145,000		145,000
Gravesend Anch.	1984	1998	4.7	28,000		28,000
Stapleton Anch.	-	-	-	0		0

(1) No maintenance since last improvement

(2) Not maintained in past 25 years

(3) Existing rate adjusted to base conditions

(4) From previously published reports

PRELIMINARY CHANNEL DESIGN

Design Criteria

E43. The navigation channels in this study were designed in accordance with the guidelines and criteria contained in the following documents:

- EM 1110-2-1613 "Hydraulic Design of Deep Draft Navigation Channels", 8 April 1983, 8 January 1994 (Draft Revision)
- ER 1110-2-1404 "Hydraulic Design of Deep Draft Navigation Channels", 31 January 1996
- PIANC PTC II-30 "Approach Channels – A Guide for Design", June 1997

E44. In addition, numerous coordination meetings were held with the various pilot organizations (Sandy Hook Pilots, harbor pilots, docking pilots, etc), the US Coast Guard, and local sponsors to insure that the proposed channel improvements would provide the safest navigation for all vessels while meeting the needs of the port facilities and the maritime community.

Design Vessels

E45. The design vessels are based upon economic projections of the vessels most likely to call on the Port of New York and New Jersey in the near future. Two design vessels were selected to represent the future fleet – a Maersk K-Class container ship and a Suezmax tanker. The dimensions of these design vessels are provided in **Table E5**.

Table E5
Design Vessel Dimensions

Vessel	**Maersk K-Class**	**Suezmax**	**Maersk S-Class**
Type	Container Ship	Tanker	Container Ship
Maximum Draft	46 ft	55 ft	47.5 ft
Length Overall (loa)	1044 ft	926 ft	1138 ft
Length between Perpindiculars (lpp)	991 ft	880 ft	1088 ft
Beam	140 ft	144 ft	140 ft

E46. Also included in the table are the dimensions of the Maersk S-Class container ship. Although not considered as a design vessel for this study at this time, a check was made to determine if the S-class vessel could use the proposed channels. The draft of this ship is 1.5 ft greater than the design vessel. This could safely transit the proposed 50 ft channels if it light loaded to a draft of 46 ft, or if it scheduled its transits to coincide with 1.5 ft of additional tide above mlw. The width of the navigation channels designed for the K-class would be adequate for the S-class as well, since the beam of the S-class is the same as that of the K-class, and the width of the channel is a function of the vessel beam.

E47. The channel features designed as a function of the vessel length include the turning basins which are a direct multiple of the vessel length, and the width of channel bends which are function of the ratio of the channel bend radius to ship length. The three major turning areas, Anchorage Channel for ships entering Port Jersey, Newark Bay for ships entering South Elizabeth and Elizabeth Channels, and the Bergen Point Bend for ships entering Howland Hook, are all adequate for both vessels. The 1600 ft turning basin at Bay Ridge channel is only 1.4 times the length of the S-class, which may restrict the turning maneuver to a period around slack tide when currents are less than 0.5 knots.

E48. It is expected that the 9% decrease in the ratio of the channel bend radius to ship length of the S-class as compared to the K-class vessel will have a minimal effect on the channel width in bends. The detailed design of the individual bends will be conducted in the design phase of the study utilizing ship simulation studies.

Pathways

E49. The design of the various channels was conducted utilizing the concept of pathways, wherein each pathway defines the entire ship transit from deep water to port. This was necessary since the design of a particular channel would depend not only upon the design vessel but also upon the final destination of that vessel. For example, in the evaluation of Kill Van Kull for vessels entering the Arthur Kill, tankers would require a 60 ft channel straight through Bergen Point, while container ships would require a 50 ft channel plus a turning basin for backing into or out of the Arthur Kill. To simplify the analyses, these paths coincided with economic reaches. 7 pathways, each of which have Ambrose Channel and a portion of Anchorage Channel in common, were proposed based upon ship destination.

- Pathway 1 - Kill Van Kull, Newark Bay to Port Elizabeth
- Pathway 2 - Kill Van Kull, Arthur Kill to Howland Hook
- Pathway 3 - Kill Van Kull, Arthur Kill to Gulfport
- Pathway 4 - Port Jersey Channel
- Pathway 5 - Bay Ridge Channel
- Pathway 6 - Red Hook Flats, Stapleton and Gravesend Anchorages for Containerships

- Pathway 7 - Red Hook Flats, Stapleton and Gravesend Anchorages for Tankers

E50. Final destinations were subsequently modified based upon facilities proposed in the final “Without Project” and “With Project” conditions. For more details, see “Without Project Conditions Report” and “With Project Conditions Report”

Channel Alignment

E51. The alignment of the proposed channels follows the existing alignment in most cases. Where new or expanded facilities are proposed, the channels are aligned to provide a berthing area of 150 ft between the channel and the proposed bulkhead.

Channel Width

E52. The channel width for the entrance channel, Ambrose Channel, was based upon guidance contained in PIANC PTC II-30 for outer channels exposed to open water. The guidance takes into account such factors such as ship speed, prevailing cross winds, both cross currents and longitudinal currents, significant wave height, aids to navigation, bottom surface, depth to draft ratio, cargo hazard level, bank conditions and traffic density. The results of the analysis indicate that, for the severe wind, wave and current conditions that could be encountered offshore, the recommended channel width is approximately 2100 ft for two way traffic. However, based upon the consistency of the ship track plots from the ship motion study, and meetings with the various harbor pilots, the existing width of 2000 ft is judged to be adequate.

E53. The width of the proposed interior channels was designed in accordance with guidance contained in EM 1110-2-1613. This guidance is based upon such factors as traffic pattern (one way or two way), design vessel dimensions, channel cross section shape, current speed and direction, quality of aids to navigation and variability of channel and currents. For one way channels, widths can vary from 2.5 times the vessel beam for a well defined channel with minimal currents to 5.5 times the vessel beam for a variable channel with stronger currents. Two way channels can vary from 4 to 8 times the vessel beam. The recommended channel widths for the various navigation channels within the Port are provided in **Table E6**.

E54. The channel width in bends is increased because the swept path of a ship making the turn is wider than the path of the ship in a straight channel. The width of the swept path is dependent upon the ratio of the turn radius/ship length and the deflection angle. Other factors to be taken into account are ship yaw angle, ship dimensions, ship rudder angle, bank effects, aids to navigation and current and other physical conditions. The guidance recommends turn width increase factors (a multiple of the vessel beam) of 0 to 2.0, with a recommended turn radius ratio not less than 3, based upon the maneuverability of the vessels. However, many of the interior channel bends in the Port have turn radius ratios less than 3. These channel bends are safely transited since vessels typically utilize tug support and/or bow and stern thrusters. Turn width increase factors for these channel bends may increase to 3 or more.

Table E6 Recommended Channel Widths									
		Cross section							
	Traffic	**Type**	**Config.**	**Cur-rent**	**Beam Multi-plier**	**Ship – Beam (ft)**	**Width (ft)**	**Exist. Width (ft)**	**Use (ft)**
Ambrose	2 Way	Trench	Constant	High	14.8 15.3	T-144 C-140	2131 2142	2000	2000
Anchorage	2 Way	Trench	Constant	High	6.5	T-144	936	2000	2000 (1)
Kill Van Kull	2 Way	Trench	Constant	Mod.	5.5	T-C av 142	781	800	800
Newark Bay	2 Way	Trench	Variable	Mod.	5.5	C-140	770	800	800
Newark Bay S. Elizabeth	1 Way	Trench	Constant	Mod.	3.25	C-140	455	290	500
Arthur Kill	1 Way	Trench	Variable	Mod.	4.0	T-144	576	500-600	600 (2)
Bay Ridge	1 Way	Trench	Constant	High	4.0	C-140	560	1200-1750	600
Port Jersey	1 Way	Canal	Constant	Mod.	3.0	C-140	420	200	500
Claremont	1 Way	Trench	Constant	Mod.	3.25	C-140	455		500
NJ Pierhead	1 Way	Trench	Constant	Mod.	3.25	C-140	455	500	500

(1) Deepening of the full width (2000 ft.) of the existing channel is recommended due to the high volume of traffic and the fact that Anchorage Channel provides access to anchorage areas and adjacent channels on both sides of the harbor.

(2) Although a 600 ft. channel is recommended, physical constraints, such as bulkheads, bridge piers and berthing areas, preclude full widening of the channel at certain locations.

Channel Depth

E55. The maximum channel depth is designed to permit the safe and efficient transit of a fully loaded design vessel at any phase of the tide. The determination of the navigation channel depth is based upon the loaded static summer salt water draft of the design vessel, plus allowances for various underkeel clearances such as ship squat, water density, ship response to waves, and safety clearance. See **Figure E2** below. The selection of the actual project design depth is determined by economic analysis of the expected project benefits compared with the project cost at various alternative depths. Refer to the economic appendix for details of the optimization analyses.

Squat

E56. Squat is the tendency of a vessel underway to sink and trim in the waterway, thereby reducing the underkeel clearance. The sinkage is due to the reduction in pressure on the ship's hull resulting from the increased water velocity passing the ship. In a shallow or confined channel, squat tends to increase because the blockage caused by the ship creates a higher water velocity around the hull, lowering the actual water surface. Another component of squat is dynamic trim, or the change in pitch of a vessel due to the forward motion. Generally it has been found that most full bodied ships such as tankers and bulk carriers trim down at the bow, and sleeker containerships trim down at the stern. The magnitude of the squat depends on several factors including ship speed, dimensions, ship blockage coefficient, and channel depth. Allowances for squat for various channels within the Port are provided in **Table E7** below.

Table E7
Ship Squat (ft)

Channel	Width	Container	Tanker
Ambrose	2000 ft	See Ship Motion Study Below	
Anchorage	2000 ft	1.3	2.0
Kill Van Kull	800 ft	1.0	1.5
Arthur Kill	500 ft	1.2	1.9
Bay Ridge	600 ft	1.2	N/A

Ship Motion from Waves

E57. The ship response from waves can be an important factor in the design of navigation channels. The ship motion from waves is more pronounced in entrance or bar channels, which tend to be exposed to ocean waves, than it is in interior channels where wave energy is limited. There are 3 modes of vertical motion: pitch (rotation about the transverse axis), roll (rotation about the longitudinal axis) and heave (vertical displacement), as shown on **Figure E3**. The magnitude of vertical motion is a function of many factors, including wave parameters (height, period, duration, direction, celerity), ship characteristics (length, beam, draft, speed direction of transit), currents, winds, etc. The ship motion due to waves in Ambrose Channel was determined by a numerical modeling study conducted at WES.

Ship Motion Study

E58. A vertical ship motion study was conducted at WES to determine the total underkeel clearance required for the design vessels in Ambrose Channel. The study included wave modeling in the NY Bight and Lower Bay to determine incident wave conditions, a ship tracking study (utilizing DGPS receivers on board vessels inbound and outbound) to measure vertical ship motions, and a ship motion model to predict the vertical ship motion of vessels under various wave conditions.

E59. The ship transits monitored in the ship tracking study were modeled using wave data obtained at the time of the ship transit and ship models that represented the type, size and draft of the vessels, in an attempt to reproduce the actual vertical motion of the ships in transit. Adjustment factors were determined based upon a comparison of the measured data from the tracking study and the computed data from the ship motion model. The ship motion model was then applied for design conditions, evaluating both design vessels (tanker and container ship) for both inbound and outbound transits, and normal as well as design (1 year) wave conditions.

E60. The results of the model study concluded that, for the design wave condition, the design container ship would require 7 ft of underkeel clearance and the design tanker would require 6 ft of underkeel clearance. Details of the model study can be found in Draft Report “Entrance Channel Depth Design, Ambrose Channel, New York Harbor”.

Water Density

E61. The design draft is given in relation to ocean salt water, which has a salinity concentration of 33 ppt. When a vessel enters a port with brackish or fresh water, the draft of the vessel will increase in proportion to the decrease in water density. The decrease in unit weight of water, from 64.0 lb/cu ft at 33 ppt to 62.4 lb/cu ft at 0 ppt, will increase the draft of a vessel by 2.6%. **Table E8** contains the water density allowances for the design vessels for the various channels within the port.

Safety Clearance

E62. A safety clearance is provided between the hull of the ship in transit and the design channel bottom to minimize the risk of damage to the vessel due to bottom irregularities and debris. The safety clearance also accounts for uncertainties such as tide stage, survey tolerances, etc. A safety clearance of 2 ft is provided for channels with a soft bottom; for channels consisting of rock or other hard material such as consolidated sand or clay, the safety clearance is increased to 4 ft. The additional 2 ft in safety clearance is required only for the initial construction of the navigation channel in hard material. In time, as the channel begins to shoal, a safety clearance of 2 ft will be maintained since the recently deposited material tends to be soft.

Table E8
Water Density Allowances

Location	Channel	Salinity (ppt)	Density (lb/ft3)	Container (ft)	Tanker (ft)
Lower Bay	Ambrose	33	64.0	0	0
Upper Bay	Anchorage Bay Ridge Port Jersey	20	63.4	0.4	0.5
The Kills	Kill Van Kull Newark Bay Arthur Kill	12	63.0	0.7	0.9

Total Underkeel Clearance

E63. The total underkeel clearance required for initial construction for the various channels in the port are provided in **Table E9** below:

Table E9
Total Underkeel Clearances (ft)

	Ambrose		**Anchorage**		**Kill Van Kull**		**Arthur Kill**		**Newark Bay**	**Bay Ridge**	**Port Jersy**
Vessel Type	C	T	C	T	C	T	C	T	C	C	C
Vessel Draft	46	55	46	55	46	55	46	55	46	46	46
Squat	See Below		1.3	2.0	1.0	1.5	1.2	1.9	1.2	1.2	1.2
Wave Motion			0	0	0	0	0	0	0	0	0
Water Density			.4	.5	.7	.9	.7	.9	.7	.4	.4
Safety Clearance			2	2	4	4	4	4	4	2	4
Total Underkeel Clearance	7.0*	6.0 *	3.7	4.5	5.7	6.4	5.9	6.8	5.9	3.6	5.6
Required Channel Depth (Calculated) Use	53 53	61 61	49.7 50	59.5 60	51.7 52	61.4 62	51.9 52	61.8 62	51.9 52	49.6 50	51.6 52
Maintained Channel Depth	53	61	50	60	50	60	50	60	50	50	50

C – Container ship, T – Tanker, * - From Ship Motion Study

DESCRIPTION OF THE PRELIMINARY CHANNEL IMPROVEMENT ALTERNATIVES

Pathway 1 – Kill Van Kull, Newark Bay (Design Vessel – Container Ship)

E64. Ambrose Channel, deepened to –53 ft mlw, will remain at its present width of 2000 ft and will follow its present alignment. It will be extended 2400 ft seaward along its present bearing out to deep water. Ambrose Light Tower was recently relocated 1.5 nautical miles ESE of its present location. A large mound (possibly construction rubble?) immediately NW of the present Ambrose Light Tower has been removed to –55 mlw. The pilot area is situated between the new tower and the sea buoy marking the entrance to Ambrose Channel. The pilots use this area to bring their pilot boat along side the incoming and outgoing vessels for boarding.

E65. Anchorage Channel, deepened to –50 mlw, will remain at its present width of 2000 ft, but will be deepened only from the Narrows to the junction with the Kill Van Kull.

E66. Kill Van Kull, deepened to –52 mlw, will remain at its present width of 800 ft and will follow its present alignment.

E67. Newark Bay South Reach, and Elizabeth Channel, deepened to –52 mlw, will remain at their present width and will follow its present alignment. Improvements to the main channel will extent 1500 ft north of the Elizabeth Channel to facilitate vessels turning and backing into port. The South Elizabeth Channel will be widened to 500 ft. The berthing areas along the Elizabeth Port Authority Marine Terminal will be widened to 150 ft.

E68. The layout of Pathway 1 is shown in **Figure E4.**

Pathway 2 - Kill Van Kull, Arthur Kill to Howland Hook (Design Vessel – Container Ship)

E69. Ambrose Channel, Anchorage Channel and Kill Van Kull will be improved as previously described in Path 1. In addition, the portion of the Newark Bay South Reach immediately adjacent to the Kill Van Kull will be deepened to –52 mlw to provide a turning basin for container ships to turn and back into (or out of) Howland Hook.

E70. The Arthur Kill will be deepened to –52 mlw from the junction with the Kill Van Kull to the western limit of the Howland Hook facility, along the alignment of the 41 ft (without project) channel. In addition, the channel will be widened to the north opposite Howland Hook back to the limits of the existing channel.

E71. The layout of Pathway 2 is shown in **Figure E5.**

Pathway 3 - Kill Van Kull, Arthur Kill to Gulfport (Design Vessel – Tanker)

E72. Ambrose Channel, deepened to –61 mlw, will remain at its present width of 2000 ft and will follow its present alignment. It will be extended 5400 ft seaward along its present bearing out to deep water. The mound of construction rubble would be removed as previously described in Path 1.

E73. Anchorage Channel, deepened to –60 mlw, will remain at its present width of 2000 ft, but will be deepened only from the Narrows to the junction with the Kill Van Kull.

E74. Kill Van Kull, deepened to –62 mlw, will remain at its present width of 800 ft and will follow its present alignment. Tanker traffic in the Kill Van Kull is one way (westbound). Tankers enter the Kill Van Kull from Anchorage Channel and sail west into the Arthur Kill. These tankers depart southbound through the Arthur Kill and Raritan Bay. Theoretically, a step channel deepened for tankers (60ft mlw) to accommodate one way traffic would be adequate. However, there are nine separate bends in the Kill Van Kull as it meanders between New York and New Jersey. In such a channel, large deep draft vessels tend to straighten their course to the greatest extent possible, in effect, crossing from one side of the Kill Van Kull to the other. Should an oncoming vessel be encountered, each vessel must maneuver to the outside of the channel to pass at a safe location. Considering the vessel traffic practices, size of the vessels, the density of traffic, the hazardous nature of the cargo, the rock channel bottom and the problems associated with marking a step channel, a step channel for one way traffic in the Kill Van Kull was judged to be unsafe. All pilots interviewed concurred with that decision. Through the Bergen Point Reach, however, the channel improvement would remain a constant 800 ft since tankers entering the Arthur Kill would exit southbound and not turn around at Bergen Point as containerships do.

E75. The Arthur Kill, deepened to –62 mlw from Bergen Point to Howland Hook, would be deepened along the same alignment as described for Path 2. From Howland Hook to Gulfport, the channel would be widened, and in some cases narrowed, to provide a 550 ft channel. The narrowings, from 600 ft to 550 ft, are necessary to provide adequate berthing areas of 150 ft for the facilities at Tosco and GATX outside the limits of the channel.

E76. The layout of Pathway 3 is shown in **Figure E6.**

Pathway 4 - Port Jersey Channel (Design Vessel – Container Ship)

E77. Ambrose Channel will be improved as previously described in Path 1.

E78. Anchorage Channel, deepened to –50 mlw, will remain at its present width of 2000 ft, but will be deepened only from the Narrows to a point 1000 ft north of the junction with Port Jersey Channel.

E79. Port Jersey Channel deepened to –52 mlw, will be improved to a width of 500 ft between the Global Marine Terminal and MOTBY peninsulas. The entrance flare will be 1500 ft at the junction with Anchorage Channel and taper to 500 ft at the intersection with the NJ Pierhead Channel. The wide flare of the approach channel was necessary due to the fact that vessels inbound on a flood tide will be turning broadside across the current and be set (drift) to the north.

E80. The existing 1200 ft turning basin at the head of Port Jersey Channel is inadequate for the k-class container ship, which has a length over all of 1044 ft. Widening of the existing turning basin is not a practical solution since it would require the construction of sheet pile retaining structures to stabilize existing structures. Without a turning basin, vessels must either back into or out of Port Jersey. In order to facilitate the backing maneuvers, the northern channel limit is straightened, removing a narrow portion of the New Jersey flats. Deepening Anchorage Channel 1000 ft to the north will permit inbound vessels bring the bow past Port Jersey Channel, and readily swing the stern around and then back into port.

E81. The layout of Pathway 4 is shown in **Figure E7.**

Pathway 5 - Bay Ridge Channel (Design Vessel – Container Ship)

E82. Ambrose Channel will be improved as previously described in Path 1.

E83. Anchorage Channel, deepened to –50 mlw, will remain at its present width of 2000 ft, but will be deepened only from the Narrows to the junction with Bay Ridge Channel.

E84. The proposed width of Bay Ridge Channel, deepened to –50 mlw, will be 600 ft, reduced from the current width of 1200 to 1750 ft. The width of the existing channel was based upon the fact that the existing finger piers required that a ship turn perpendicular to the channel before berthing. The 600 ft one way channel would be adequate for the proposed facility with two deep draft berths. The proposed turning basin, with a diameter of 1600 ft, is located opposite the terminal, enabling vessels to back out of or into port.

E85. The layout of Pathway 5 is shown in **Figure E8.**

Pathway 6 – Red Hook Flats Anchorage, Stapleton Anchorage and Gravesend Anchorage (Design Vessels – Containership)

E86. Ambrose Channel will be improved as previously described in Path 1.

E87. Anchorage Channel, deepened to –50 mlw, will remain at its present width of 2000 ft, but will be deepened only from the Narrows to the northern limit of Red Hook Anchorage.

E88. Red Hook Flats Anchorages 21B and 21C would be deepened to –50 mlw. In addition, the portions of Areas 21B and 21C adjacent to the existing Bay Ridge Channel would be expanded eastward 600 – 1100 ft to the channel limits of the proposed Bay Ridge Channel.

E89. Stapleton Anchorage and Gravesend Anchorage would be deepened to –50 mlw at their present limits.

E90. The layout of Pathway 6 is shown in **Figure E9.**

Pathway 7 – Red Hook Flats Anchorage, Stapleton Anchorage and Gravesend Anchorage (Design Vessels – Tanker)

E91. Ambrose Channel will be improved as previously described in Path 3.

E92. Anchorage Channel, Red Hook Flats Anchorages 21B and 21C, Stapleton Anchorage and Gravesend Anchorage, will be deepened to –60 mlw to the limits described in Pathway 6

E93. The layout of Pathway 7 is also shown in **Figure E9,** since it is the same as the layout for Pathway 6.

IMPACTS OF THE PROPOSED CHANNEL

Numerical Modeling Study

Background

E94. A numerical modeling study, conducted at Waterways Experiment Station (WES), was formulated in cooperation with CENAN-EN-HH personnel as the most effective means of studying the effects of the deepening of the navigation channels within the New York and New Jersey Harbor. The effects of concern to this study are hydrodynamics, and sedimentation. Water quality concerns are being independently addressed by a parallel study.

Model Approach

E95. The issues that have a bearing on sediment transport within the harbor area are those that affect the basic hydrodynamics. The effects of the project on the hydrodynamics when properly addressed will, in turn, result in appropriate estimates of influences of the project on the sedimentation environment. In deepening the navigation channels, the potential exists for the accentuation of the effects of density variations over the water column associated with salinity intrusion on currents. Deepening of the channel will lead to reduced current velocities within the channel, less vertical mixing and the ability for the salt water to move farther upstream. The modeling approach taken for the study therefore must deal with these effects on the salinity regime in the vertical. Therefore, the model study here includes the use of a three-dimensional hydrodynamic/sediment transport model (RMA-10-WES). That model was applied to the entire domain of the study, but focuses attention on the fine sediments of the inner harbor channels above the Narrows where the greatest effects on density currents are expected.

Two Dimensional (2-D) Model

E96. The sedimentation within Ambrose Channel is primarily the result of sand shoaling associated with the littoral supply of sediment. For the Ambrose Channel, where the sedimentation is wave-dominated, the effects of the changes in channel depth on density currents are assumed to be overwhelmed by the effects of the wave environment. Therefore, the sediment transport modeling for the Ambrose Channel was performed using the two-dimensional depth-averaged version of the TABS modeling system: RMA-2 for hydrodynamics and SED-2D-WES for the sediment transport. The models were modified for this study to include the effects of the wave climate on the currents. A wave model was developed to propagate waves from deep water into the harbor and to develop locally generated wind waves. The wave field was then interpolated onto the TABS-MD finite element mesh and the radiation stresses computed and included in the momentum equations for the model. This approach resulted in wave induced currents within the littoral zone that, when combined with the tidal forcing, lead to very complex current patterns. The sediment transport model was then driven by both the currents from the combined wave and tidal forcing for net water movement, and the wave field itself for the additional shear stresses associated with the short period orbital velocities. The wave induced current velocity capability was also added to the three-dimensional model.

Model Description

E97. The mesh developed for the Ambrose Channel sedimentation study has 29511 nodes and 9436 elements, as shown in **Figures E10 a & b**. The overall domain of the model includes a portion of New York Bight outward in a circular arc about 40 miles from Sandy Hook, approximately 100 miles of Long Island Sound from Montauk Point to East River, and most of the major tributaries to their head of tide. The Hudson River runs approximately 150 miles from the Battery to the head of tide at Albany, NY. The model includes Raritan River below Fieldview Dam and South River below Duhernal Dam, to its confluence with the Raritan River. The Passaic River below Dundee Dam and the Hackensack River below Oradel Dam are included in the mesh. All of the major bays in the harbor (i.e. Jamaica Bay, Raritan Bay, Upper Bay, and Newark Bay) are included with significant resolution.

2-D Model Verification

E98. The 2D model was verified for tidal propagation throughout the harbor using tidal amplitude variations and phasing as the measure of model performance. The prototype field tidal data was extracted from NOAA/NOS predicted tide tables. The model tidal forcings were selected as a repeating tide of an amplitude midway between a mean tide range and the average spring tide range. This was felt to be a representative tide and would serve well in the sediment transport simulations. Details of the tidal verification will be included in the draft modeling report.

E99. The current velocities in the harbor were verified against a set of acoustic Doppler current profilings (ADCP) collected by CEWES in 1994. The locations of these profiling cross sections and the comparison of the 2D model current velocity distribution with the depth-averaged velocities from the ADCP data will be included in the draft modeling report.

E100. The sediment transport verification was performed by developing a set of representative wave conditions to drive both the hydrodynamic model and the sediment transport model. Initial simulations with tide only, without wave energy, showed that negligible sediment movement occurred for the Ambrose channel. This validated the assumption that the sediment transport is dominated by the waves for the bar channel.

