Lake Montauk Harbor, East Hampton, NY
Shallow Draft
Navigation Study
Appendix A: Engineering and Design
September 2020

Photograph provided by Frank Buonaiuto, New York District, USACE

New York State
Department of
Environmental Conservation

U.S. Army Corps of Engineers
North Atlantic Division
New York District

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1.0 INTRODUCTION

Lake Montauk Harbor is a home port and a port of call for commercial and recreational vessels. The existing Federal navigation channel is 150 feet wide and has a federally authorized 12 foot channel and harbor depths which are only marginally adequate for many of the current commercial vessels. The objectives of this study are to provide adequate channel dimensions to ensure reliable navigation for two-way traffic for the existing and future fleets; to provide efficient maintenance; and to efficiently utilize beach quality dredge material obtained from the channel deepening and channel maintenance to reduce erosion on the west shoreline beach.

Lake Montauk Harbor is on the northern shore of the south fork of Long Island, New York, approximately three miles west of Montauk Point, and 125 miles east of New York City. It is within the Town of East Hampton, Suffolk County, New York (Figure 1). The harbor is landlocked on the east, south and west sides, and connected on the north side with Block Island Sound by the inlet. The study area additionally encompasses the Block Island Sound shorelines bounded by Fort Pond Bay on the west and Shagwong Point on the east. The project was designated to the study objective of navigation improvement as primary benefit and storm damage reduction as an incidental benefit.

Lake Montauk is two miles long in a north-south orientation. It has an average width of 0.7 miles and encompasses 1,037 acres with a mean depth of seven feet. It is a homeport and a port of call for commercial and recreational vessels. There are several marinas for commercial vessels, a yacht club and small-craft facilities on both sides of the entrance to Lake Montauk Harbor. Gasoline, diesel fuel, water, ice, marine supplies, and space for transients are available.

Figure 1: Project Location

Inlet and Navigation History

Two rock jetties stabilized the inlet. The east and west jetties are approximately 1,100 and 980 feet in length, respectively, with top elevations at +8 feet Mean Lower Low Water (MLLW) and are separated by 500 feet. Star Island, located south of the inlet within the lake, is 0.5 miles long in a north-south direction and 0.2 miles wide. It is connected to the mainland by a causeway. The U.S. Coast Guard Station is located at the northern end of Star Island with direct access to the inlet. Coonsfoot Cove is between Star Island and the northwestern shore of the lake (Figure 2). The channel and turning basin servicing Coonsfoot Cove have been maintained by Suffolk County. There has been extensive development of the Coonsfoot Cove area to provide services for commercial fishing vessels, charter boats, and pleasure craft. The Federal navigation project for the improvement of Lake Montauk Harbor was authorized by the River and Harbor Act of 2nd March 1945 (House Document 369, 76th Congress, 1st Session). The existing project provides for the following:

- A Federal channel 12 feet deep at MLLW and 150 feet wide, extending from the 12 foot contour in Block Island Sound to the same depth in the existing yacht basin east of Star Island. The length of the existing Federal channel is approximately 0.7 miles.
- A boat basin, 10 feet deep at MLLW, 400 feet wide and 900 feet long, located northwest of Star Island.

The historical development of Lake Montauk Harbor jetties, channel, and boat basin are chronologically summarized in Table 1.