E101. A wave model (STWAVE) was developed to propagate waves from deep water into the harbor. Two grids were utilized. A seaward grid had a uniform spacing of 200 m. The boundary conditions for this portion of the model were derived from the sea buoy located near the outer grid boundary. The results of the 200 m grid were then used to develop the boundary conditions for the finer, 100 m grid. The results of the 100 m grid, which extended into the harbor, were interpolated onto the TABS finite element grid. The wave model is based on a spectrum of wave heights, periods and directions, and outputs significant periods, heights and directions over the grid domains. The wave propagation, refraction and diffraction were performed as a steady state computation. The wave conditions simulated are presented in **Table E10**. For the Ambrose channel simulations no locally generated waves were included because they have minimal impact on the channel shoaling when compared to the larger ocean waves.

E102. The “no wave” condition in the table was the collection of all the wave directions measured at the sea buoy that were moving away from the harbor. For the geometry of New York bight, that is essentially about 270 degrees of the wave directions.

Table E10
Wave Conditions Tested

Wave Period (sec)	Wave Direction (deg.)	Wave Height (m)	Frequency
No wave	All Other Directions	No wave	0.538
4	135	2.5	0.100
6	112	2.5	0.142
6	135	1.0	0.030
6	135	2.5	0.030
6	157	2.5	0.130
8	135	2.5	0.030
		Total	1.000

Three-Dimensional (3-D) Modeling

E103. The three-dimensional modeling effort was designed to assess the sedimentation issues associated with the channel deepening of the inner harbor channels. Inner harbor sedimentation is predominantly associated with fine sediments. The 3D model RMA-10-WES was applied using the cohesive sediment formulation of the model. The technical approach was to use the verified two-dimensional mesh developed for the bar-channel analysis as a starting point for the 3D-model mesh.

Mesh revisions

E104. The 3D-model domain was identical to the overall domain of the 2D modeling effort. This allowed the use of common boundary condition specifications. The model mesh from the 2D effort was revised so that overall less resolution was used in the ocean and Lower Bay portions of the mesh. The resolution was reduced in the vicinity of the Claremont channel, but resolution was added in the Newark Bay area.

3D Resolution

E105. The 3D mesh took advantage of the ability to specify certain zones of the system as 2D while limiting the 3D resolution to only the deeper channels of the harbor. The majority of the ocean area was modeled as 3D, with the zone of 3D resolution beginning at a distance where the water depth reaches 100 feet in the natural channel between the harbor and the bight. The 3D resolution is extended to the ocean shoreline into relatively shallow water, and is 2D into the surf zone. At the harbor entrance transect the model is 3D from Sandy Hook to Rockaway Point. Inside the transect the 3D resolution extends through the primary deep channels connecting the Lower Bay with Upper Bay via the Narrows and Arthur Kill via the Raritan bay channel. The shallower areas of Lower bay were simulated as depth averaged (2D).

E106. The deepest channels in the mesh were simulated with 3 elements over the water column. Because the velocity and salinity are represented by quadratic basis functions, this gives seven nodal values over the water column. This was believed to be adequate to resolve any vertical variations in the current velocity structure expected in the harbor.

Model Description

E107. The model RMA-10-WES is a three-dimensional (3D) finite element model that solves the full Navier-Stokes equations of motion. The model formulation includes the hydrostatic assumption in the vertical momentum equation. Turbulence closure is handled by the Boussinesq approximation, invoking an eddy viscosity. The eddy viscosity can either be set as a spatially varying constant or can be varied spatially and temporally computed by either a Peclet number specification or by the Smagorinsky method. The horizontal momentum equations also include the advective terms, coriolis forces, bottom friction, wind stress and wave induced stresses. The finite element formulation uses a mixed interpolation scheme of linear basis functions for water depth and quadratic basis functions for velocities and constituents (salinity, temperature and sediment concentration). Nonlinear terms in the equations are solved via a Newton-Raphson iterative scheme within each model time step. The time dependence terms are formulated using a finite difference method.

E108. The model utilizes the technique of marsh porosity, a statistical representation of the sub-element scale spatial variability in bathymetry or topography. This was used primarily in the study mesh to include the effects of the Hackensack Meadowlands. The marsh porosity parameters were set so that the water depth never went negative. This approach left a very thin layer of water (effective depth) in the wetlands at low tide that was hydraulically inactive due to the relationship between water depth and friction. The 3D-model mesh is designed to be a vertical modification to a 2D mesh by specifying the vertical resolution as a property of the 2D mesh.

Hydrodynamic Verification

E109. The 3D model was verified to two basic hydrodynamic conditions. The first verification test was a repetitive tidal condition with a forcing tide between a mean and spring tide range. This test was driven by the same boundary conditions as used in the 2D model verification of the same conditions. The second test was of a period in the late summer of 1995, as a portion of the Battelle data collection effort.

E110. The purpose of the repeating tide verification test was to provide a comparison to the general long-term tidal propagation and phasing within the harbor, for which extensive documentation has been performed. The conditions for the tides were a repeating tide of a period of 12.5 hours with an amplitude of between a mean and spring tide; 5.15 ft at Sandy Hook and 2.6 ft at Montauk Point in Long Island Sound. For this verification run the river inflows were set to mean flows. The time step in the model was 0.5 hour.

E111. The 3D model test for repeating tide was run for 125 hours to allow for the spin up of tidal energy and for the development of a dynamic equilibrium for the flow and salinity fields. The propagation characteristics within the harbor were then developed and compared with field observations extracted from the NOAA manual of tides.

E112. The 3D model was also run to verify the model against the Battelle 1995 data set. The verification period was for the period of 12-15-1995 through 12-30-95. The ocean boundary conditions for the Atlantic were developed by filtering and averaging the Battelle field data at Shark River Inlet and Jones Inlet. An amplification of 15 % was necessary to match the Sandy Hook tide signal. That amplification is consistent with previous modeling experience in modeling the harbor for specification of the ocean boundary in the Bight. The Long Island Sound boundary condition was developed from filtering the field data from NOS Montauk Point, Fort Pond Bay Station. These boundary conditions are summarized in the table below. The river inflows were taken from USGS data sources when available for September 1995, and when unavailable lower flows from historical data from September were approximated. The model was run for 100 hours with a time step of 0.5 hour.

Sediment Modeling

E113. The sediment model capabilities in RMA10-WES were implemented using a single sediment class. The hydrodynamic model was initialized and operated for 125 hours to reach a dynamic equilibrium with respect to flows and salinity fields. A 12.5 hour repeating tide and steady freshwater inflows (12,000 cfs in Hudson River) were used at the model boundaries. The last tidal cycle from this run was used repeatedly to drive the sediment model hydrodynamics.

E114. The sediment model bed was initialized with seven layers, which had solids content increasing vertically downward. The model was operated dozens of tidal cycles while currents and shear-stresses eroded the bed to bring the bed into quasi-equilibrium with the flow.

E115. The sediment model was adjusted by comparing suspended material concentrations to field data. No harbor-wide synoptic data sets exist. Data collected by Battelle in 1991 and the City of New York in 1990 and 1991 were used to compare to the model results. The goal was to reproduce reasonable suspended sediment concentrations, which were in quasi-dynamic equilibrium, which changed with tidal flows but whose mean values did not change appreciably between tidal-cycles. There is a large gap between freshwater and other input sediment sources, and total shoaling rates in the Harbor. By reproducing normal ranges in suspended solids concentration it was assumed that the model would be reproducing important sediment recirculation processes within the Harbor. Highest observed suspension concentrations occur in the Hudson River at the north end of Manhattan Island, and the model successfully reproduced a concentration maximum in this area. The salinity and density stratification effects are greatest in this area, and contribute to sediment trapping.

E116. After the model bed was eroded to equilibrium, the model water column was then re-initialized at 30 mg/l of suspended sediment and the model operated 300 hours, the last 50 hours of which were used to compute depositional quantities. The deposition rates were then extrapolated to a year and a dredging analysis performed on the resulting bathymetry.

Alternatives tested

E117. Four alternatives were tested in the model: the existing channel condition, the “base” condition, the Plan 1 (nominal 50 ft channel) and the Plan 2 (nominal 60 ft channel) channels. The existing channel condition represents the geometry (width, depth and alignment) of the current navigation channels within the Port. The model verification was performed utilizing the existing conditions geometry.

E118. The base conditions represent the channel geometry expected to be in place immediately prior to the construction of this project. Base conditions include deepening of the Kill Van Kull and Newark Bay Channels to -45 mlw; deepening of the Arthur Kill, from the confluence with the Kill Van Kull to Gulfport to depths of -41/-40 mlw; and deepening of the Port Jersey Channel to a depth of -41 mlw. The base condition for all other channels in the port is the existing geometry.

E119. Plans 1 and 2 were designed to evaluate the maximum potential impacts of the various project alternatives. Plan 1 includes all of the improvements for Paths 1, 2, 4, and 5. In effect, the recommended plan of improvements for the containerships.

E120. Plan 2 includes all of the improvements for Paths 1, 2, 3, 4, 5, 6 and 7; that is, Plan 1 plus the -60 ft mlw channel to Gulfport (with Ambrose Channel at -61 mlw) and the anchorage areas. Plan 2 will evaluate the maximum potential impacts of this project.

Conditions Tested

E121. The conditions tested for all four of the alternatives were the same as used in the model verification. This was the representative repeating tide between a mean and a spring range. The river discharges were held at their mean values used in the verification. The wave conditions from the verification were repeated for all of the design alternatives.

Results

E122. The results of the 3-D hydrodynamic model simulations have been summarized for 27 gage locations selected throughout the navigation channels in the harbor. These locations were chosen for their interest for navigation purposes. The locations are shown in **Figure E11**. The summary of the effects of the channel deepenings on the tidal elevations in the harbor are presented in **Table E11**; the effects of the deepening on current velocity magnitudes are presented in **Table E12**.

E123. The effects of the channel deepenings on tides indicate that there is an increase in tide range into the harbor with a maximum increase of 0.05 ft for Plan 1 and 0.19 ft for Plan 2. The 0.19 ft increase in tide range represents a .09 ft increase in high tide and a .10 ft decrease in low tide. The increases in tide range in the rest of the harbor are a proportion of that maximum change as a function of distance into the harbor. In the Arthur Kill, the farthest point from the Upper Bay, the increase in tide range averages less than half of the maximums.

E124. The effects of the channel deepenings on current velocities are generally a reduction of currents for the locations that lie within the channels that are deepened. Those reductions are the result of an increase in the cross sectional area of the channel that carries the tidal discharge. For those stations in Upper Bay where the channels are not deepened, there is a general increase in current velocities. In general, velocity changes for Plan 1 are minor (less than 0.1 fps) with maximum decrease of .27 fps occurring in the Arthur Kill. The maximum decrease in velocity for Plan 2 was 0.78 fps in the Upper Bay.

Table E11 Tide Stage Effects (ft, mlw)*											
	Base			**Plan 1**				**Plan 2**			
Station	Max	Min	Range	Max	Min	Range	Change	Max	Min	Range	Change
Ambrose 1	5.53	-0.1	5.63	5.53	-0.11	5.64	0.01	5.52	-0.11	5.63	0
Ambrose 2	5.46	0.12	5.34	5.46	0.11	5.35	0.01	5.47	0.09	5.38	0.04
Ambrose 3	5.45	0.19	5.26	5.46	0.18	5.28	0.02	5.47	0.15	5.32	0.06
Ambrose 4	5.32	0.23	5.09	5.33	0.22	5.11	0.02	5.38	0.19	5.19	0.1
Ambrose 5	5.36	0.33	5.03	5.37	0.31	5.06	0.03	5.44	0.26	5.18	0.15
Ambrose 6	5.36	0.34	5.02	5.38	0.32	5.06	0.04	5.45	0.26	5.19	0.17
Ambrose 7	5.35	0.36	4.99	5.37	0.34	5.03	0.04	5.46	0.27	5.19	0.2
Ambrose 8	5.25	0.41	4.84	5.26	0.4	4.86	0.02	5.32	0.33	4.99	0.15
Red Hook 1	5.36	0.29	5.07	5.37	0.27	5.1	0.03	5.44	0.21	5.23	0.16
Red Hook 2	5.39	0.35	5.04	5.41	0.32	5.09	0.05	5.48	0.25	5.23	0.19
Buttermilk 1	5.36	0.34	5.02	5.37	0.32	5.05	0.03	5.45	0.24	5.21	0.19
East River 1	5.17	0.43	4.74	5.18	0.42	4.76	0.02	5.23	0.37	4.86	0.12
Hudson River 1	5.24	0.47	4.77	5.25	0.46	4.79	0.02	5.31	0.41	4.9	0.13
Port Jersey 1	5.38	0.36	5.02	5.4	0.33	5.07	0.05	5.47	0.27	5.2	0.18
Kill Van Kull 1	5.40	0.42	4.98	5.42	0.39	5.03	0.05	5.49	0.33	5.16	0.18
Kill Van Kull 2	5.47	0.44	5.03	5.48	0.44	5.04	0.01	5.55	0.36	5.19	0.16
Kill Van Kull 3	5.56	0.44	5.12	5.58	0.43	5.15	0.03	5.63	0.38	5.25	0.13

Table E11 (con't) Tide Stage Effects (ft,mlw)												
	Base			**Plan 1**				**Plan 2**				
Station	Max	Min	Range	Max	Min	Range	Change	Max	Min	Range	Change
Bergen Point 1	5.60	0.43	5.17	5.61	0.43	5.18	0.01	5.64	0.39	5.25	0.08
Newark Bay 1	5.63	0.45	5.18	5.65	0.45	5.2	0.02	5.68	0.4	5.28	0.1
Newark Bay 2	5.68	0.47	5.21	5.69	0.46	5.23	0.02	5.71	0.43	5.28	0.07
Newark Bay 3	5.69	0.49	5.2	5.71	0.49	5.22	0.02	5.73	0.45	5.28	0.08
Arthur Kill 1	5.71	0.23	5.48	5.72	0.23	5.49	0.01	5.77	0.22	5.55	0.07
Arthur Kill 2	5.69	0.29	5.4	5.7	0.29	5.41	0.01	5.73	0.27	5.46	0.06
Arthur Kill 3	5.65	0.33	5.32	5.67	0.33	5.34	0.02	5.71	0.31	5.4	0.08
Arthur Kill 4	5.64	0.35	5.29	5.66	0.36	5.3	0.01	5.7	0.32	5.38	0.09
Arthur Kill 5	5.64	0.38	5.26	5.66	0.38	5.28	0.02	5.71	0.33	5.38	0.12
Arthur Kill 6	5.64	0.41	5.23	5.67	0.41	5.26	0.03	5.72	0.36	5.36	0.13

* Table contains minor rounding errors

Table E12
Current Velocity Magnitude Effects (ft/sec)

Station	Base (Max)	Plan 1 (Max)	Change	Plan 2 (Max)	Change
Ambrose Channel 1	1.76	2.02	0.26	2.08	0.32
Ambrose Channel 2	2.73	2.81	0.08	2.96	0.23
Ambrose Channel 3	2.8	2.89	0.09	2.74	-0.06
Ambrose Channel 4	3.3	3.46	0.16	3.09	-0.21
Ambrose Channel 5	2.59	2.49	-0.10	1.81	-0.78
Ambrose Channel 6	2.11	2.08	-0.03	1.73	-0.38
Ambrose Channel 7	2.59	2.64	0.05	2.56	-0.03
Ambrose Channel 8	3.45	3.47	0.02	3.48	0.03
Red Hook Anchorage 1	2.06	1.92	-0.14	1.86	-0.20
Red Hook Anchorage 2	1.41	1.32	-0.09	1.25	-0.16
Buttermilk Channel 1	2.48	2.49	0.01	2.38	-0.10
East River 1	4.25	4.31	0.06	4.33	0.08
Hudson River 1	2.74	2.9	0.16	2.72	-0.02
Port Jersey 1	1.1	1.11	0.01	1.1	0.00
Kill Van Kull 1	2.55	2.52	-0.03	2.59	0.04
Kill Van Kull 2	2.84	2.84	0.00	2.75	-0.09

Table E12 (con't) Current Velocity Magnitude Effects (ft/sec)					
Station	Base (Max)	Plan 1 (Max)	Change	Plan 2 (Max)	Change
Kill Van Kull 3	2.06	1.8	-0.26	1.83	-0.23
Bergen Point 1	1.74	1.57	-0.17	1.74	0.00
Newark Bay 1	1.58	1.6	0.02	1.71	0.13
Newark Bay 2	1.25	1.24	-0.01	1.29	0.04
Newark Bay 3	1.19	1.23	0.04	1.29	0.10
Arthur Kill 1	1.54	1.45	-0.09	1.42	-0.12
Arthur Kill 2	1.49	1.55	0.06	1.43	-0.06
Arthur Kill 3	1.74	1.71	-0.03	1.08	-0.66
Arthur Kill 4	1.65	1.38	-0.27	0.92	-0.73
Arthur Kill 5	1.49	1.22	-0.27	1.18	-0.31
Arthur Kill 6	0.92	0.94	0.02	1.35	0.43

* Minor rounding error

E125. The effects of the channel deepening on shoaling in the portions of the Ambrose Channel that will require dredging are presented in **Table E13**. These volumes were derived from an extrapolation of the shoaling rates in the navigation channels as developed in the model simulations, applying the frequencies above. The volumes were then obtained by integrating the deposition over the zones of the channel where dredging will be required.

E126. The results generated for the interior channel maintenance requirements were developed by applying the 3-D sediment transport model for cohesive sediment transport. The model was applied to all four alternatives and the resulting deposition patterns extrapolated to represent a year for dredging requirements. The results of those simulations are also presented in **Table E13.** These results are summarized by channel reach within the harbor. Because of the nature of these simulations, the best indication of the impacts of the channel deepening will be the shoaling indexes, which are the ratios of the plan dredging volumes to the base dredging. These ratios can then be applied to the actual historical dredging volumes by reach.

Table E13 Improved Conditions Shoaling Rates							
		Plan 1			Plan 2		
Channel	Base (cy/yr.)	Shoal Index	Shoaling Rate	Increase	Shoal Index	Shoaling Rate	Increase
Ambrose	400,000	1.08	432,000	32,000	1.16	464,000	64,000
Anchorage	0	0.90	0	0	1.85	0	0
KVK Con Hook	20,800	1.26	26,200	5,400	1.29	26,900	6,100
KVK Bergen Pt	4,000	1.13	4,500	500	0.83	3,300	-700
Newark Bay Main	211,000	1.00	211,100	100	0.90	189,400	-21,600
NB Port Elizabeth	121,000	1.13	136,700	15,700	1.05	126,900	5,900
NB Port Newark	226,000	1.04	235,100	9,100	1.03	233,400	7,400
AK N.Shooters Is	115,000	0.97	111,700	-3,300	0.70	80,700	-34,300
AK Eliz–Gulf	7,000	1.25	8,800	1,800	1.97	13,800	6,800
Bay Ridge (+RH)	520,000	0.99	512,700	-7,300	1.22	635,100	115,100
Port Jersey	58,000	0.92	53,200	-4,800	1.14	66,400	8,400
Claremont	25,000	1.13	28,300	3,300	1.30	32,500	7,500
NJ Pierhead	40,000	1.07	42,700	2,700	1.14	45,700	5,700
Red Hook Anch	145,000	0.97	140,300	-4,700	1.57	227,200	82,200
Gravesend Anch	28,000	1.10	30,800	2,800	1.02	28,600	600
Stapleton Anch	0	1.18	0	0	1.07	0	0
Totals	1,920,800	1.02*	1,974,100	53,300	1.11*	2,173,900	253,100

*Calculated from Totals

SECTION II: LRR - SHIP SIMULATION MODELING

Introduction

Background

E127. The Feasibility Report for New York and New Jersey Harbor Navigation Study, completed in December 1999 by the New York District, recommended channel improvement that would deepen and widen various channels throughout the New York Harbor. These channels included Ambrose Channel (the entrance channel through the Lower Bay); Anchorage Channel up to Port Jersey Channel, Port Jersey and Red Hook Channels in the Upper Bay; and Kill Van Kull, Newark Bay, and Arthur Kill Channels to the west of the Upper Bay as shown in **Figure E1**. The channels would be deepened to 50 ft (Ambrose to 53 ft) to accommodate the newest fleet of containerships expected to call on the Port. As previously stated, the preliminary layout in the feasibility study was based upon US Army Corps of Engineers and PIANC guidelines. The detailed design of each channel width was further refined through the use of ship simulation modeling.

Purpose and Scope of Work

E128. Since the completion of the feasibility report mentioned above, the Maersk S-Class containership has been introduced and is projected to be the longest vessel that will call upon New York Harbor. It served as one of the design vessels for this study. The purpose of this ship simulation modeling program was to evaluate the adequacy of the channel improvements proposed in the feasibility study for the Maersk S-Class containership. Between April 2001 and August 2002, four separate simulation studies were conducted: Bergen Point/Port Elizabeth Channels, Ambrose Channel, Port Jersey Channel and the Arthur Kill.

E129. The focal point of the testing program is the evaluation of the proposed channel width. In addition to the size of the design vessel, there are several other factors that effect the width requirement for a navigation channel:

- Vessel maneuverability
- Environmental conditions
- Obstructions in the channel
- Amount of vessel traffic
- Type of vessel traffic

E130. Vessel maneuverability is an indication of how well the vessel responds to the input (i.e. rudder and engine commands) given by the pilot. One measurement is how quickly the vessel starts to turn once rudder is given, how quickly it stops when counter rudder is given. Another is the speed at which a vessel reacts to the engine. During the course of his work, the pilot encounters a wide variety of ships each with its own unique handling characteristics.

E131. Environmental conditions include wind, waves, currents, fog, or anything that is natural and affects the pilot or ship. Obstructions in the channel could be as tragic as a wrecked vessel, but more likely would be a vessel, such as a dredge, anchored within the channel. Vessel traffic will dictate if the channel width required to support two way traffic. A mix of vessel types, with varying speeds, may introduce an overtaking situation.

E132. Prior to each simulation study, meetings were held with representatives of each pilot organization, the US Coast Guard and local sponsor to define the scope of each study. Critical channel locations, vessel types, traffic and speed, tide and wind conditions were discussed to identify the testing scenarios best suited for the evaluation of the proposed channel improvements. For example, one scenario could be the S-class containership backing out of South Elizabeth Channel, turning in Newark Bay, and sailing south around Bergen Point into Kill Van Kull, with maximum flood tide and 25 knot NW winds. Scenarios are set up to look at "reasonable" extreme conditions. They could be a specific combination of wind, tide and heading that would be most difficult for the pilots to handle. Obviously, in hurricane force winds, a pilot would not attempt to leave berth. Through the course of testing, the scenarios could be modified to address concerns not previously identified. Testing in the first week included all scenarios. Depending upon the results of the first week, testing in later weeks may concentrate on problem areas with only limited testing on non-problem areas.

E133. The simulations for Bergen Point and Newark Bay Channels were conducted at The Army Transportation School's Full Mission Bridge Simulator, located at Fort Eustis, VA, because at that time, the ERDC simulator was being upgraded. The ship simulations for Ambrose Channel, Port Jersey Channel and the Arthur Kill were conducted at the ERDC-CHL Ship/Tow simulator located at the Coastal and Hydraulics Lab at Waterways Experiment Station in Vicksburg, Ms.

The ERDC-CHL Ship/Tow Simulator

E134. The ERDC-CHL Ship/Tow Simulator is the Corps of Engineers only research and development navigational simulator. It is a real time simulator—if the harbor transit takes 45 minutes into New York Harbor, it will take 45 minutes with the simulator. Control of the simulator by the pilot is similar to what the pilot experiences onboard an actual vessel and has been referred to as "The Man in the Loop". The pilot can monitor his commands using the precision navigation displays at the pilot console.

E135. The current simulator setup, has two identical simulator bridges as shown in **Figure E12**, that can be used independently if two separate runs are being conducted, or they may be integrated for two-way traffic. In the integrated mode each pilot is able to view the position of the other vessel. The pilot can monitor the progress visually on the visual screens and/or on the radar display.

E136. The visual screen in each bridge is capable of showing a 240-degree viewing angle continuously (field-of-view); however, the orientation of this field-of-view is controlled by the pilot and can be directed 360 degrees (as if he is turning his head) to show whatever the pilot needs to see. For backing maneuvers such as an outbound containership leaving Howland Hook, the pilot could rotate the field of view to allow him to see both the bow and stern, just as he would from the wing of the bridge. There are also controls that allow the pilot to change his perspective and "walk out on the wing" of the bridge. Another feature gives the pilot control over the orientation of the horizon, allowing him to tilt the view up or down, as if he were tilting his head downward to see the water or upward to view crane booms.

E137. The hydrodynamic model calculates movement in six degrees of freedom for the vessel. This movement is influenced by the pilot's actions through engine controls, rudder angle, bow and stern thrusters, tug usage, and display parameters. Environmental forces such as currents, shallow water, under keel clearance, waves, and bank and wind forces, also affect the ship's movement during testing.

E138. Special cases can also be observed in the ERDC-CHL Simulator. An example of this is seen during an integrated run. During these tests, when the two passing ships are in close proximity to each other, the hull of each vessel interacts with the other. This interaction causes a change in the handling of both vessels. The size of each ship is also a factor during these cases. If one ship is significantly larger than the other, the smaller vessel will be more affected during passing than the larger vessel. These changes are validated and accounted for within the simulator software.

Data Development

Required Data

E139. The following types of information were required to adequately model the study area and identify problem areas and concerns of the Corps of Engineers, the local sponsor, local area pilots, and other interested parties:

a. A reconnaissance trip to organize the scope of the project, collect pictures and video of the study area, and talk to area pilots and District personnel about project concerns.

b. A channel database containing the geometry (depths) of the existing and design channels. This database also includes the channel side-slopes, over-bank depth, and current magnitude and direction.

c. A visual scene database of the study area that is displayed by the simulator projection system. Navigation aids, buildings, docks, and other visual queues that are normally available to pilots are displayed.

d. A radar database for the study area similar to the radar display found onboard most ships.

e. Hydrodynamic ship models for the simulator, capable of representing the design vessel and any other ships used for the study.

Reconnaissance Trip

E140. The reconnaissance trip is typically conducted at the start of a simulation study for the purpose of observing navigation conditions in the channel, meeting with pilots, and photographing the channel to develop the visual scene. The recon for Port Jersey and Arthur Kill was undertaken April 30 and May 1, 2002.

E141. Representatives of NAN and ERDC boarded board the *Hual Tropicana* at approximately 0845 on April 30, shortly after the ship passed through the Verrazano-Narrows Bridge. The *Hual Tropicana*, a 590 ft long, 96 ft wide car carrier, was inbound to the North East Auto Terminal (NEAT) on the end of the Port Jersey Channel. Three video cameras were mounted on the ship. One camera pointed forward, across the bow, the other two pointed port and starboard. A handheld GPS was placed on the starboard wing to record the transit. The ship arrived at the dock at approximately 0915. We remained onboard while vehicles were unloaded. The Hual Tropicana sailed from NEAT at approximately 1120. We disembarked with the Sandy Hook Pilot at approximately 1300, and boarded the pilot boat to await an inbound ship.

E142. The study team boarded the *Wallenius WilhelsmenTalisman* from the pilot boat at approximately 1610 on April 30. The *Talisman*, a 787 ft long x 106 ft wide car carrier was inbound to NEAT. The *Talisman* arrived at the NEAT at 1800. The video cameras were installed inside, due to rain, thus limiting their effectiveness.

E143. At approximately 1100 on May 1 representatives of NAN and ERDC boarded the *Tromso Trust* west of the Verrazano-Narrows Bridge. The *Tromso Trust* is a 898 ft long tanker with a beam of 144 ft, and was loaded to a 37 ft draft. One Sandy Hook Pilot and two docking pilots from Moran Towing accompanied us. Three video cameras were mounted on the ship. One camera pointed forward, across the bow. The other two pointed port and starboard. A handheld GPS was placed on the starboard wing to record the transit. The *Tromso Trust* arrived at Tosco Refinery at approximately 1230.

E144. Since simulations of the Kill Van Kull and Newark Bay had been previously conducted in 1996, a formal recon trip for that portion of the testing was not conducted. Nor was a formal recon trip conducted for Ambrose channel, since the available visual scene was adequate for this study. However, for both of these studies, meetings were held with the pilots, USCG and local sponsor to discuss the details of the simulations.

Channel Database

E145. Channel current velocities were developed using the TABS-MD hydrodynamic 2D numerical modeling system at ERDC-CHL. This system employs a finite element method to solve the depth-integrated governing equations. The computational mesh used in this study was a modified version of the mesh developed for the Feasibility Study for the New York and New Jersey Harbor Navigation Study, a portion of which is shown in

Figure E10a. The model currents were tidally driven with a constant-amplitude, single-harmonic, repeating tide with a tide range of 5.2 ft and a tidal period of 12.5. Maximum flood, maximum ebb, and high water slack current velocities were extracted from the hydrodynamic model in ASCII format for incorporation into the ship simulation study.

E146. These currents, along with their respective depths, were incorporated into the simulation model for testing. The database was generated with the use of cross-sections that define the navigable area that the ship can use during the simulation of the project area. The currents and depths in the channel are defined along those cross-sections for the hydrodynamic model to apply to the hydrodynamic ship model during testing.

Visual Scene Database

E147. The visual scene database includes the terrain (land and water) and objects (buildings, docks, navigational aids, etc.) and can be laid out and developed with the use of:

- *a.* Topographic maps
- *b.* Navigation Charts
- *c.* Aerial photographs
- *d.* Still photographs of the area
- *e.* Video footage of the area
- *f.* Plan drawings or blueprints
- *g.* Written information (i.e. Coast Guard Light List, etc.)

E148. The base visual scene for New York Harbor in this instance was obtained from Computer Sciences Corporation (CSC) as part of the new ERDC-CHL Ship/Tow simulator installation. Some modifications to this existing New York visual scene were required to update it to present-day conditions. An example of the visual scene of Kill Van Kull near the Bayonne Bridge appears in **Figure E13**.

Radar/ECDIS Database

E149. **Figure E14** shows an example image from the ECDIS and radar screens of the Ship/Tow Simulator. These screens are displayed at the pilot console, **Figure E13**. Options on both devices can be altered by the pilot to their personal preference. The radar console is typical of those found onboard ships today. The ECDIS consoles are becoming more common on ships; however, many still do not have them available for the pilot. In some of these cases the pilot will bring aboard his own ECDIS system, typically run from a laptop computer, and use it during the transit.

E150. The data for the radar display is created from a 2D line drawing of the bank outline of the study area with points inserted for the navigation aids. The ECDIS database for the existing conditions was already available from the CMAP software that runs the

ECDIS. For design conditions to be viewable, a chart with design changes must be created and converted to an S-52 electronic chart format.

Ship Database

E151. The following ships were used for testing purposes:

- *a.* Susan Maersk containership, 1138 ft length overall (LOA) x 140 ft beam (B) x 46 ft draft (T).
- *b.* 132K-ton Tanker, 875 ft LOA x 144 ft B x 39 ft T.
- *c.* SL Performance containership, 950 ft. LOA x 106 ft B x 33 ft T
- *d.* Bob Hope cargo ship, 950-ft LOA x 105-ft B x 35-ft T
- *e.* Two-barge tow
- *f.* 80K-ton Tanker
- *g.* Asian Banner

E152. CSC created both the hydrodynamic and visual models for these ships. The Susan Maersk and the 132K-ton Tanker were used as own-ships (ships that are controlled by a pilot) and traffic-ships (ships being controlled by the SOS operator).

Simulation Program

E153. The simulation-testing program consists of three parts: validation, design tests, and presentation of results. Validation is typically begun as soon as the simulation databases have been completed and pilots are available. If the pilots schedule allows, design testing begins one to two weeks after validation. Presentation of the study results is carried out in stages. Initial results are sometimes discussed even before design testing has been completed. Preliminary results are typically given to the District after full analysis of the test results has been done. The final stage of the presentation of the results is the published report.

E154. During validation, two pilots licensed for the Port of New York traveled to Vicksburg, MS, and participated in simulated transits within the study area for one week using conditions that currently exist in the harbor. During this process the simulation is fine-tuned to the point that the pilots are satisfied that the model is acting as close to the prototype as can be expected. It is also at this time that any problems are worked out, such as missing objects in the visual scene, problems with the handling of the ship, or any unusual or missing forces caused by currents, wind, bank effects, etc.

E155. During the design tests, the teams of pilots run the transits through each of the scenarios in the test plan in order to evaluate the proposed channel improvements. The pilots are instructed to pilot the simulated vessels as they would a real ship, with actual engine and tug commands. If the simulation is to be of any value, it needs to be as realistic as possible. Pilots were given the option of using a helmsman or taking the wheel themselves. Most chose not to use the helmsman. The details of the testing plan are described below.

E156. The third part of the study is the presentation of results. During testing, output from the simulation runs is recorded into an output file on the computer. The data this file records includes the ship's speed, heading, engine rpm, rudder position, rate-of-turn, and tug usage. This data is recorded at intervals specified by the operator and is typically used to create the ship track plots shown in the plates at the end of a report. Each ship icon indicates the ship's location and heading at regular intervals throughout the transit. Rudder position can also be displayed; however, when docking maneuvers, slow speeds, or large transit areas are involved the rudder indicator can clutter the display or can be too small to see and is left out of the plates.

E157. In addition to track plots, navigation study results are also presented in the form of pilot opinion. At the end of each simulation, the pilot was given a form to record his thoughts on the exercise. These forms are used during the analysis of the track plots. The pilots were also given a final questionnaire at the end of their simulation session. The completed questionnaires are included as an appendix to the simulation report.

Pilot Participation

E158. Typically, six licensed pilots from the Port of New York/New Jersey participated in each study – two pilots per week over 3 weeks of testing. Each pilot team consisted of one Sandy Hook Pilot, and one Docking Pilot, either from NY/NJ Harbor Pilots or from Metro Pilots. However, for the Ambrose Channel simulations, only Sandy Hook Pilots participated in the study.

E159. The New York and New Jersey Sandy Hook Pilot Association has the responsibility of bringing the ships from sea to a position off berth within the Port of New York and New Jersey. Sandy Hook Pilots will board a vessel from the pilot boat at the entrance to Ambrose Channel and guide the vessel into the Upper Bay. Once in the Upper Bay, vessels bound for berth requiring tug assistance will take on a federally licensed Docking Pilot, typically off the Con-Hook range. The Docking Pilot, with the assistance of one to three tug boats, will guide the vessel thru interior channels and dock the vessels at berth. Each pilot group brings a broad range of expertise and experience to the simulations.

E160. The Bergen Point/Newark Bay Channel simulations were the first to utilize the S-Class containership. Since the S-Class containership has not yet called on the Port of New York, no New York Pilot has had any first hand experience with that ship. For that particular study, a Maersk-Sealand Senior Captain flew in from Copenhagen to assist during validation. The Senior Captain had extensive experience with the design ship, and used his knowledge to speed up the validation process by providing invaluable information on the handling of the ship.

Bergen Point/Port Elizabeth Channel Simulations

Purpose

E161. The purpose of this testing was to evaluate the adequacy of the recommended channel improvements to accommodate the Maersk S-Class containership. Several channel locations were identified as potential hazards for the larger vessel. They included the bend at Bergen Point, the South Elizabeth Channel, and the maneuvering area opposite Port Elizabeth.

E162. The concerns at Bergen Point, are the southern bank during an outbound transit, particularly with an ebb tide, and the point itself on inbound transits on a flood tide. With a strong current and wind working together, pilots have to be vigilant to keep the vessel from encroaching upon these areas.

E163. The entrance to South Elizabeth Channel is a difficult maneuver with the current length of vessels in the harbor. The approach of the longer and wider S Class Containership to the terminal there, plus the requirement that a Pana-Max size vessel be able to maneuver around a docked S Class ship to continue to Berth 98 will determine modifications needed for this section of channel.

E164. The concern at Elizabeth Pierhead Channel is whether or not the design ship will still be able to turn within the maneuvering area opposite Port Elizabeth. After discussions with the District and the Pilots it was decided that the addition of docked vessels was not necessary for this simulation. If a vessel were to be a berth the maneuvering ship would merely begin its turn at a time that would allow it to avoid the docked vessel.

E165. The only concern for Elizabeth Channel is the distance beyond the channel that the deepening needs to be extended to allow sufficient room for the transiting vessel to maneuver. During flood tide, vessel will continue to drift northward with the current as it makes its turn while during ebb tide, vessel will go beyond the entrance of the channel and drift southward with the tide as it makes its turn. Both of these maneuvers require that the deep draft vessel be able to go beyond the entrance of Elizabeth Channel during the turn. This drift is a critical part of the entrance to the channel for both bow in and bow out maneuvers. Since the channel will not be deepened beyond that which required for these maneuvers, the optimization of this safety cushion is the focus of this portion of the study. The width of the channel here, although not a secondary concern by any means, has not proven to be a problem in the past, and is not expected to pose a problem with the deeper channel.

Testing Scenarios

E166. The simulations for Bergen Point and Newark Bay Channels were conducted at The Army Transportation School's Full Mission Bridge Simulator, located at Fort Eustis, VA. The testing phase of the study involved three weeks of simulations run with pilots licensed for New York Harbor. Testing included the –45 ft channel as the existing condition and the –50 ft channel as the design condition. **Table E14** shows the full list of simulated transits.

E167. The original scenarios for South Elizabeth Channel were revised to include a panamax containership inbound and outbound to Pier 98, the inner berth, with an S-Class ship in the outer berth to fully examine the proposed width of the South Elizabeth channel. Since a model of a panamax containership was not available at Ft Eustis, the Bob Hope, an Army cargo vessel with similar handling characteristics, was utilized.

Table E14
Bergen Point/Newark Bay Channels – Simulation Runs

Run	Channel	Heading	Tide	Scenerio
1	45 ft	Inbound	Max Flood	Start in Bergen Pt East Reach & turn into Newark Bay. Pull into South Elizabeth Channel, Bow in.
2	45 ft	Inbound	Max Flood	Start in Bergen Pt East Reach, & turn into Newark Bay. Turn and back into South Elizabeth Channel, Bow out.
3	45 ft	Outbound	Max Ebb	Start in South Elizabeth Channel, bow in. Back into Newark Bay and turn ship. Turn into Bergen Pt West Reach. Run ends when ship passes through Bayonne Bridge.
4	45 ft	Outbound	Max Ebb	Start in South Elizabeth Channel, bow out. Turn into Newark Bay. Turn into Bergen Pt West Reach. Run ends when ship passes through Bayonne Bridge.
5	45 ft	Inbound	Max Flood	Start in Newark Bay Main Channel, Turn and dock at Elizabeth Pierhead Channel Starboard Side to berth.
6	45 ft	Outbound	Max Ebb	Start Port side to berth at Elizabeth Pierhead, Turn and depart south into Newark Bay Main Channel
7	45 ft	Inbound	Max Flood	Start in Newark Bay Main Channel, Turn and back into Elizabeth Channel
8	45 ft	Outbound	Max Ebb	Start in Elizabeth Channel, bow in. Back out and turn south into Newark Bay Main Channel
9	50 ft	Inbound	Max Flood	Start in Bergen Pt East Reach, & turn into Newark Bay. Turn and back into South Elizabeth Channel, Bow out.

Table E14 (con't) Bergen Point/Newark Bay Channels – Simulation Runs				
Run	**Channel**	**Heading**	**Tide**	**Scenerio**
10	50 ft	Outbound	Max Ebb	Start in South Elizabeth Channel, bow in. Back into Newark Bay and turn ship. Turn into Bergen Pt West Reach. Run ends when ship passes through Bayonne Bridge.
11	50 ft	Inbound	Max Flood	Start in Newark Bay Main Channel, Turn and dock at Elizabeth Pierhead Channel Starboard Side to berth.
12	50 ft	Outbound	Max Ebb	Start Port side to berth at Elizabeth Pierhead, Turn and depart south into Newark Bay Main Channel
13	50 ft	Inbound	Max Flood	Start in Newark Bay Main Channel, Turn and back into Elizabeth Channel
14	50 ft	Outbound	Max Ebb	Start in Elizabeth Channel, bow in. Back out and turn south into Newark Bay Main Channel
15	50 ft	Inbound	Max Ebb	Start Bob Hope in Bergen Point, Susan Maersk docked at SEC. Dock starboard side to berth.
16	50 ft	Inbound	Max Ebb	Start Bob Hope in Bergen Point, Susan Maersk docked at SEC. Dock port side to berth.
17	50 ft	Inbound	Max Flood	Start Bob Hope in Bergen Point, Susan Maersk docked at SEC. Dock starboard side to berth.
18	50 ft	Inbound	Max Flood	Start Bob Hope in Bergen Point, Susan Maersk docked at SEC. Dock port side to berth.

Simulation Results

E168. The results of the simulations in Bergen Point showed that there is not much difference between the existing and improved channel, even for the larger, deeper vessel. The approach to the turn remained the same, and the available space towards Shooters Island was sufficient to allow the slightly wider radius turn. However, the pilots also indicated that outbound to Kill Van Kull was more difficult than inbound to Newark Bay. With the exception of one run, the difference in the "swept path" of the ships between the –45 ft and the –50 ft channel runs is no more than a beam width. The problems at Bergen Point remain the same for both of the channel depths, current and wind. As long as the pilot is able to compensate for these with his vessel or vessel and tugs, the turn at Bergen Point will be passable.

E169. The results of the simulations of the South Elizabeth Channel indicated that the flare at the entrance as first tested needed to be modified. No modifications to the flare were included in the Feasibility study recommendations. A flare was added in the simulations, and the testing indicated that the added flare could be reduced and still provide adequate channel clearance for vessels entering and leaving South Elizabeth Channel. The results of the South Elizabeth tests and some Pierhead Channel runs also showed that there is adequate in the maneuvering area opposite the Elizabeth Pierhead Channel to turn an S-Class containership.

E170. The final tests in Newark Bay were to determine how far north into the Newark Bay Main Channel the deepening needed to be extended to accommodate vessels backing out of the Elizabeth Channel and turning in Newark Bay. The results of the testing indicated that the extension of the deepening north to Buoy C"15A" was adequate.

E171. **Figures E15-E18** contain sample track plots of the Bergen Point - Newark Bay simulations.

Conclusions

E172. The plan of improvement for Bergen Point recommended in the feasibility study is considered to be sufficient for the larger design vessel used in this study. Assist tugs will still have to be used as they are presently; however, there does not appear to be a major increase in the demands placed upon them.

E173. The widened flange for the transition between Newark Bay and South Elizabeth Channel for the –50 foot design channel, shown in **Figure E16**, turned out to be more than was really needed by the pilots. The momentum of the vessel as it starts its turn out of Newark Bay during normal operation carries it beyond the point first decided upon as the beginning of the flange. Although the larger flange could be utilized by vessels after the pilots grew accustomed to the new channel configuration, the trackplots and the pilot's reaction to the tests do not show it to be necessary. Decreasing the length of the Newark Bay starting point; but keeping the South Elizabeth Channel pivot point the same, results in a flange that better fits the maneuvering in this area. The slightly shortened flange still gives the larger vessel more space for maneuvering as well as providing extra space for any vessel docking in Berth 98. This in addition to the wider channel proposed by the District, should solve the problems encountered at South Elizabeth Channel.

E174. The maneuvering area opposite the Elizabeth Pierhead Channel appears to be adequate for the larger design vessels in its current form. As the pilots indicated during the weeks of testing, any problems that occur from turning in the channel with another vessel docked nearby is alleviated by maneuvering up or down along the dock face to a point where there are no vessels obstructing the area. In the slight chance that this is not possible, then the pilot has the option of turning his vessel at Elizabeth Channel.

E175. The results of the simulation indicate that the extension of the main channel to the north to facilitate vessels backing out of or into Elizabeth Channel could be shortened to end around Buoy C”15A”. This recommendation will be taken into consideration in the future detailed design of the channel.

Ambrose Channel

Purpose

E176. Although originally evaluated for two way traffic in the feasibility study, there are times in the Ambrose Channel, given the amount and types of traffic, when scheduling and other factors dictate that “meeting and passing” and “overtaking and passing” occur simultaneously. This configuration of harbor traffic would occur in the early morning hours (3 a.m. to 6 a.m.) as the vessels schedule morning arrivals to take advantage of longshoreman crews.

Testing Scenarios

E177. The testing phase of the study involved three weeks of simulation runs with six pilots licensed for New York Harbor. Testing included the –45-ft channel as the existing condition and the –53-ft channel as the design condition with vessel configurations as shown in **Table E15**.

E178. The tests were run in a random order to minimize familiarity with one particular set of conditions. The pilots also were moved from ShipSim1 to ShipSim2 at various times. During passing, communication between the pilots was carried out by two-way radio. Communication with traffic-ships controlled by the SOS was also by two-way radio. Typical information passed during this time included: 1) present ship speed, 2) position in relation to navigational aids, 3) intent to pass, and 4) ship’s attitude from wind and/or waves.

E179. Early morning (3 a.m. – 6 a.m.) transits were simulated using nighttime visibility. Buoy, range, bridge, and vessel lights are important visual queues for these tests. Equally important are the ECDIS and radar displays.

E180. Wind for the testing was an average of 45 knots on the open ocean. Variability built into the model allows for gusts above and lulls below this speed. As the vessel moved inbound, into the “Narrows”, the wind speed was reduced to 25 knots to account for the reduction caused by the terrain. Winds, as well as other conditions for the run, are considered “reasonable extremes”. While the Corps cannot design a channel for two-way traffic in hurricane conditions, it also does not expect every day to be sunny and calm. Therefore, a “reasonable extreme” is decided upon with the help of weather data, the District, and the pilots. Forty-five knot winds are common enough in the Harbor Entrance Channels that it was decided that they should be included in the design criteria.

Table E15 Ambrose Channel – Simulation Runs				
Own Ships	**Traffic Ship(s)**	**Tide**	**Wind**	**Wave**
132k Tanker – Inbound Susan Maersk – Inbound	Susan Maersk – Outbound	Ebb	45	6
132k Tanker – Inbound Susan Maersk – Inbound	132k Tanker – Outbound	Ebb	45	6
132k Tanker – Inbound Susan Maersk – Inbound	132k Tanker – Outbound	Ebb	45	15
132k Light – Outbound Susan Maersk – Outbound	132k Tanker – Inbound Susan Maersk – Inbound	Ebb	45	15
132k Tanker – Inbound Susan Maersk – Inbound	132k Tanker – Outbound 80k Tanker – Outbound	Ebb	45	6
132k Tanker – Inbound Susan Maersk – Inbound	132k Tanker – Outbound Bulk Carrier – Outbound	Ebb	45	15
Susan Maersk – Inbound Susan Maersk – Outbound	2 – 132k Tankers – Inbound 80k Tanker – Tanker Tug/Barge – Outbound	Ebb	45	15
132k Tanker – Inbound Susan Maersk – Inbound	Susan Maersk – Outbound	Flood	45	6
132k Tanker – Inbound Susan Maersk – Inbound	Susan Maersk – Outbound	Flood	45	15
132k Tanker – Outbound Susan Maersk – Outbound	Susan Maersk – Inbound	Flood	45	15
132k Light – Outbound Susan Maersk – Outbound	Susan Maersk – Inbound	Flood	45	15
132k Light – Outbound Susan Maersk – Outbound	132k Tanker – Inbound Susan Maersk – Inbound	Flood	45	15
132k Light – Outbound Susan Maersk – Inbound	132k Tanker – Inbound Tug/Barge – Outbound	Flood	45	15
Susan Maersk – Inbound Susan Maersk – Outbound	2 – 132k Tankers – Inbound 80k Tanker – Inbound Tug/Barge – Outbound	Flood	45	15
Susan Maersk – Inbound Susan Maersk – Outbound	2 – 132k Tankers – Inbound 80k Tanker – Outbound Tug/Barge – Outbound	Flood	45	15

E181. In this study, two wave conditions were chosen, 6 ft and 15 ft. This wave height represents the wave height in the open ocean. As the vessel transited towards and through the “Narrows”, wave height diminished significantly, as it does in the prototype. For the 6-ft wave condition, wave height reduced gradually on the inbound transit down to 2 ft. The final wave height for the 15 ft condition was 4 ft.

E182. Both wave and wind direction changed in relation to the tide. Again, this was done to test the “reasonable extreme”, or the set of conditions that most affected the vessels maneuverability. The expertise of the District and pilots make them invaluable to developing all of these testing criteria.

Simulation Results

E183. The existing conditions results, were found to be consistent with real life transits. Small deviations past the channel edge for a ship attempting to make room for a passing vessel while still in deep water are not of concern to the pilots involved in the study, pose no navigational hazard, and do not represent a loss of control on the part of the pilot. No excessive maneuvering was required for the runs, as would be expected for existing conditions.

E184. Although excessive maneuvering is an elusive term to define and must be redefined for each navigable reach, a rudder angle greater than 20 degrees for an extended period of time, and/or a full ahead engine command (given for maneuvering, not for speed) that lasts longer than normal for the reach, are all things that are looked for during each study. If these conditions occur, discussions with the pilots determine if it is an area of concern or perhaps the maneuver is normal for that particular reach of channel.

E185. Results from the design condition runs show little difference from the existing condition runs. The design tests run using nighttime visibility demonstrate the level of skill and organization of the pilots. Once the handling characteristics of the vessel and the environmental conditions are known, the pilot could choose if, where, and when to pass. These are the same steps used each time a pilot boards a ship coming into New York Harbor. No new concerns with the transits after changing to the deepened channel and the deeper draft vessels were discovered in interviews with the pilots after testing. The pilots involved expressed that the existing width and orientation of the Ambrose Channel was acceptable for the design conditions tested.

E186. **Figures E19-E21** contain sample track plots of the Ambrose Channel simulations.

Conclusions

E187. The results of testing for the New York Harbor Entrance Channel, Ambrose Channel, indicate that the larger Susan Maersk class containership will be able to navigate the existing channel boundaries with the additional draft load after the deepening of the channel bottom. Operational procedures and environmental conditions for the channel (beyond that caused by the deepening) will not change such that they cannot be adapted to by the pilots.

E188. There are no difficult turns in the Ambrose Channel transit for a good- to average-handling vessel transiting the channel by itself. Under ideal conditions, Ambrose Channel can be considered a four-lane highway with two lanes inbound and two lanes outbound. Extreme environmental conditions, such as wind, waves, currents, or other factors, can cause ships to crab and/or slide and "take up" more of their traffic lane than normal. Pilot practices indicate that under extreme conditions, passing and overtaking practices may be curtailed in the interest of safety.

E189. The results of this study indicate that the existing orientation and width configuration of the Ambrose Channel are adequate for design vessel navigation operating in current traffic patterns for the deepened state.

PORT JERSEY CHANNEL

Purpose

E190. The purpose of this testing was to evaluate the adequacy of the recommended channel improvements to accommodate the Maersk S-Class containership. Particular attention was given to the design of the flare in the outer channel and its adequacy to handle S-Class containerships backing in and out of Port Jersey. Pilots expressed concern that as ships turned into Port Jersey Channel, they would be broadside to flood and ebb currents in Anchorage Channel, with the potential of being set up on the Jersey Flats. Exposure to the currents would be more noticeable as the ship passed through the protected area within the Flats and the bow of the ship was exposed to stronger currents at the NY/NJ Pierhead Channel.

E191. Based upon the pilot concerns, the design of the flare was revised to shift the end of the flare from the eastern channel limit of the NNY/NJ Pierhead Channel, as proposed in the Feasibility Study, to a point along the inner channel that would maximize the width on the channel at the NY/NJ Pierhead Channel. This would provide the greatest margin of safety at the critical location.

E192. Also evaluated in this study was the extent of the deepening of Anchorage Channel north of the Port Jersey entrance channel. Deepening of this portion of Anchorage Channel is necessary to provide a turning area for ships backing out of Port Jersey Channel.

Testing Scenarios

E193. The testing phase of the study involved two weeks of simulation runs with five pilots licensed for New York Harbor. Four of the pilots were NY Harbor Docking Pilots and one was a Sandy Hook Pilot. Since the existing channel had been tested in previous model studies, only 50-ft channel as the design condition was tested in this study, as shown in **Table E16** below.

Table E16 Port Jersey Channel – Simulation Runs			
Run	**Heading**	**Tide**	**Scenario**
1	Inbound	Max Flood	Bow in
2	Inbound	Max Ebb	Bow in
3	Inbound	Max Flood	Turn in Anchorage Channel and Back In
4	Inbound	Max Ebb	Turn in Anchorage Channel and Back In
5	Outbound	Max Flood	Bow Out
6	Outbound	Max Ebb	Bow Out
7	Outbound	Max Flood	Back Out and Turn in Anchorage Channel
8	Outbound	Max Ebb	Back Out and Turn in Anchorage Channel

Simulation Results

E194. All pilots agreed that the proposed channel was a significant improvement over the existing channel with the dogleg entrance. They also felt that the *Susan Maersk* was more influenced by current than ships they presently take into Port Jersey and that the realigned channel was essential. Outbound backing out runs were more difficult than normal outbound runs. And inbound backing in runs were the most difficult, but doable with an extra tug.

E195. The majority of runs were successful. The only unsuccessful runs were those where Buoy G"1" in its original position marking the existing channel. Pilots stated they had difficulty determining their exact position. When Buoy G"1" was relocated to the channel corner, all runs were successful. Final Questionnaires. The pilots were unanimous in their support of the realigned Port Jersey Channel. The all supported moving buoy G "1" from it's present position to the channel corner. See **Figures E22-E24**

Conclusions

E196. The *Susan Maersk*, at a draft of 47.5 ft, is significantly larger than containerships presently using Port Jersey. The proposed realigned channel is essential to allow the *Susan Maersk* to call at Port Jersey once the channel is deepened to 50 ft. Presently, if tug used, the assistance of two tugs is required. It is possible that three tugs may be necessary for some maneuvers. Moving buoy G"1" from it's present position to the channel corner as simulated for some of the pilots appeared to give the pilots a better feel for their ship's location. It is recommended that the Port Jersey Channel be realigned as proposed.

ARTHUR KILL CHANNEL

Purpose

E197. The purpose of this testing was to evaluate the adequacy of the recommended channel improvements to accommodate the Susan Maersk, a Maersk S-Class containership. Particular attention was given to the adequacy of the proposed to handle S-Class containerships backing out of Howland Hook Marine Terminal. Currently, all containerships over 700 ft LOA back out of Howland Hook to Newark Bay, turn around in the channel at Bergen Point, and depart through the Kill Van Kull.

Testing Scenarios

E198. The U. S. Army Engineer Research and Development Center (ERDC) conducted a navigation study utilizing real-time ship simulation modeling to evaluate the proposed improvements to Arthur Kill. Model development and online testing occurred at the ERDC Waterways Experiment Station (WES) in Vicksburg, MS during the period from June to August 2002.

E199. The *SL Performance* was used to represent containership traffic in the existing conditions. The *SL Performance* is 950-ft long with a beam of 106 ft. The *SL Performance* was loaded to a draft of 33 ft for the Arthur Kill simulations. The *Susan Maersk* was the design ship for container traffic in the proposed 50-ft channel. The *Susan Maersk* is 1138 ft long and has a beam of140 ft. The *Susan Maersk* was fully loaded to a draft of 47.5 ft for simulations. A 132K tanker, 875 ft long, 144 ft beam, drafting 37 ft was used to simulate ships calling at Tosco Refinery. All tankers arrive at Tosco at high tide, when there is 39 ft of water. 4000 horsepower (HP) tugs were available for the pilot’s use. An ERDC employee in the control room controlled the assist tugs. The pilot used a radio to request tug actions. The scenarios tested in this study are shown in **Table E17** below.

Table E17
Arthur Kill Channel – Simulation Runs

Run	Ship	Channel	Heading	Tide
1	SL Performance	35 ft	Inbound	Max Flood
2	SL Performance	35 ft	Inbound	Max Ebb
3	SL Performance	35 ft	Outbound	Max Flood
4	SL Performance	35 ft	Outbound	Max Ebb
5	Tanker	35 ft	Inbound	HW Slack
6	Susan Maersk	50 ft	Inbound	Max Flood
7	Susan Maersk	50 ft	Inbound	Max Ebb
8	Susan Maersk	50 ft	Outbound	Max Flood
9	Susan Maersk	50 ft	Outbound	Max Ebb
10	Tanker	50 ft	Inbound	HW Slack

E200. During the course of the testing, at the suggestion of one of the pilots, a second plan was proposed. This plan is identical to the recommended plan, however the second plan straightened the northern channel line at the confluence with Newark Bay. This modification eliminated the dogleg maneuver where ships must turn south in the Arthur Kill Channel and then turn north into Newark Bay.

Simulation Results

E201. All inbound ships kept to the north side of the channel in the North of Shooters Island Reach. Only 1 ship, an SL Performance in the existing channel, crossed the northern channel limit. All inbound transits in the proposed channel were successful.

E202. The outbound containership simulations were the most difficult of those attempted during this study. Because there is no turning area, the ships must back east from Howland Hook and turn in the mouth of Newark Bay. The backing maneuver is over two miles long and is very tedious. Tug assistance is required during most of the transit.

E203. Several vessels crossed the northern channel limit of the North of Shooters Island Reach. The magnitude of crossing was greater for the SL Performance in the existing channel than the Susan Maersk in the proposed channel. Part of the difficulties in the backing transits may be due to the visual graphics. It was difficult to determine the exact position within the channel since pilots could not easily look down from the wing to find buoys.

E204. All vessels made the turn into Newark Bay successfully, however the Plan 2 runs with the northern channel line straightened were less difficult.

E205. **Figures E25 - E28** contains sample track plots from the simulation modeling.

Conclusions

E206. The deepening of the Arthur Kill channels had no impact upon tankers transiting the reach to call at Tosco refinery.

E207. The *Susan Maersk*, at a draft of 47.5 ft, is significantly larger than containerships presently using Arthur Kill. Simulation results indicate that either Plan 1 or Plan 2 of the proposed deepened channel will be adequate for inbound runs. However, backing these large ships out of Arthur Kill is a slow and tedious process. The track plots show that the Plan 1 simulations were successful when compared to the existing runs. However, it was obvious during observation of these simulation exercises that Plan 2 eliminated some of the maneuvering inherent in the dogleg to the south at the eastern end of the North of Shooters Island Reach and provided for as easier transit for backing out. Environmental restrictions prevented implementation of Plan 2 at this time, but it will be taken under future consideration.

DESCRIPTION OF THE LRR CHANNEL IMPROVEMENTS

E208. Ambrose Channel, deepened to –53 ft mlw, will remain at its present width of 2000 ft and will follow its present alignment. It will be extended 2400 ft seaward along its present bearing out to deep water. Ambrose Light Tower has been relocated 1.5 nautical miles ESE of its former location. The pilot area will be located between the new tower and the sea buoy marking the new entrance to Ambrose Channel. The pilots use this area to bring their pilot boat along side the incoming and outgoing vessels for boarding. The alignment of Ambrose Channel is unchanged from that proposed in the Feasibility Study.

E209. Anchorage Channel, deepened to –50 mlw, will remain at its present width of 2000 ft, but will be deepened only from the Narrows to a point 1000 ft past the northern channel limit of the Port Jersey Channel. This extension is to accommodate containerships backing out of Port Jersey Channel and turning in Anchorage Channel. The alignment of Anchorage Channel is unchanged from that proposed in the Feasibility Study.

E210. Kill Van Kull, maintained at –50 mlw, will remain at its present width of 800 - 1000 ft and will follow its present alignment. The alignment of Kill Van Kull is unchanged from that proposed in the Feasibility Study.

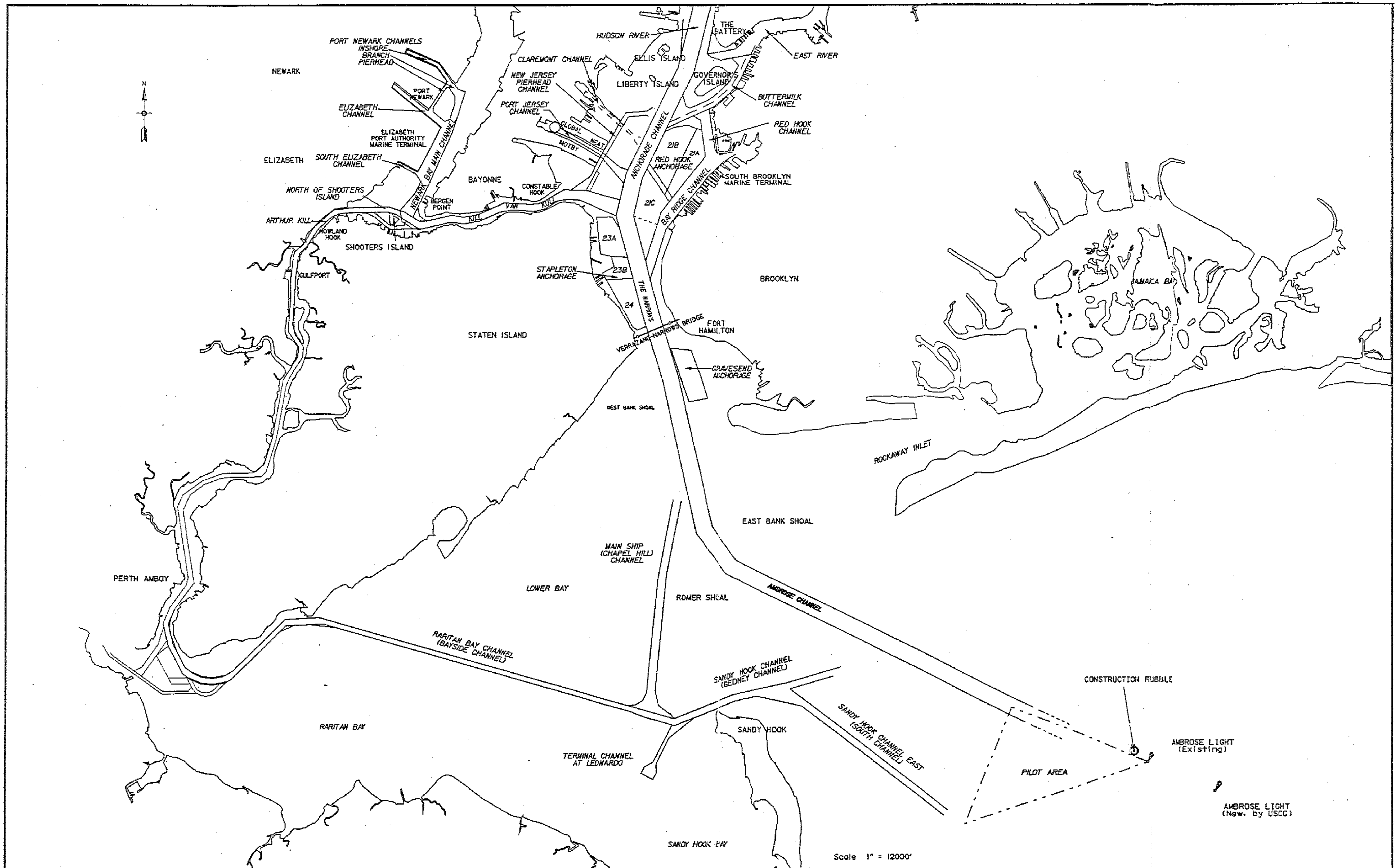
E211. Newark Bay South Reach, and Elizabeth Channel, maintained at –50 mlw, will remain at their present width and will follow the alignment as proposed in the Feasibility Study.

E212. The South Elizabeth Channel will be widened to 500 ft. The flare at the entrance to the South Elizabeth Channel will be widened 200 – 250 ft, as shown in **Figure E29**. The berthing areas along the Elizabeth Port Authority Marine Terminal will be widened to 150 ft.

E213. The Arthur Kill will be maintained at –50 mlw from the junction with the Kill Van Kull to the western limit of the Howland Hook Marine Terminal, along the alignment of the 41 ft (without project) channel. In addition, the channel will be widened to the north opposite Howland Hook back to the limits of the existing -35' Channel. Minor modifications to this North Channel line will keep the proposed channel at least 60 ft from the existing bulkhead and marina. See **Figure E30**.

E214. Port Jersey Channel, maintained at –50 mlw, will be improved to a width of 500 ft between the Global Marine Terminal and MOTBY peninsulas. The entrance flare will be 1640 ft at the junction with Anchorage Channel and taper to 500 ft at a point within the interior channel in order to maximize the channel width at the entrance to the peninsulas as shown in **Figure E31**. The southern channel limit in the entrance flare was straightened to accommodate the relocation of Buoy G"1" from its present location to the intersection with Anchorage Channel to better define the deepened channel.

E215. Bay Ridge Channel. Constructed to –50 mlw, would be improved to a width of 600 ft, with a 1600 ft turning basin opposite the terminal. No ship simulation modeling was conducted for this channel since construction of this channel will likely be deferred until a cost effective means of shipping containers across the Hudson River becomes available.



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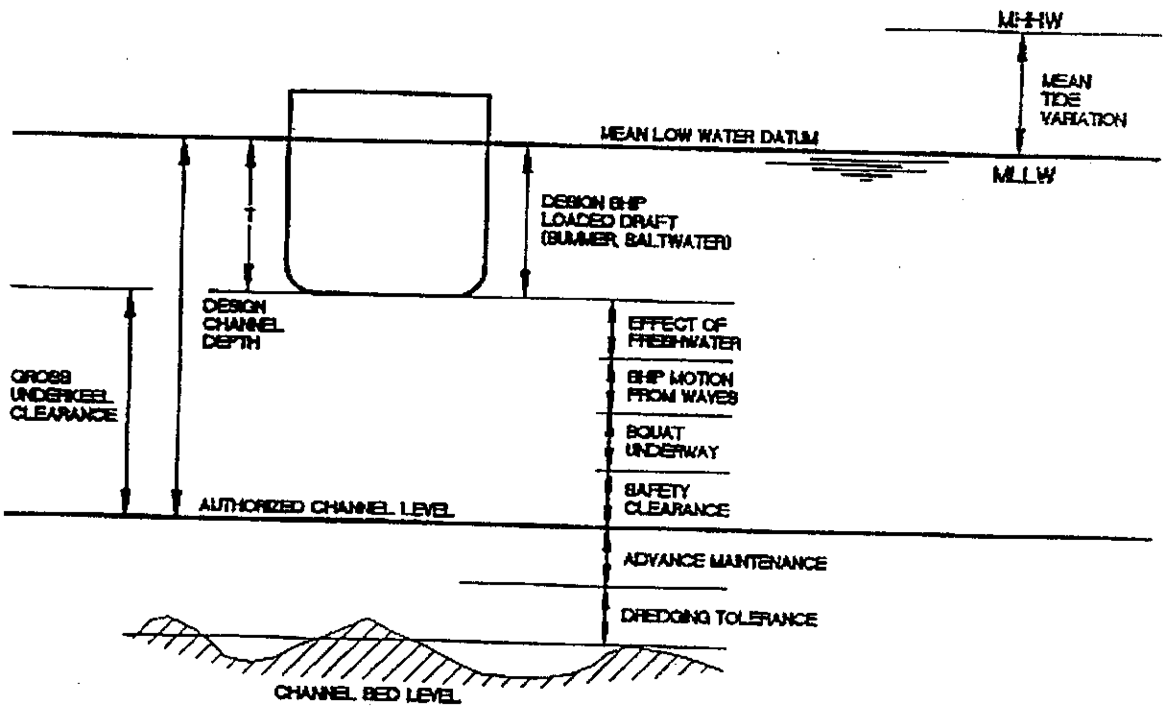
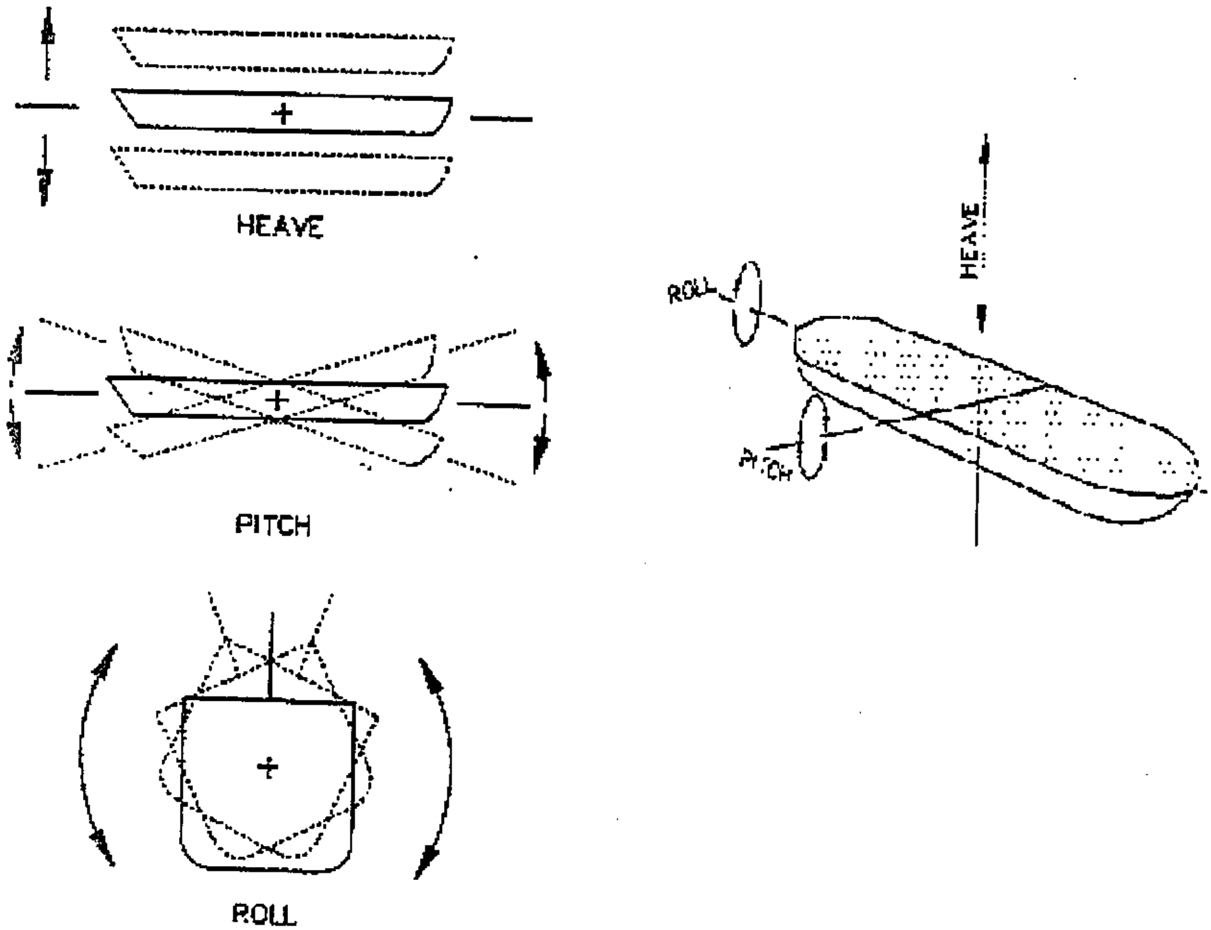
NEW YORK AND NEW JERSEY HARBOR
NAVIGATION STUDY
CHANNEL DESIGN APPENDIX

FIGURE E1
EXISTING NAVIGATION CHANNELS
NEW YORK HARBOR

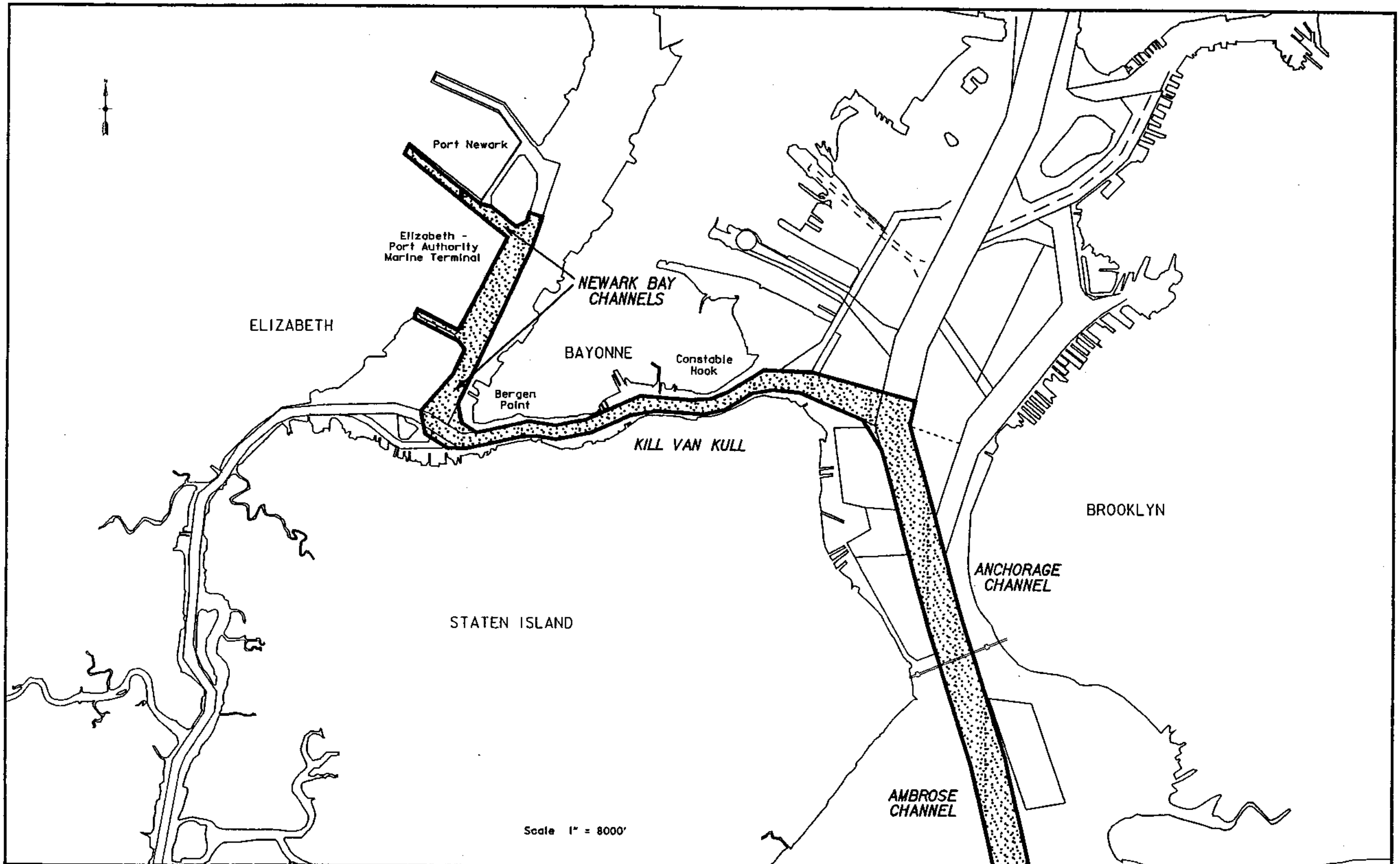


U. S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS NEW YORK, NEW YORK	NEW YORK AND NEW JERSEY HARBOR NAVIGATION STUDY CHANNEL DESIGN APPENDIX	FIGURE E2 CHANNEL DEPTH ALLOWANCES

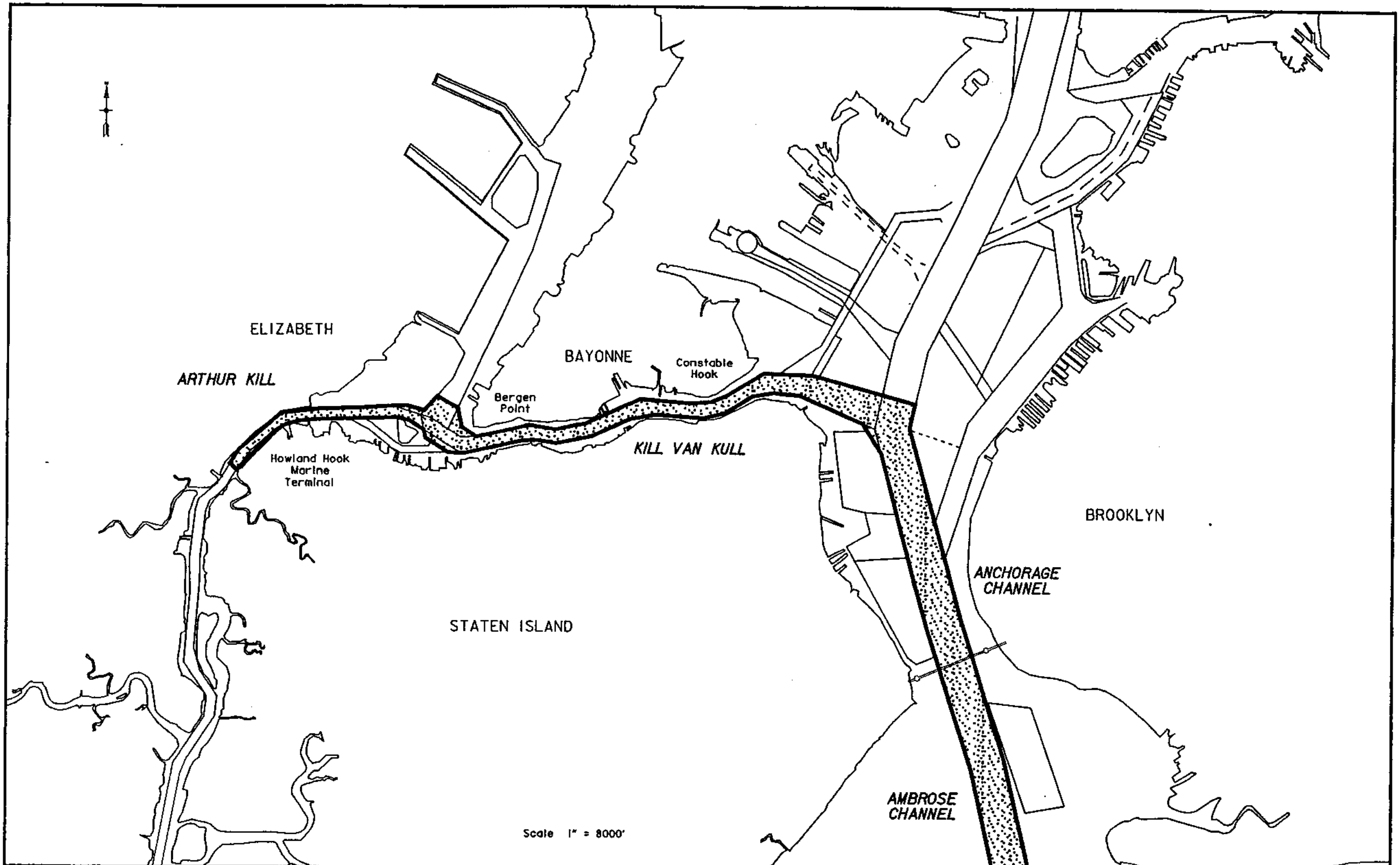
VERTICAL MOTION



U. S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS NEW YORK, NEW YORK	NEW YORK AND NEW JERSEY HARBOR NAVIGATION STUDY CHANNEL DESIGN APPENDIX	FIGURE E3 VERTICAL SHIP MOTION



U. S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS NEW YORK, NEW YORK	NEW YORK AND NEW JERSEY HARBOR NAVIGATION STUDY CHANNEL DESIGN APPENDIX	FIGURE E4 PATHWAY 1 IMPROVEMENTS KILL VAN KULL, NEWARK BAY



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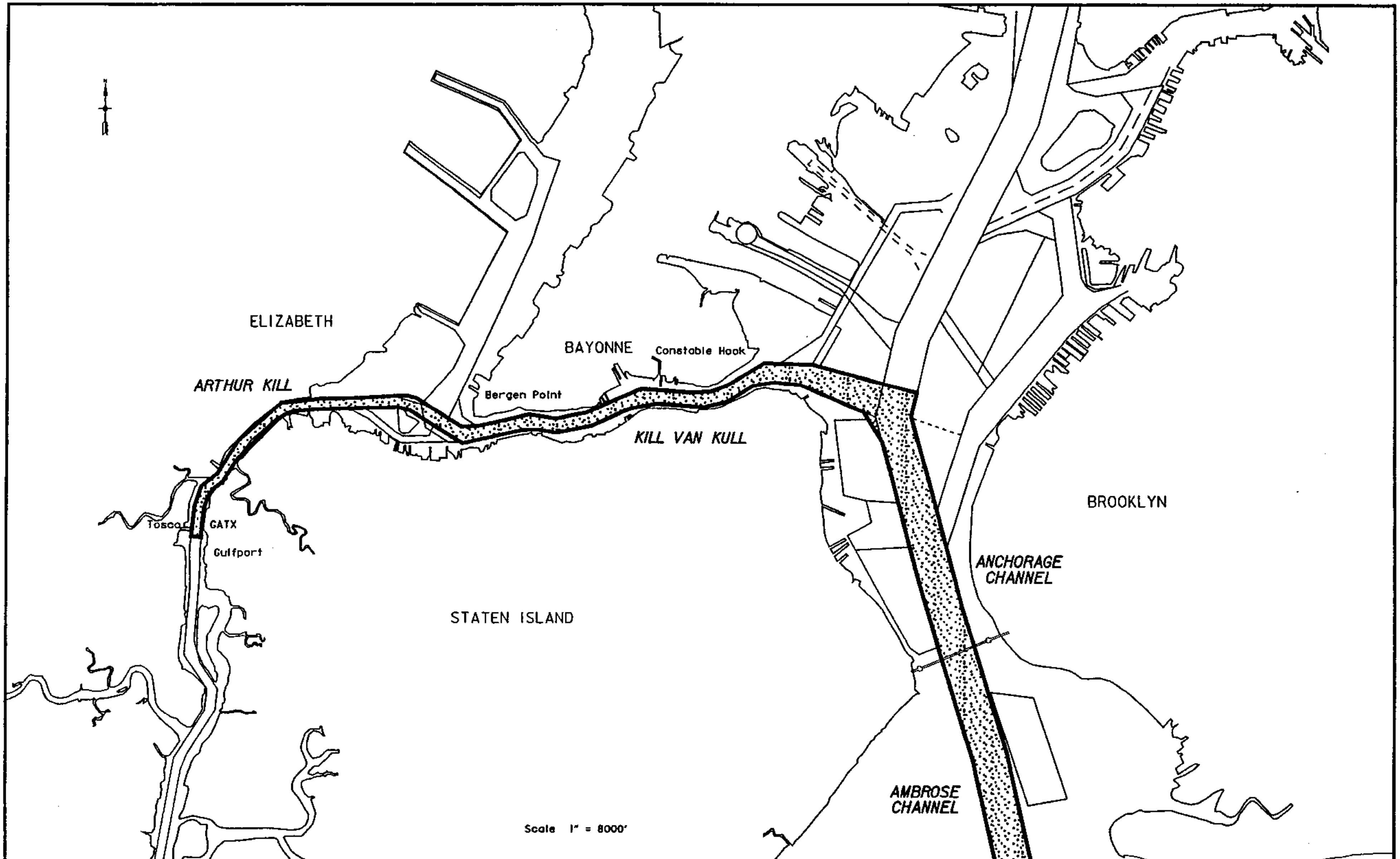
NAVIGATION STUDY
CHANNEL DESIGN APPENDIX

FIGURE E5
PATHWAY 2 IMPROVEMENTS
KILL VAN KULL, ARTHUR KILL TO HOWLAND HOOK



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NAVIGATION STUDY
CHANNEL DESIGN APPENDIX

FIGURE E6
PATHWAY 3 IMPROVEMENTS
KULL VAN KULL, ARTHUR KILL TO GULFPORT

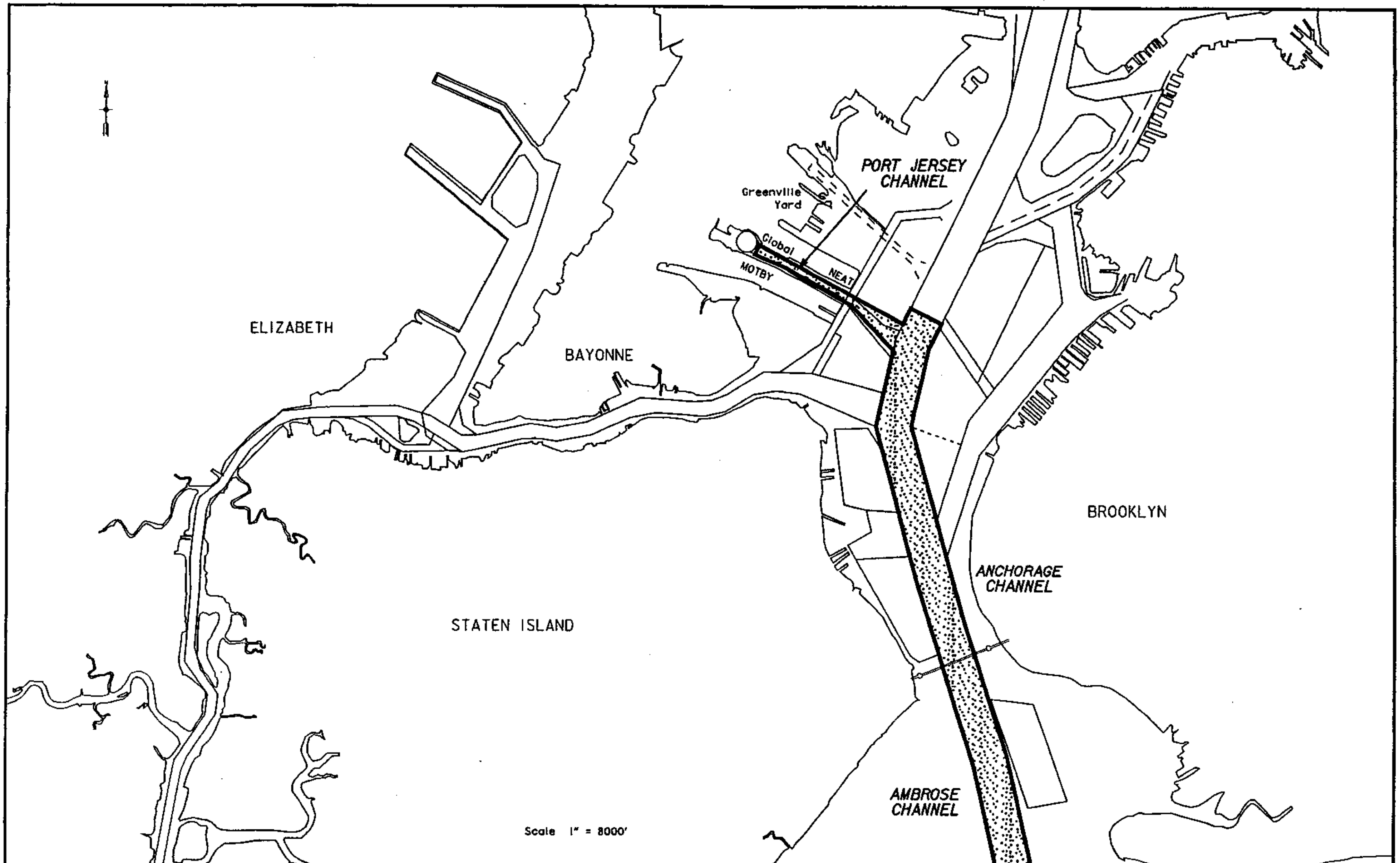

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FIGURE E7
PATHWAY 4 IMPROVEMENTS
PORT JERSEY CHANNEL

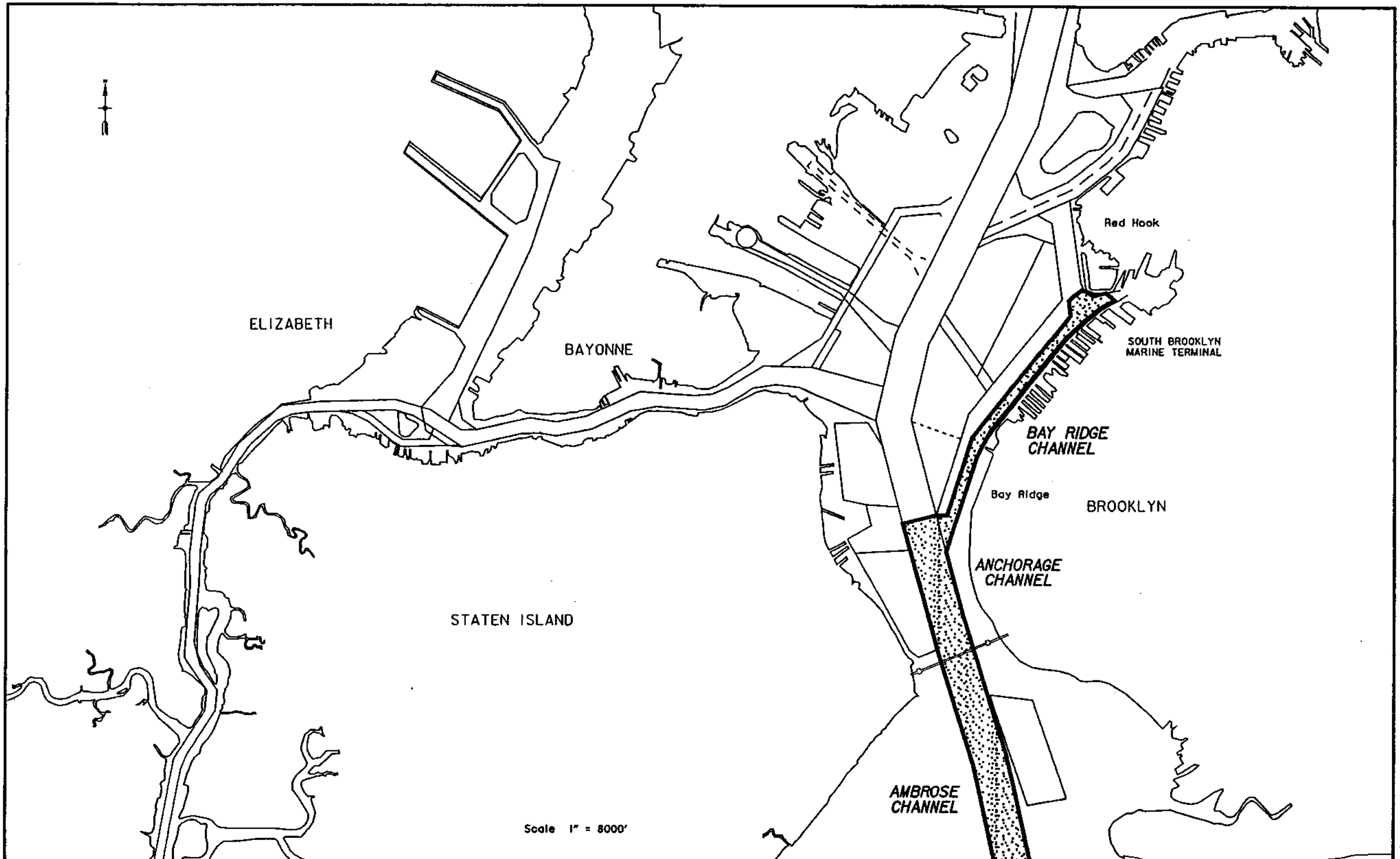

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FIGURE E8
PATHWAY 5 IMPROVEMENTS
BAY RIDGE CHANNEL

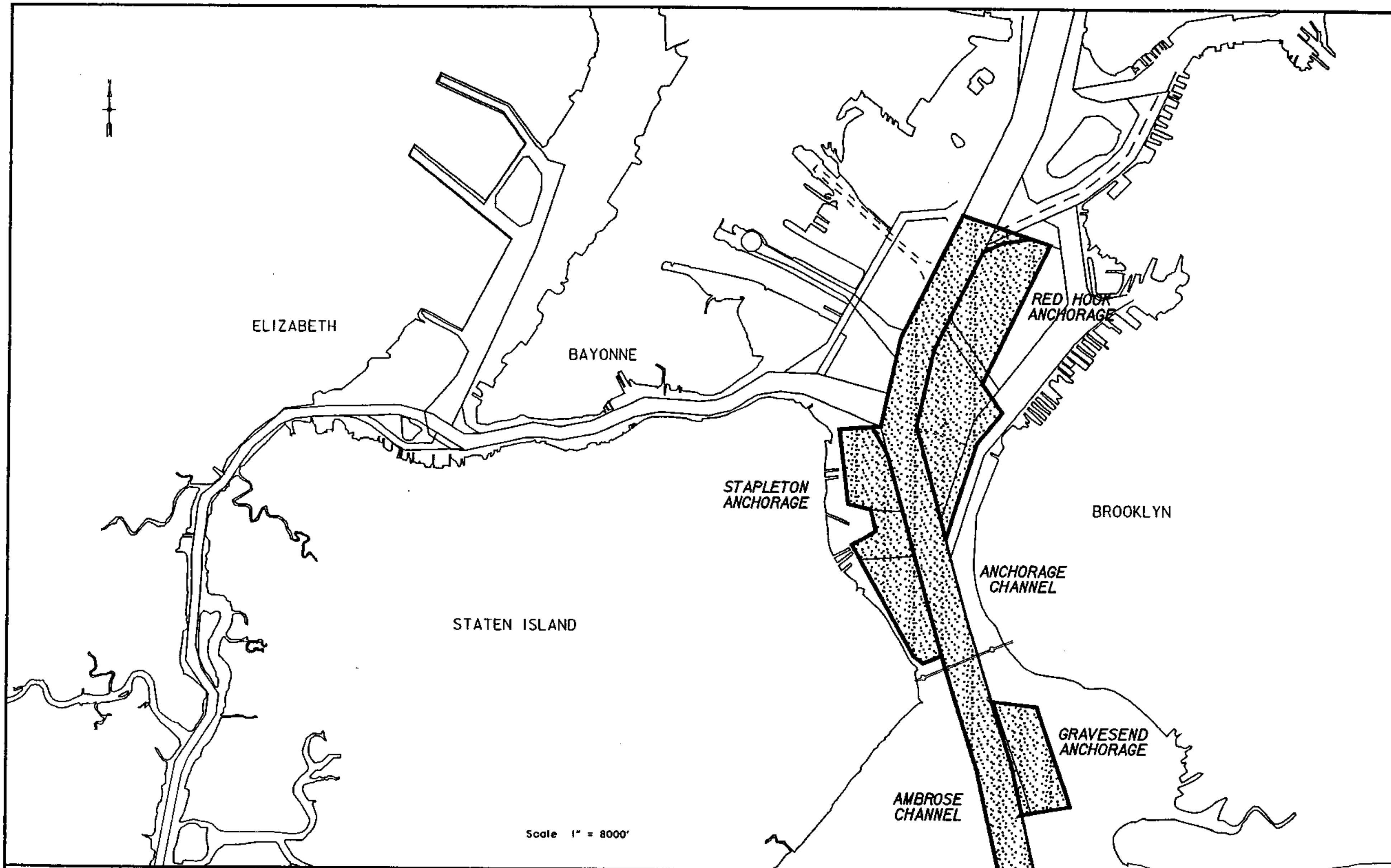

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FIGURE E9
PATHWAYS 6 & 7 IMPROVEMENTS
RED HOOK, STAPLETON AND GRAVESEND ANCHORAGES

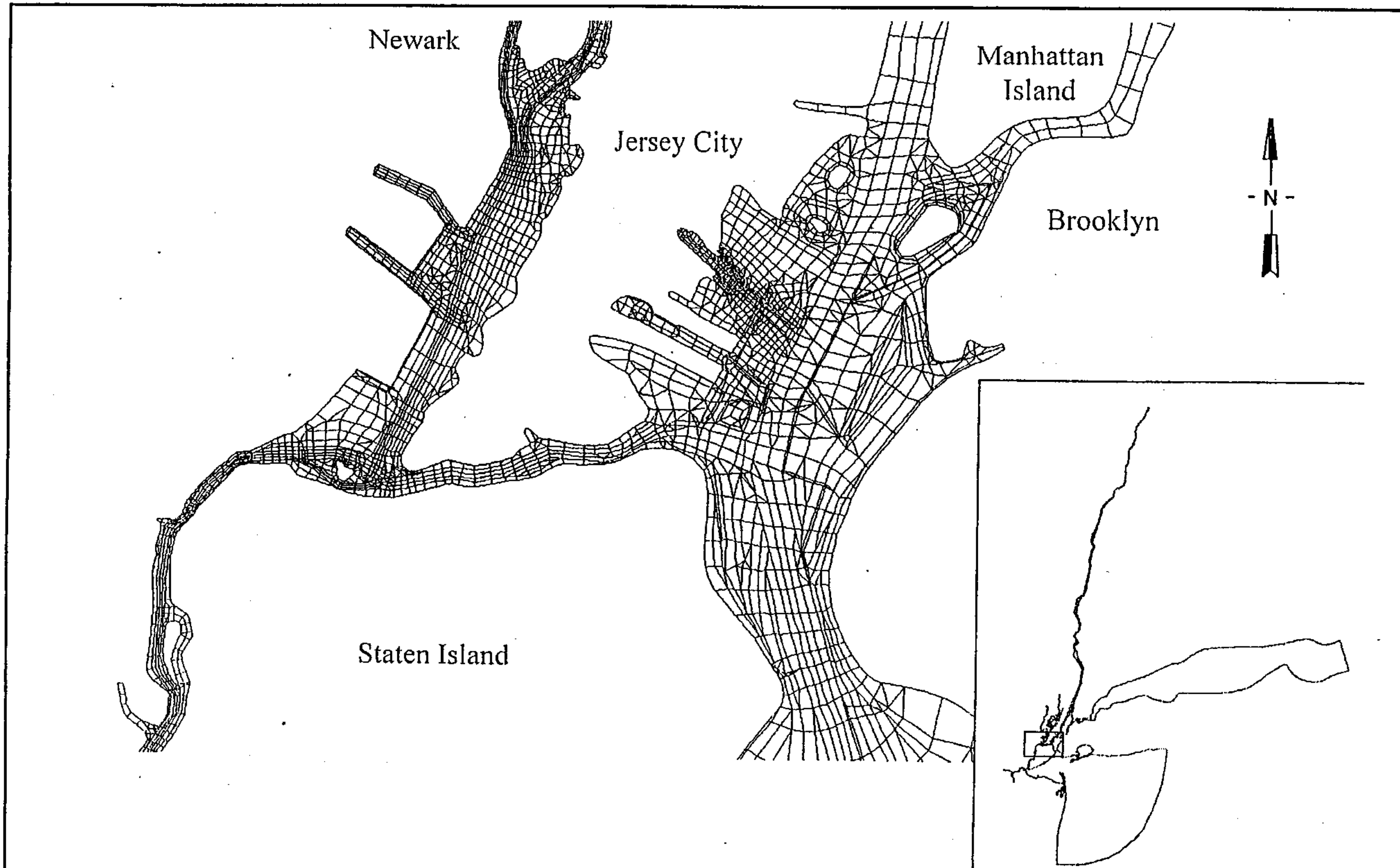

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FIGURE E10A
HYDRODYNAMIC MODEL MESH
UPPER BAY, NEWARK BAY AND THE KILLS

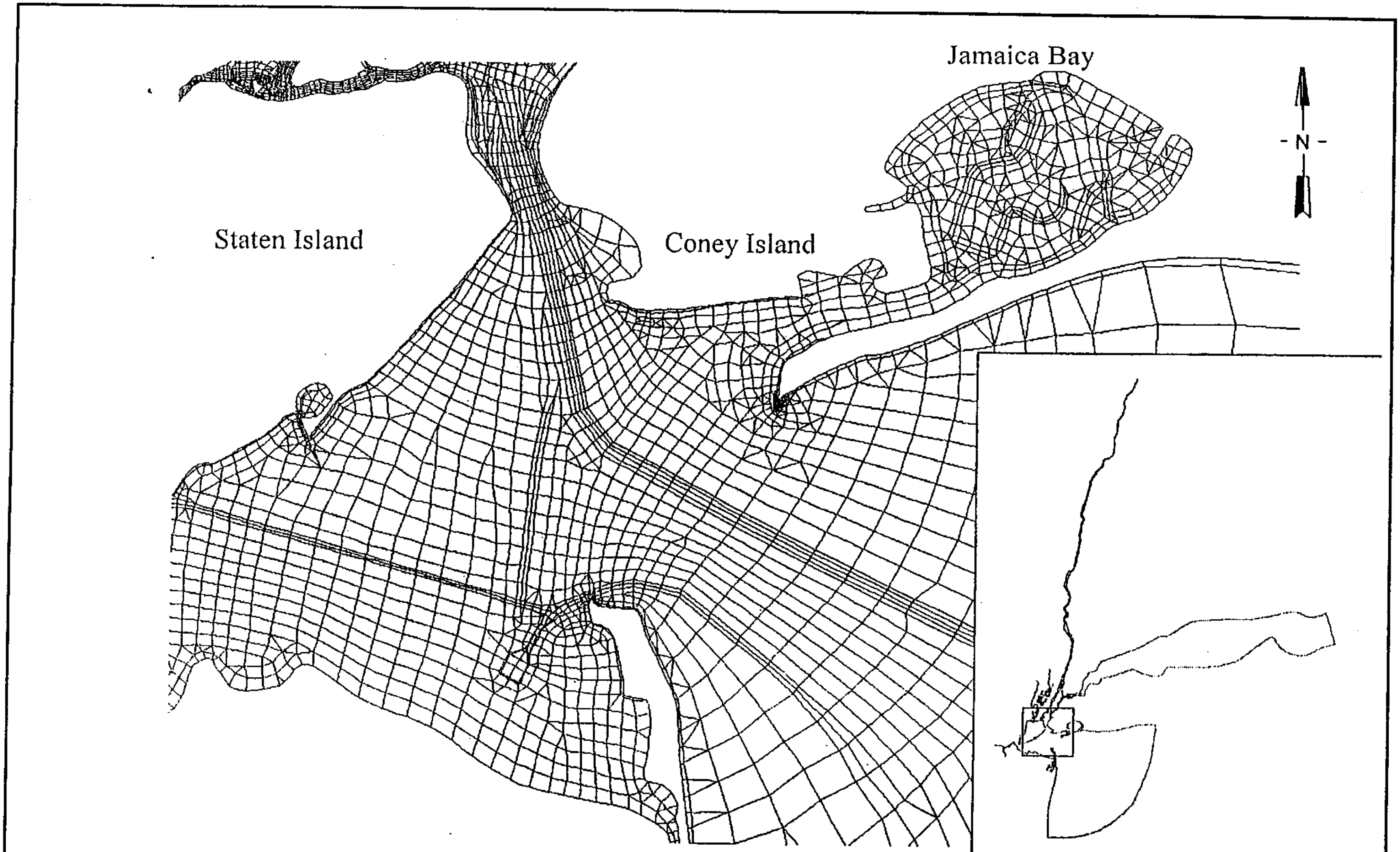

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FIGURE E10B
HYDRODYNAMIC MODEL MESH
LOWER BAY, RARITAN BAY AND JAMAICA BAY

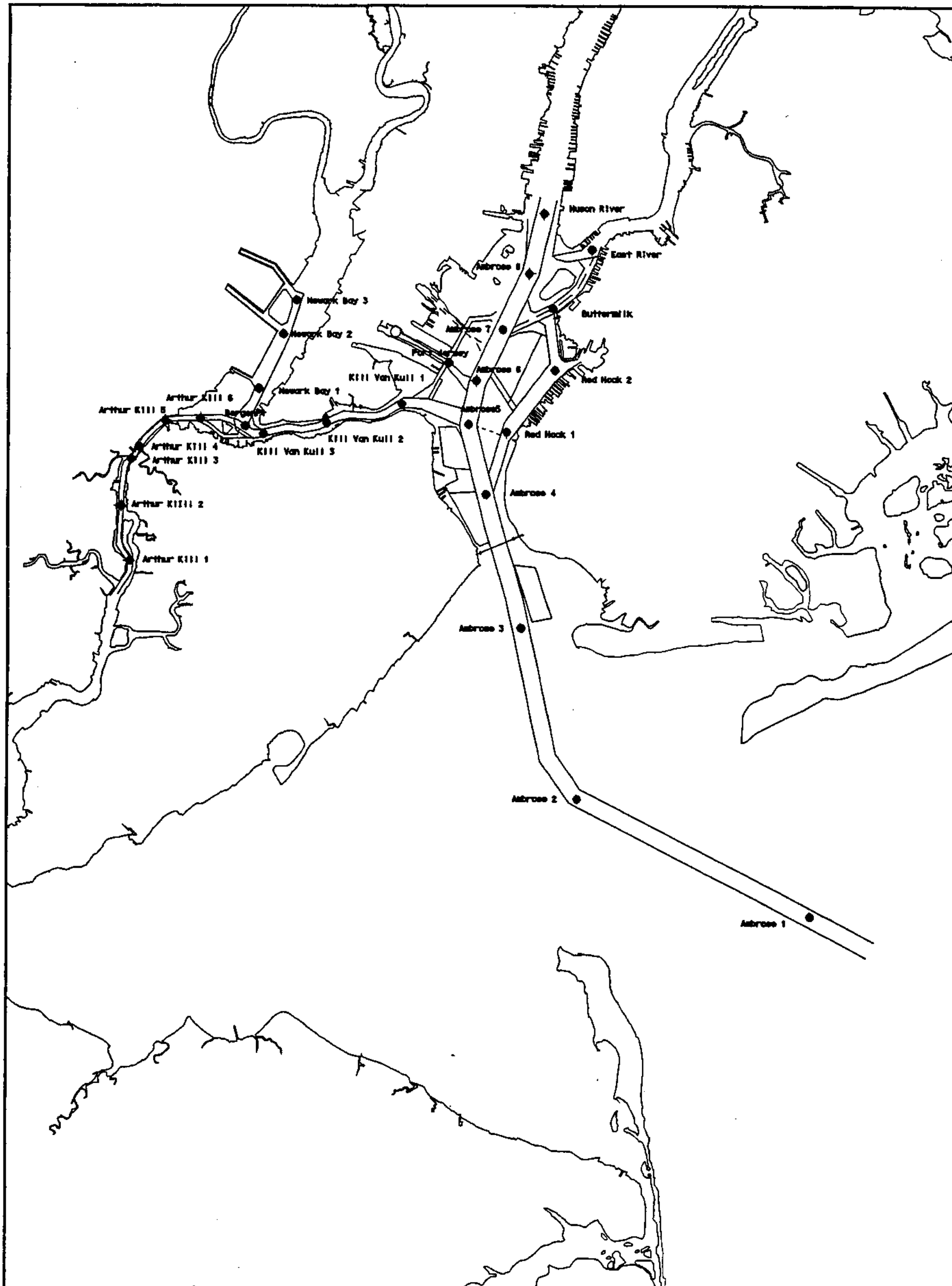

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FIGURE E11
HYDRODYNAMIC MODEL
SUMMARY GAGE LOCATIONS

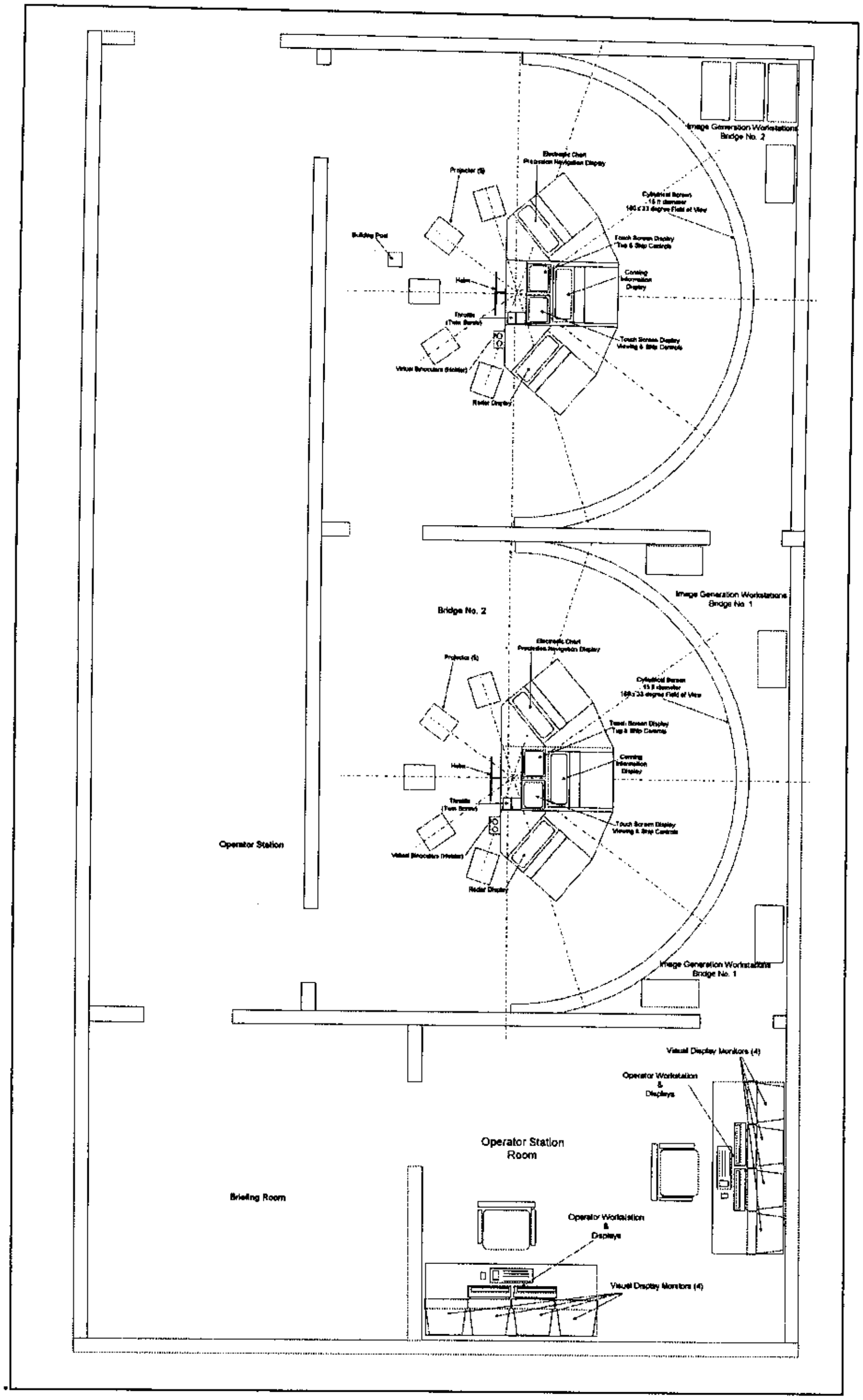
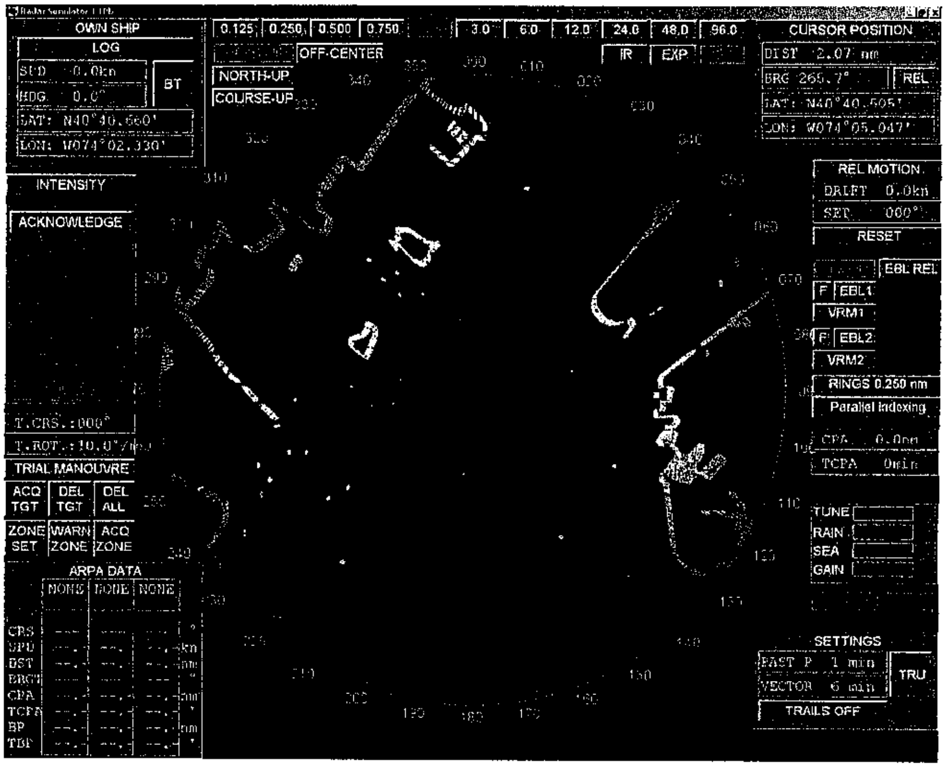


Figure 12. ERDC Simulator Layout

Figure 13. Visual Scene and Pilot Console



Radar

Electronic Chart Display & Information System (ECDIS)

Figure 14. Ship-position displays

DRAFT

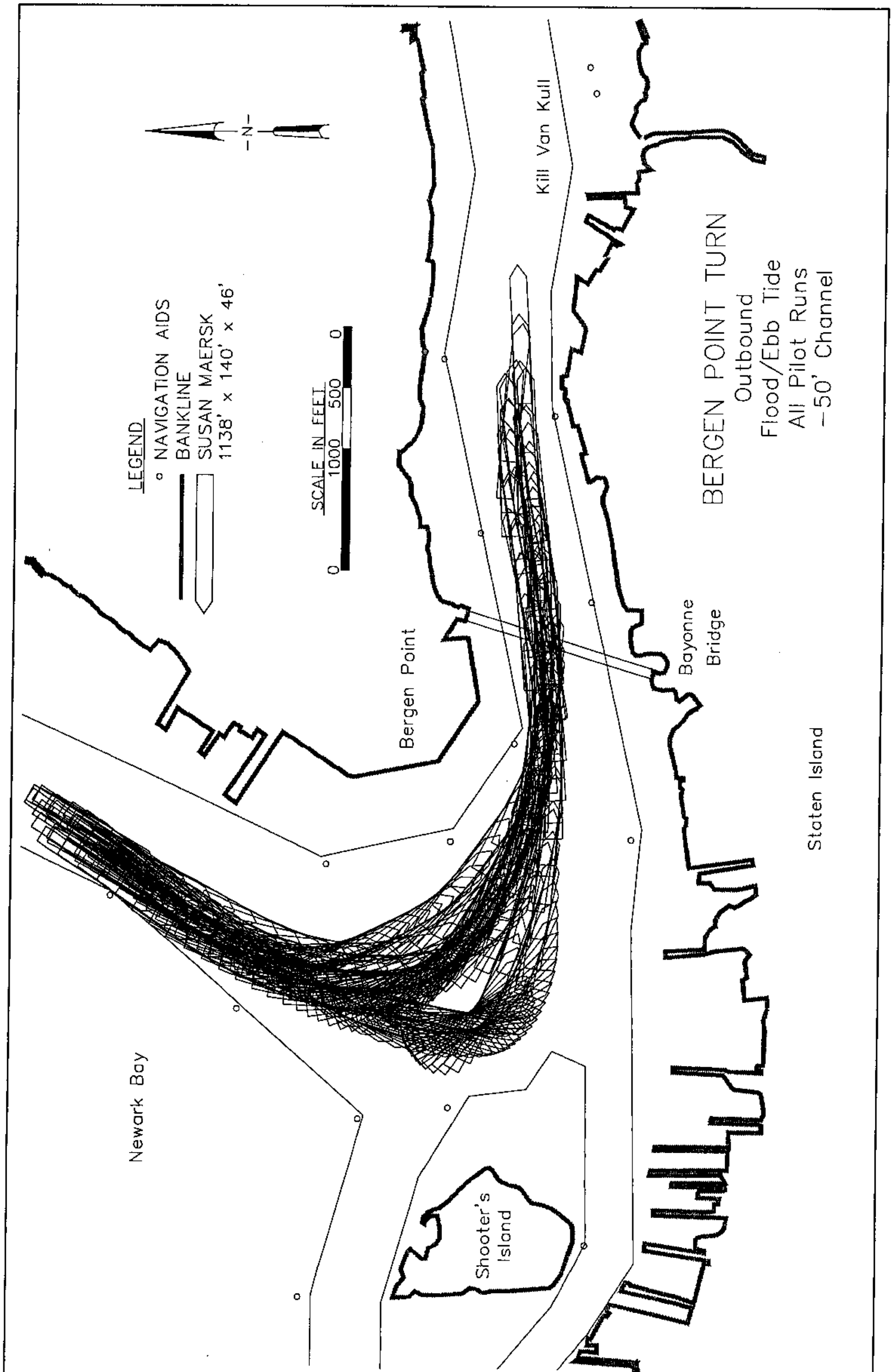


Figure 15.

DRAFT

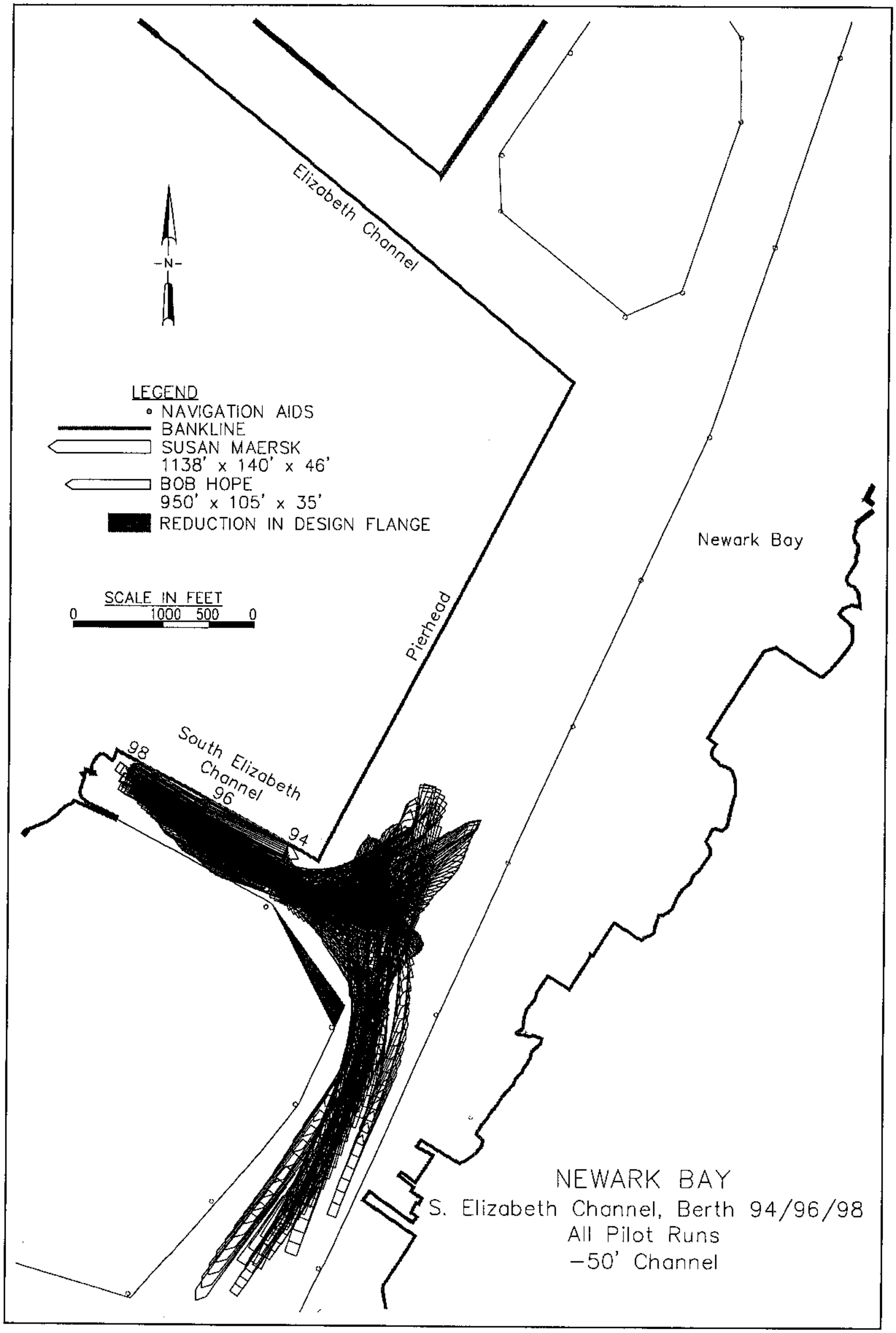


Figure 16.

DRAFT

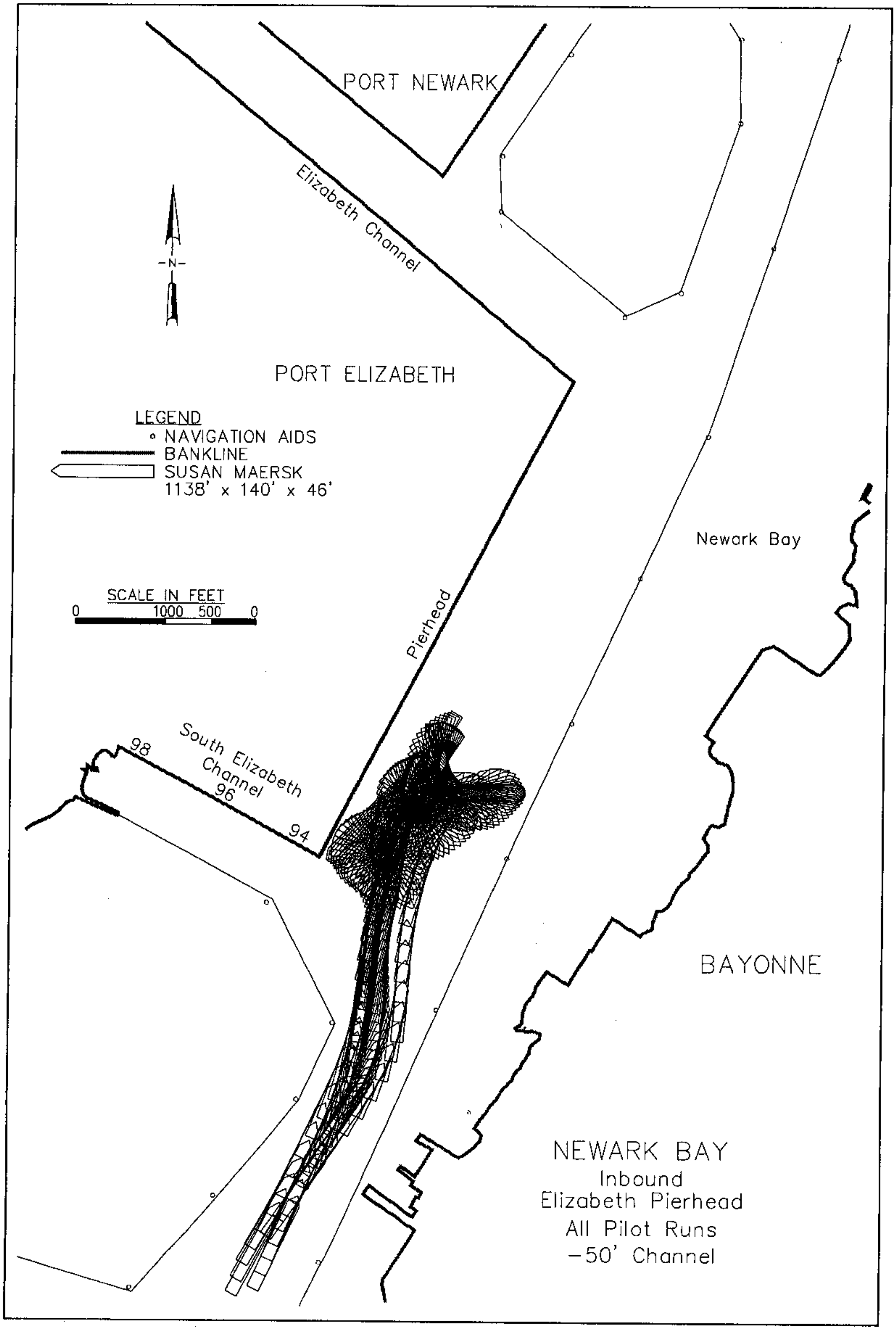


Figure 17.

DRAFT

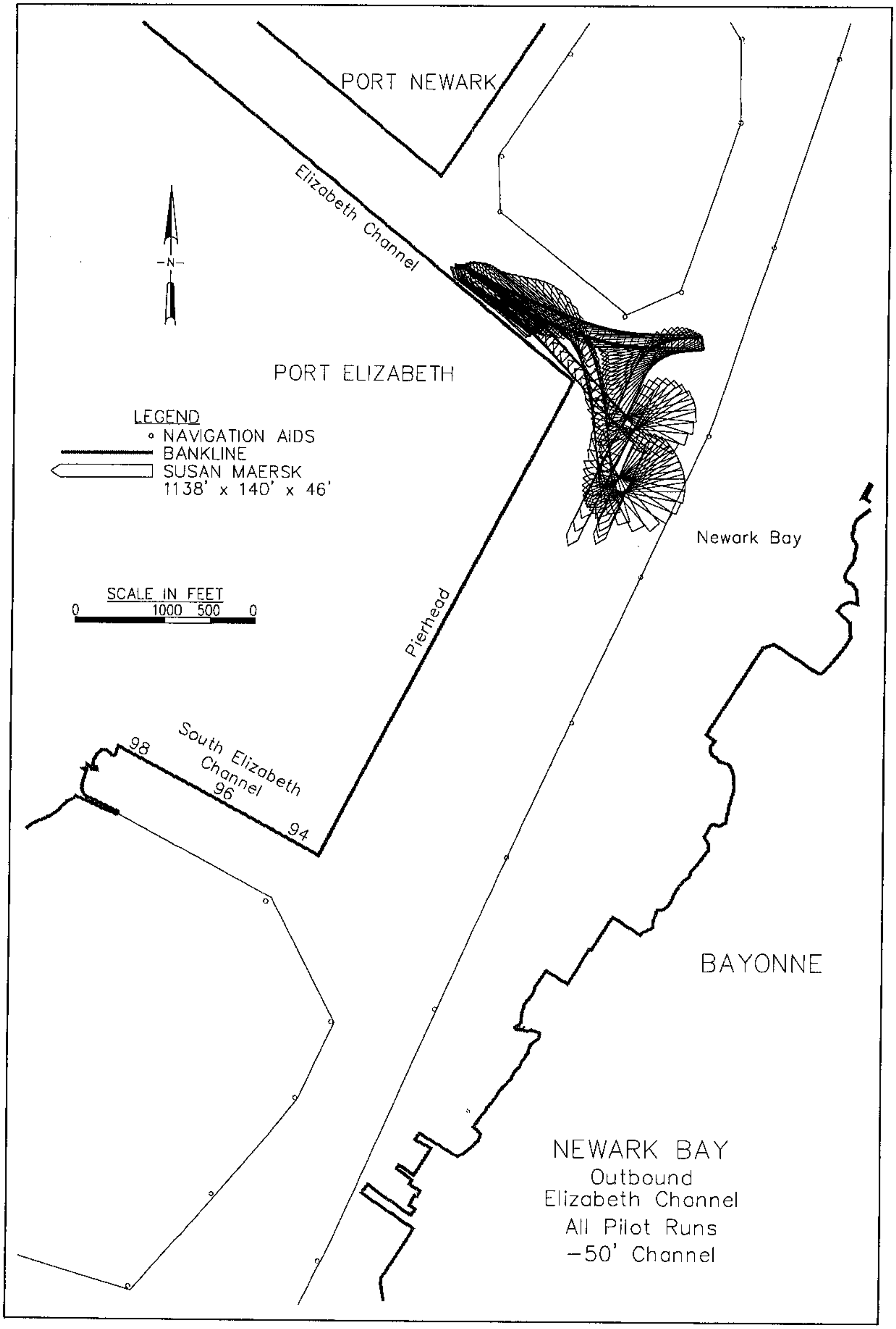


Figure 18.

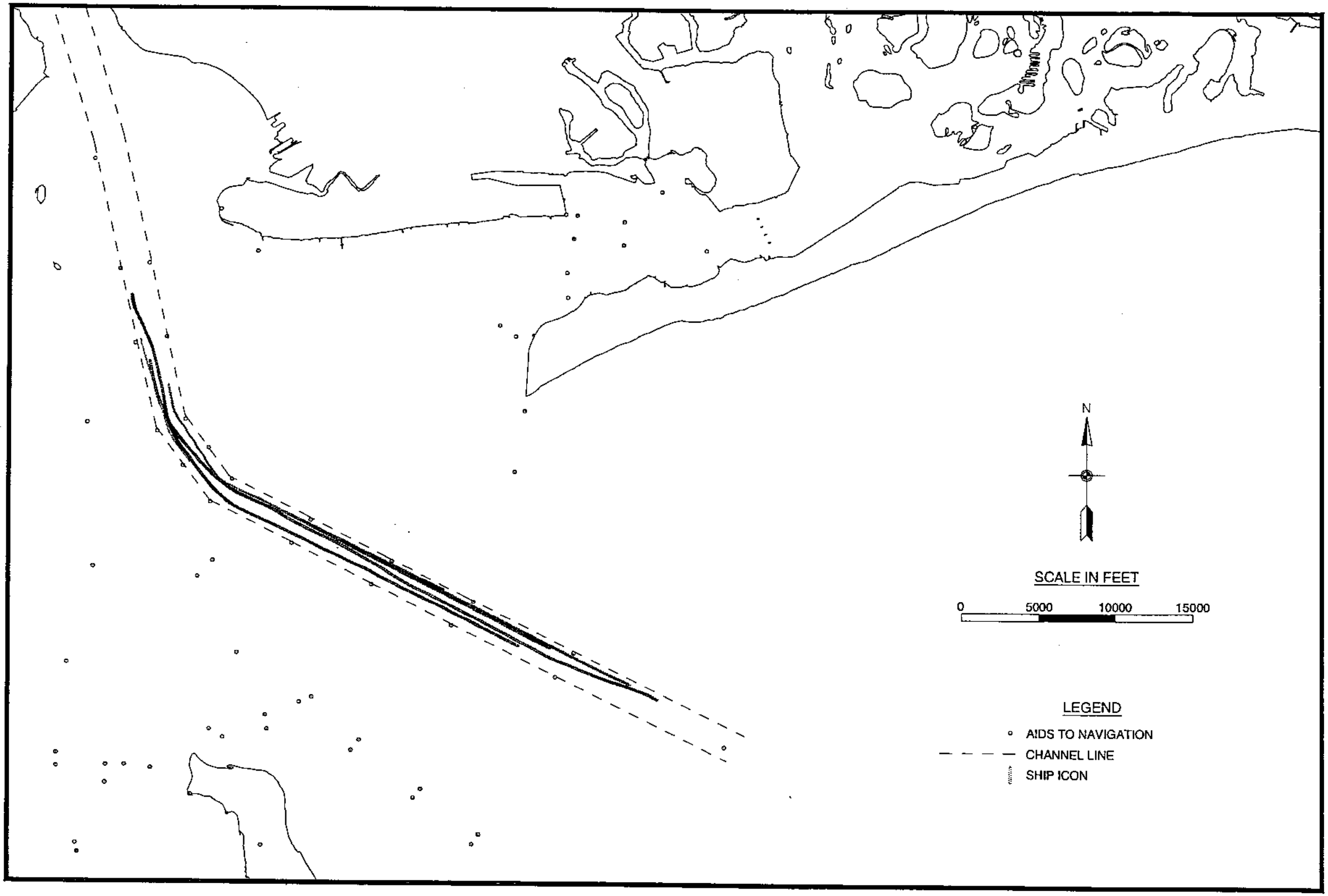

N
SCALE IN FEET
0
5000
10000
15000
LEGEND
AIDS TO NAVIGATION
CHANNEL LINE
SHIP ICON

Figure 19.

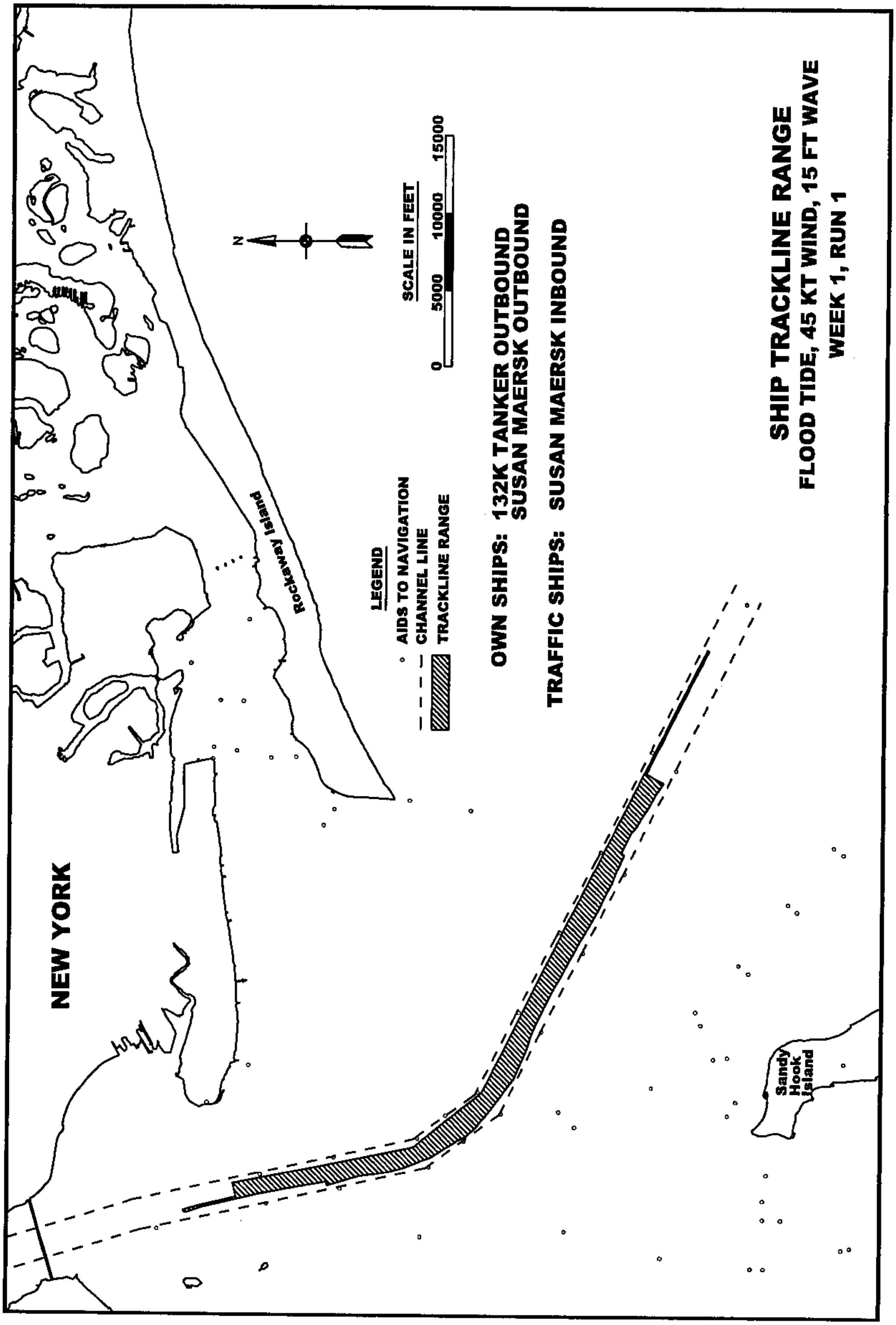
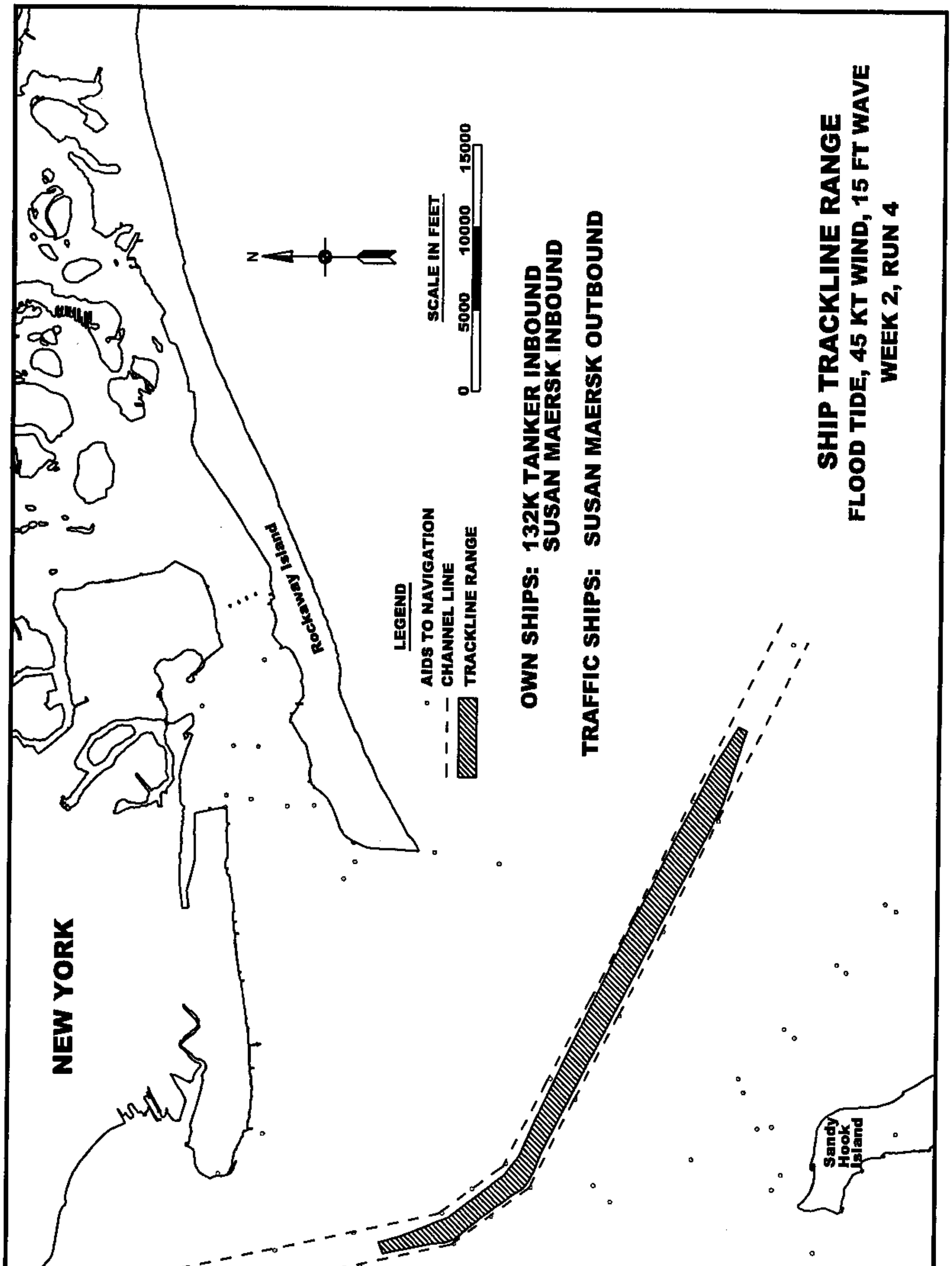
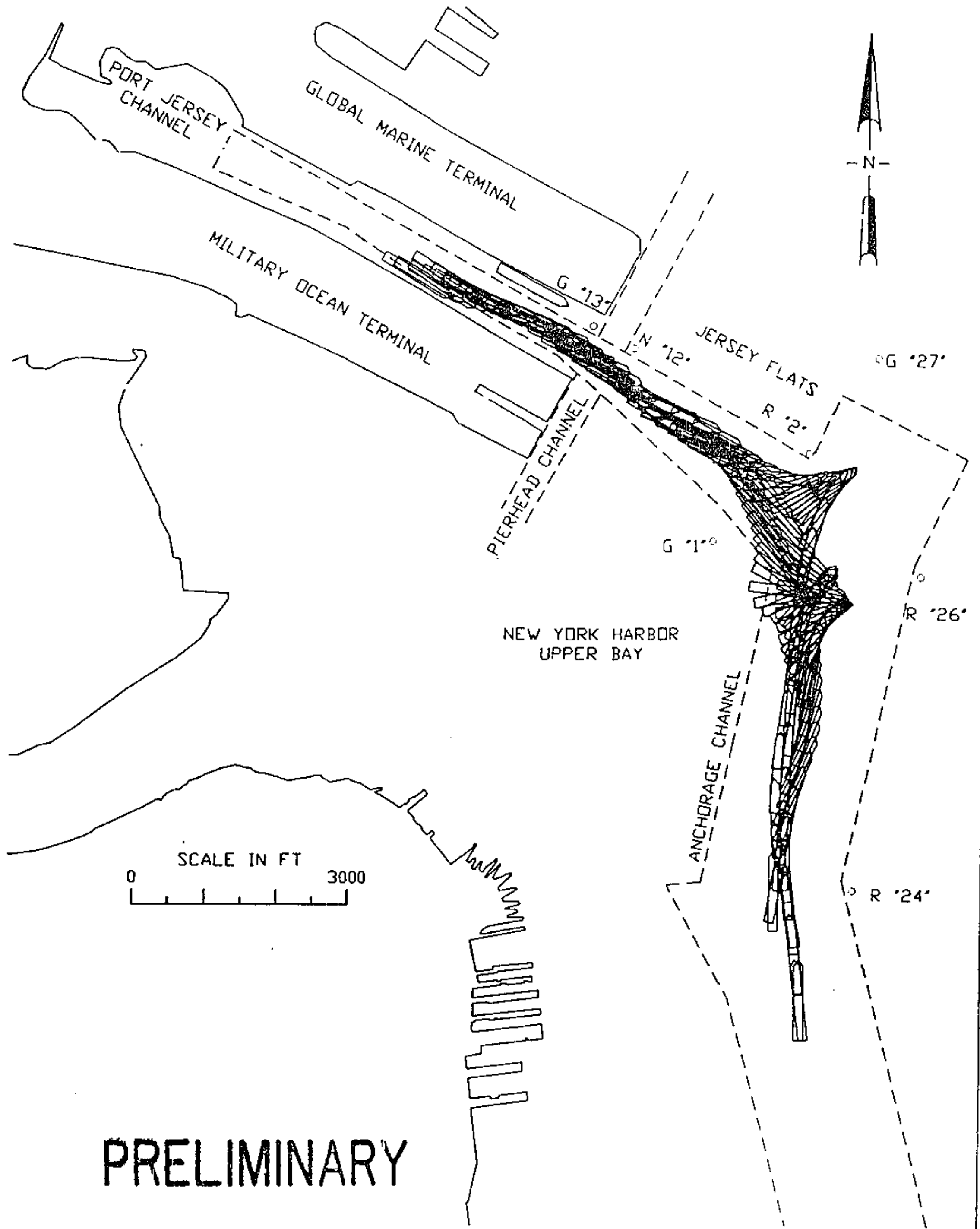

NEW YORK
Rockaway Island
Sandy Hook Island
N
LEGEND
AIDS TO NAVIGATION
CHANNEL LINE
TRACKLINE RANGE
SCALE IN FEET
0
5000
10000
15000
OWN SHIPS: 132K TANKER OUTBOUND
SUSAN MAERSK OUTBOUND
TRAFFIC SHIPS: SUSAN MAERSK INBOUND
SHIP TRACKLINE RANGE
FLOOD TIDE, 45 KT WIND, 15 FT WAVE
WEEK 1, RUN 1

Figure 20.



SHIP TRACKLINE RANGE
FLOOD TIDE, 45 KT WIND, 15 FT WAVE
WEEK 2, RUN 4
OWN SHIPS: 132K TANKER INBOUND
SUSAN MAERSK INBOUND
TRAFFIC SHIPS: SUSAN MAERSK OUTBOUND
LEGEND
AIDS TO NAVIGATION
CHANNEL LINE
TRACKLINE RANGE
SCALE IN FEET
0
5000
10000
15000
N
NEW YORK
Rockaway Island
Sandy Hook Island

Figure 21.



SHIP TRACK PLOT, PORT JERSEY
PROPOSED CHANNEL RE-ALIGNMENT, ORIGINAL BUOY POSITION
INBOUND, FLOOD TIDE, BOW OUT

Figure 22.

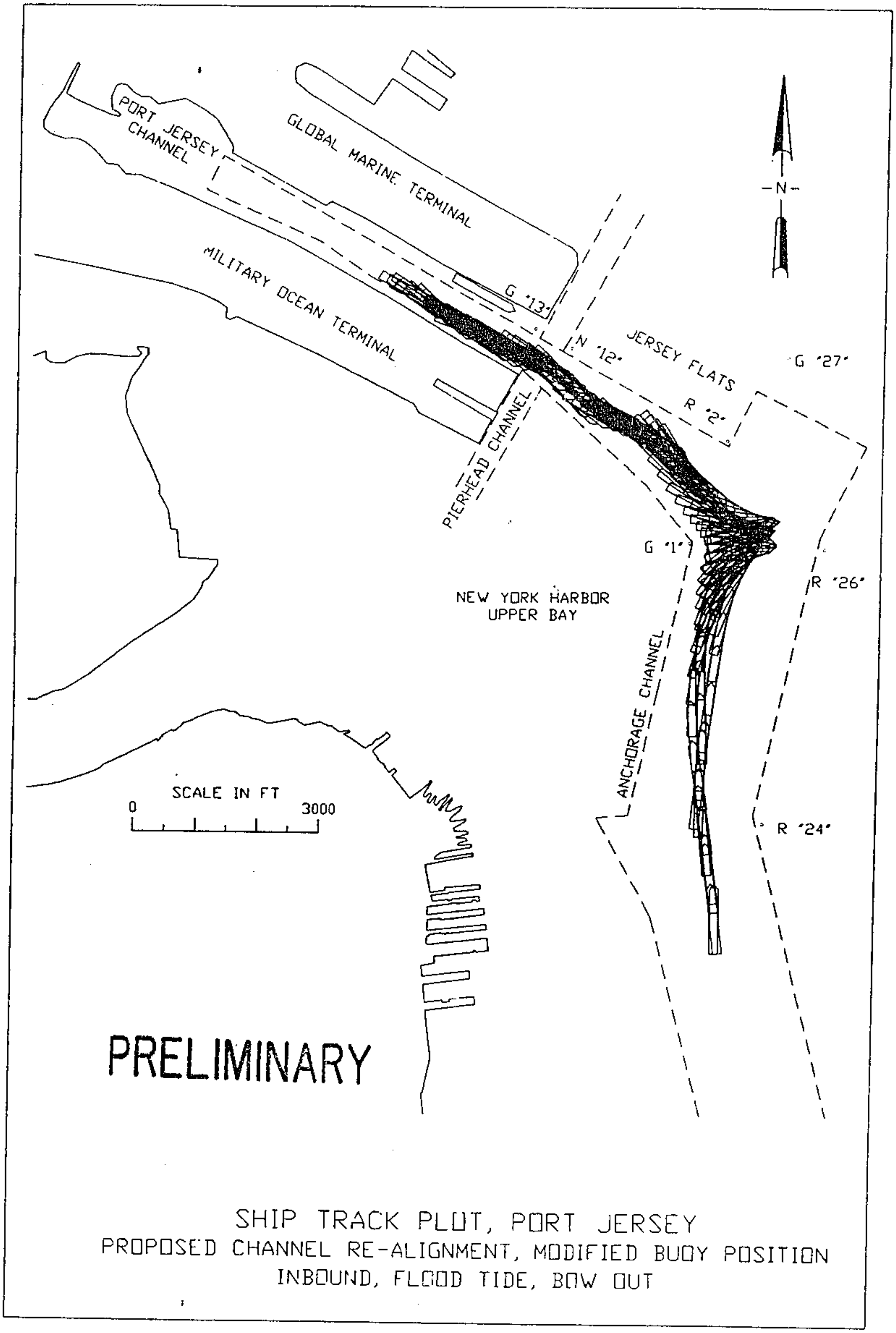

PORT JERSEY
CHANNEL
GLOBAL MARINE TERMINAL
MILITARY OCEAN TERMINAL
G "13"
N "12"
JERSEY FLATS
G "27"
R "2"
PIERHEAD CHANNEL
G "1"
NEW YORK HARBOR
UPPER BAY
R "26"
ANCHORAGE CHANNEL
SCALE IN FT
0
3000
R "24"
N
PRELIMINARY
SHIP TRACK PLOT, PORT JERSEY
PROPOSED CHANNEL RE-ALIGNMENT, MODIFIED BUOY POSITION
INBOUND, FLOOD TIDE, BOW OUT

Figure 23.

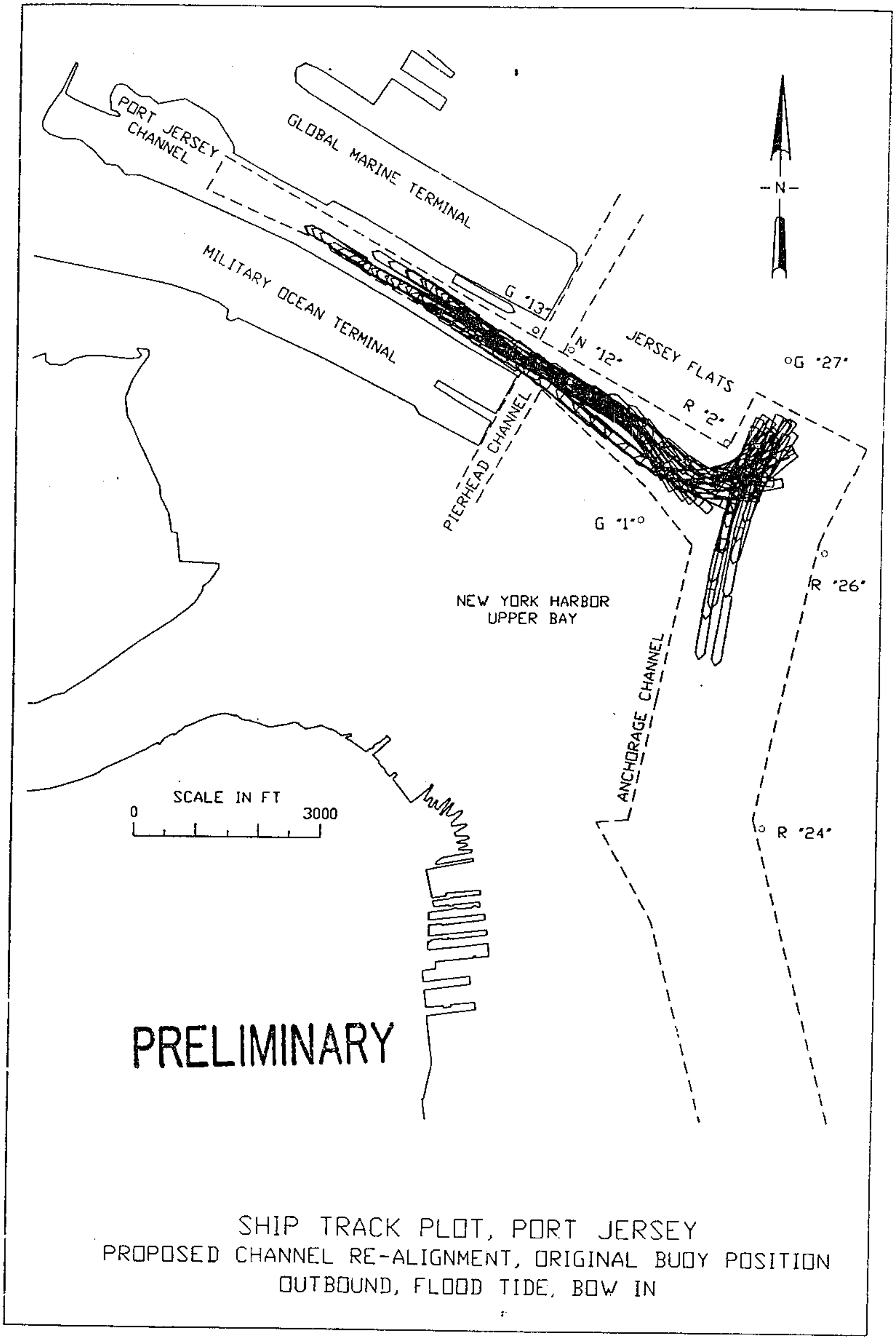

PORT JERSEY CHANNEL
GLOBAL MARINE TERMINAL
MILITARY OCEAN TERMINAL
G "13"
N "12"
JERSEY FLATS
G "27"
R "2"
PIERHEAD CHANNEL
G "1"
R "26"
NEW YORK HARBOR
UPPER BAY
ANCHORAGE CHANNEL
SCALE IN FT
0
3000
R "24"
N
PRELIMINARY
SHIP TRACK PLOT, PORT JERSEY
PROPOSED CHANNEL RE-ALIGNMENT, ORIGINAL BUOY POSITION
OUTBOUND, FLOOD TIDE, BOW IN

Figure 24.

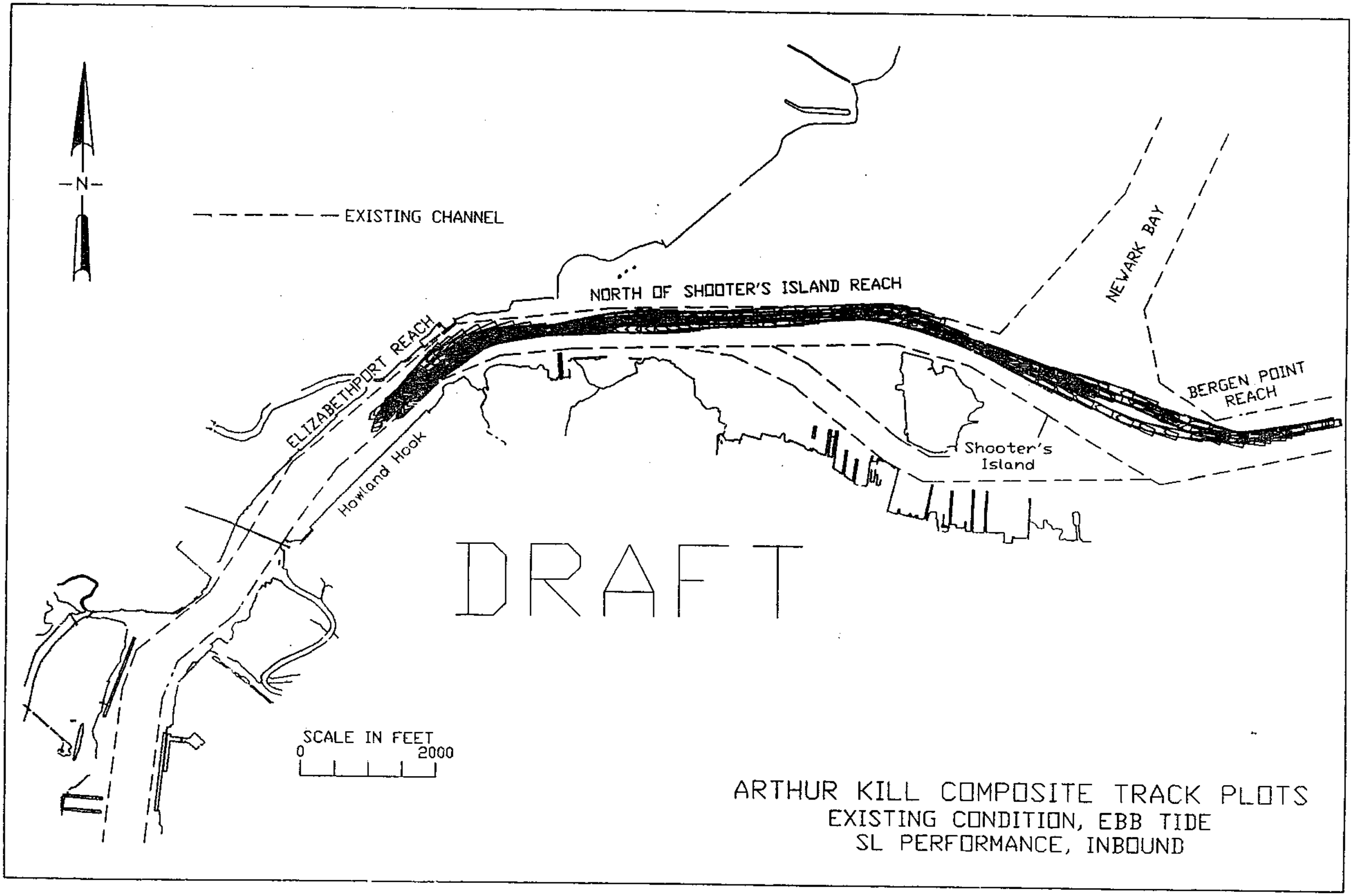

N
EXISTING CHANNEL
NORTH OF SHOOTER'S ISLAND REACH
ELIZABETHPORT REACH
Howland Hook
NEWARK BAY
BERGEN POINT
REACH
Shooter's
Island
DRAFT
SCALE IN FEET
0
2000
ARTHUR KILL COMPOSITE TRACK PLOTS
EXISTING CONDITION, EBB TIDE
SL PERFORMANCE, INBOUND

Figure 25.

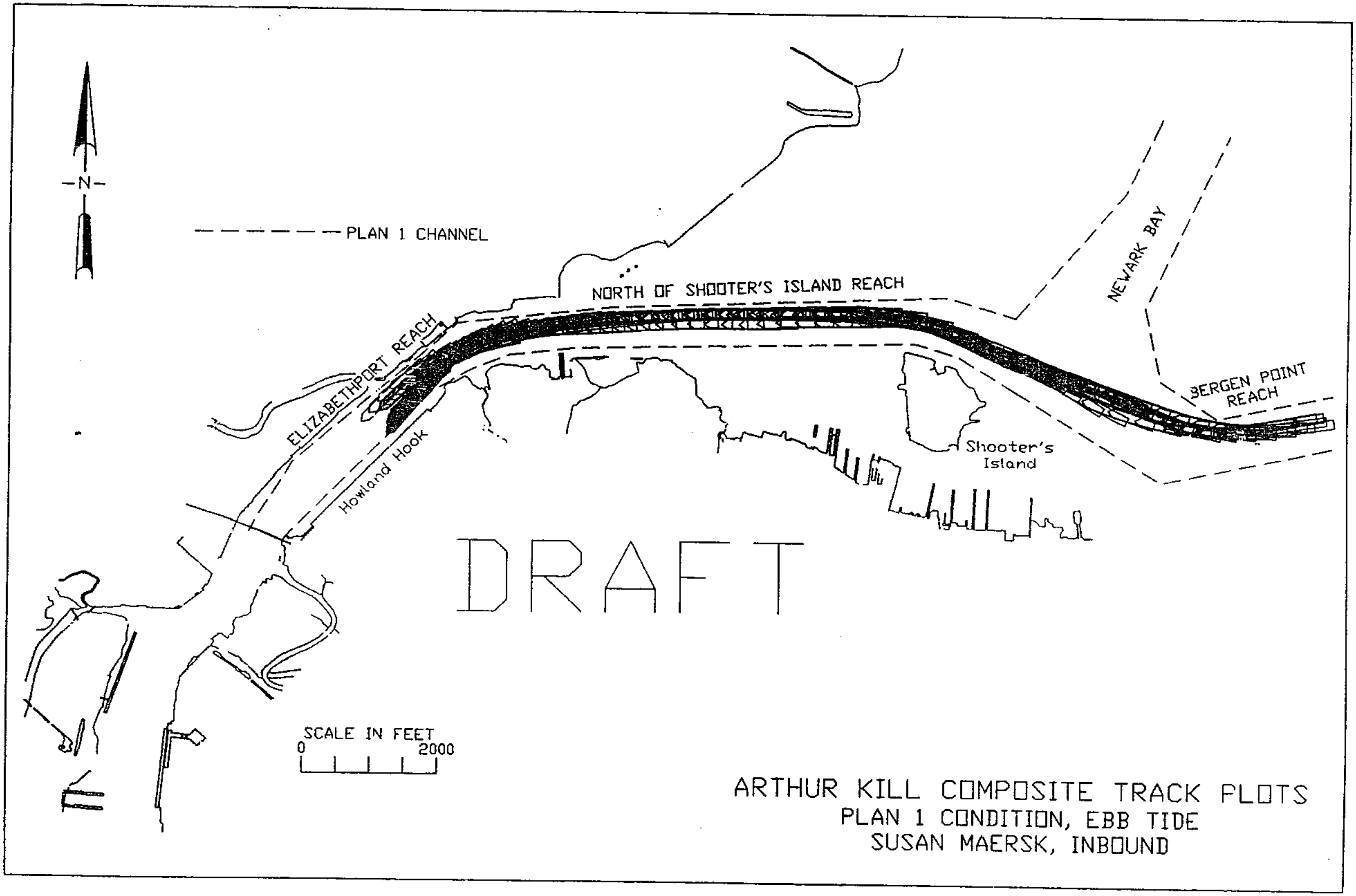

PLAN 1 CHANNEL
N
NORTH OF SHOOTER'S ISLAND REACH
NEWARK BAY
ELIZABETHPORT REACH
BERGEN POINT REACH
Howland Hook
Shooter's Island
DRAFT
SCALE IN FEET
0
2000
ARTHUR KILL COMPOSITE TRACK PLOTS
PLAN 1 CONDITION, EBB TIDE
SUSAN MAERSK, INBOUND

Figure 26.

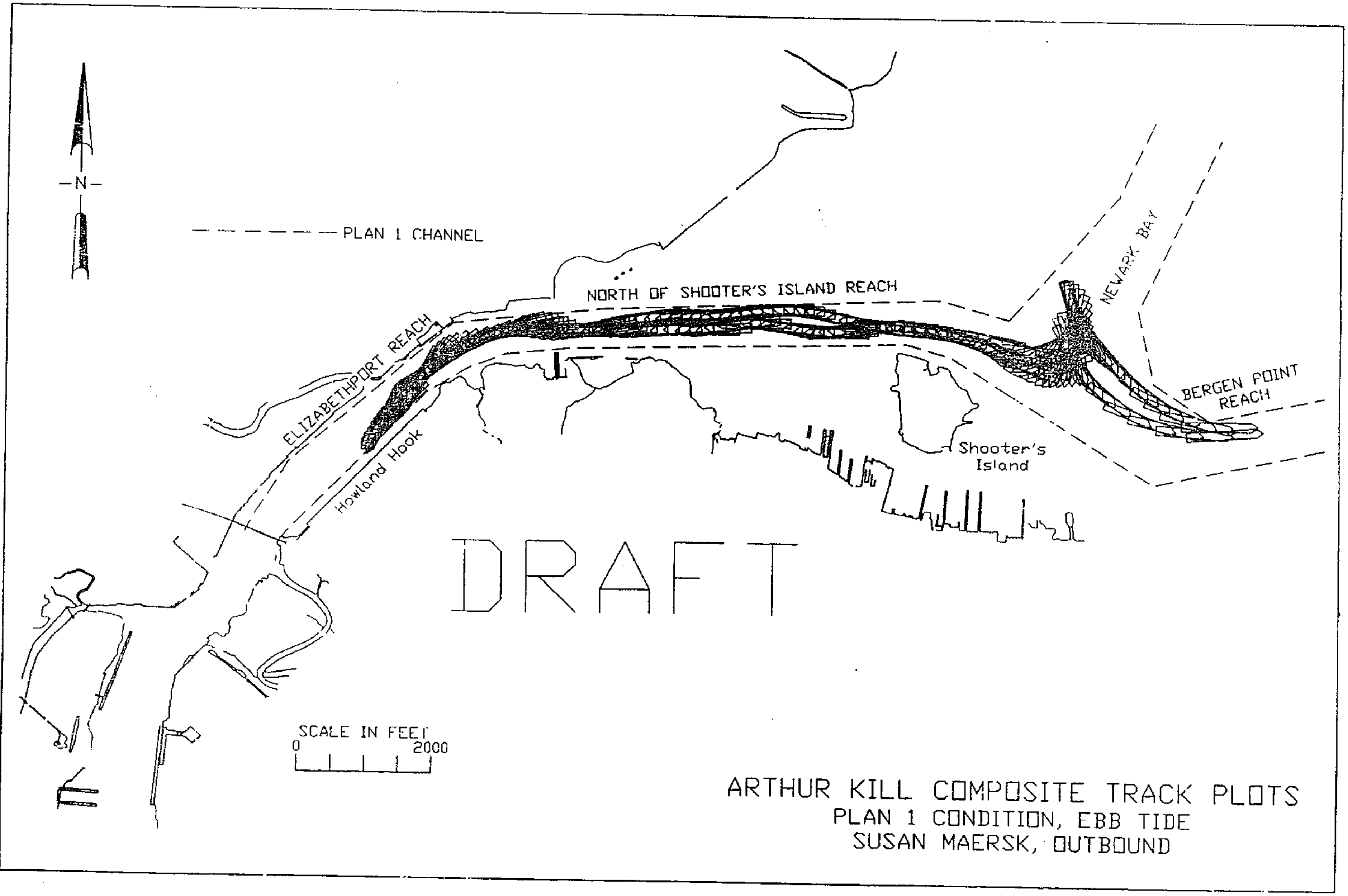
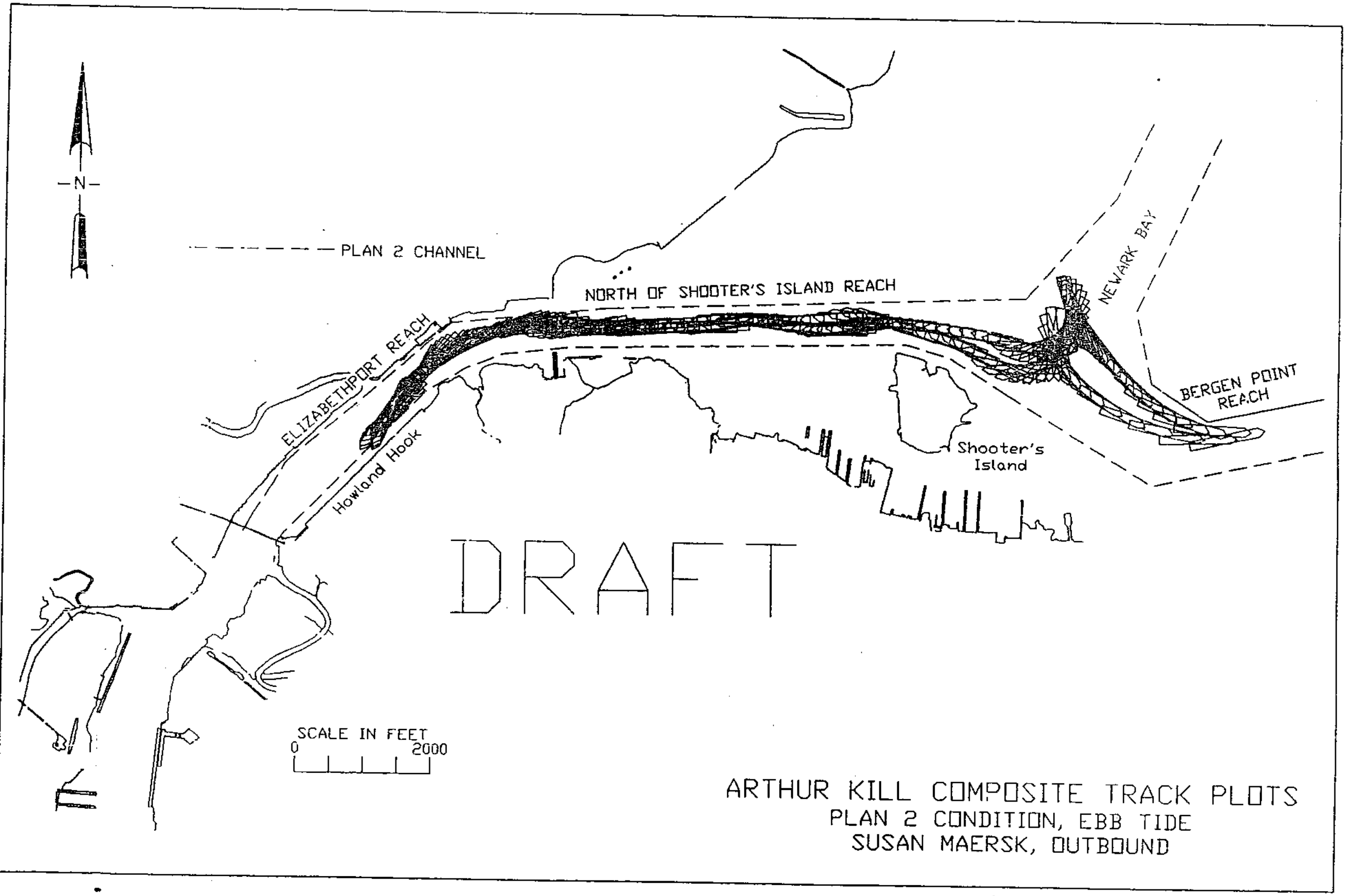

N
PLAN 1 CHANNEL
NORTH OF SHOOTER'S ISLAND REACH
ELIZABETHPORT REACH
NEWARK BAY
BERGEN POINT REACH
Howland Hook
Shooter's Island
DRAFT
SCALE IN FEET
0
2000
ARTHUR KILL COMPOSITE TRACK PLOTS
PLAN 1 CONDITION, EBB TIDE
SUSAN MAERSK, OUTBOUND

Figure 27.



N
PLAN 2 CHANNEL
NORTH OF SHOOTER'S ISLAND REACH
NEWARK BAY
ELIZABETHPORT REACH
BERGEN POINT REACH
Howland Hook
Shooter's Island
DRAFT
SCALE IN FEET
0
2000
ARTHUR KILL COMPOSITE TRACK PLOTS
PLAN 2 CONDITION, EBB TIDE
SUSAN MAERSK, OUTBOUND

Figure 28.

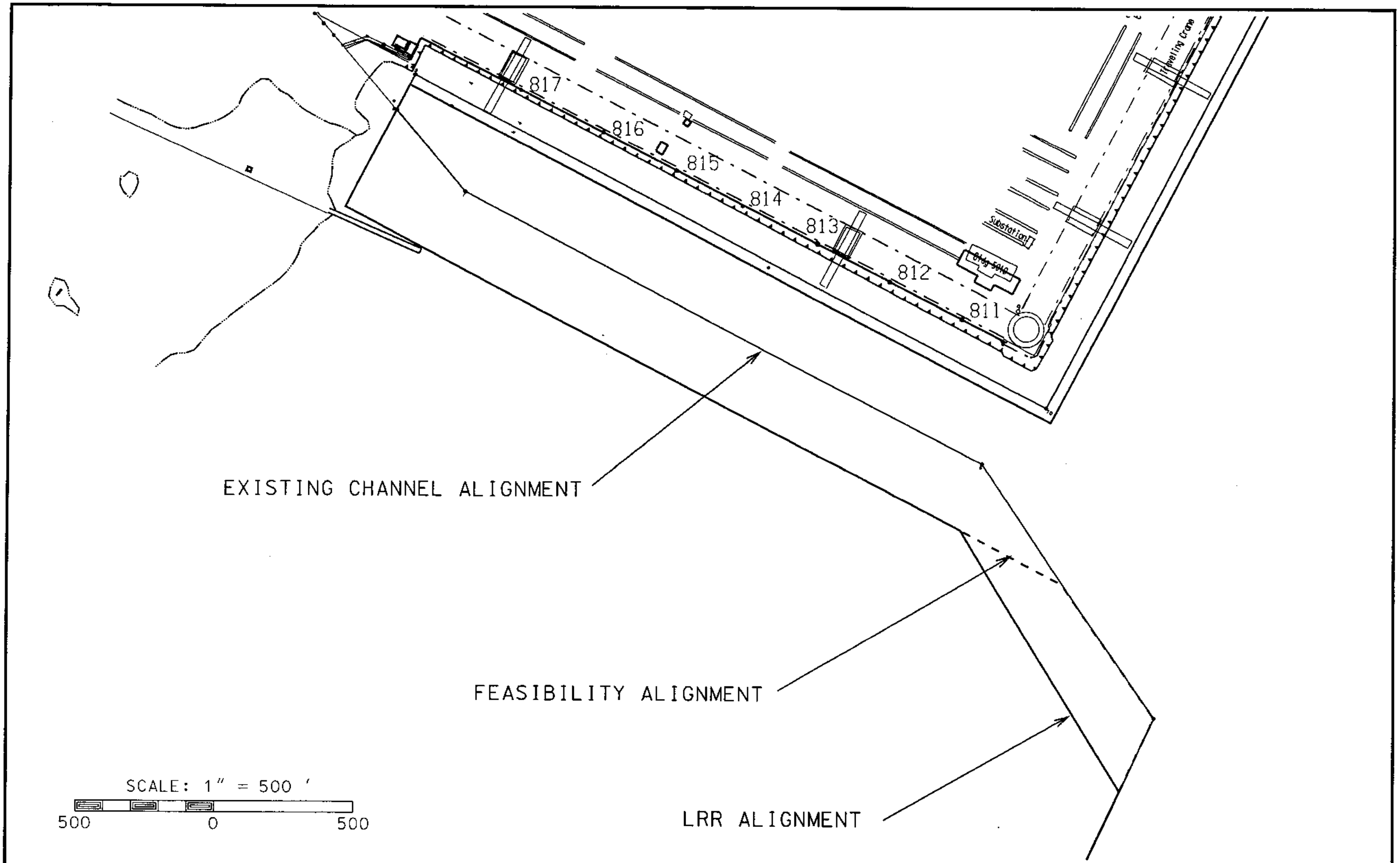


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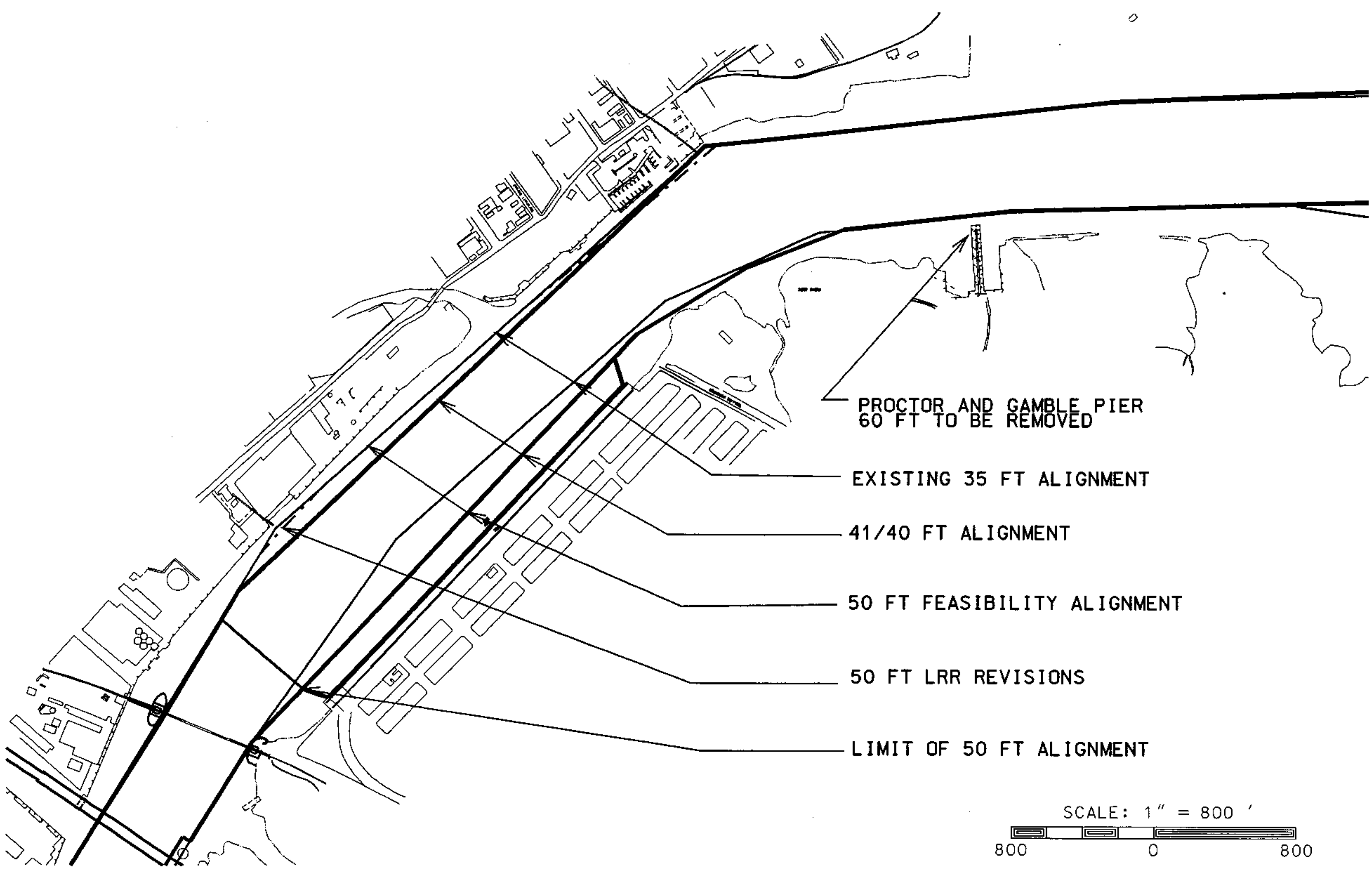
FIGURE 29
SOUTH ELIZABETH CHANNEL



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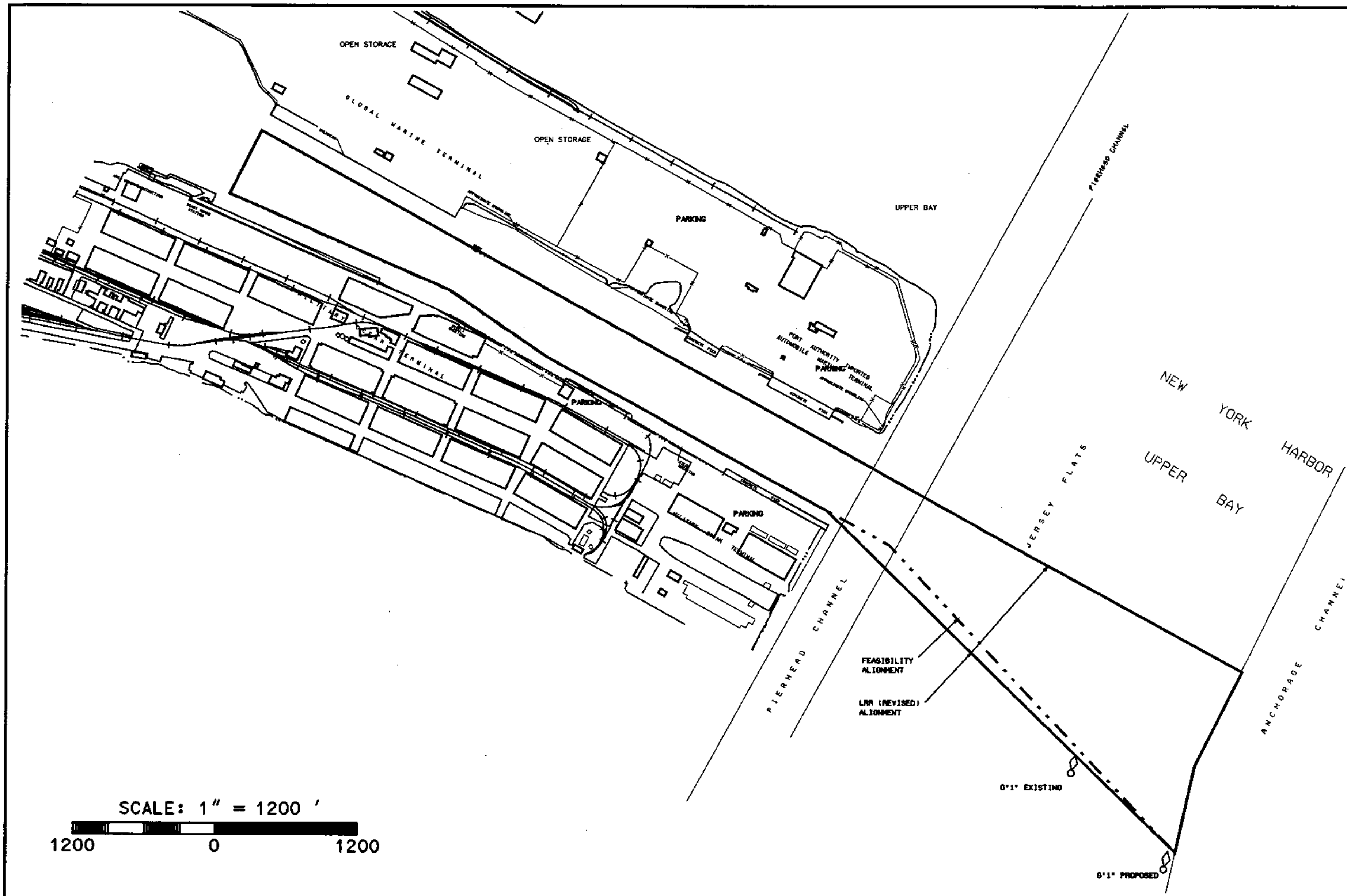

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FIGURE 31
PORT JERSEY CHANNEL

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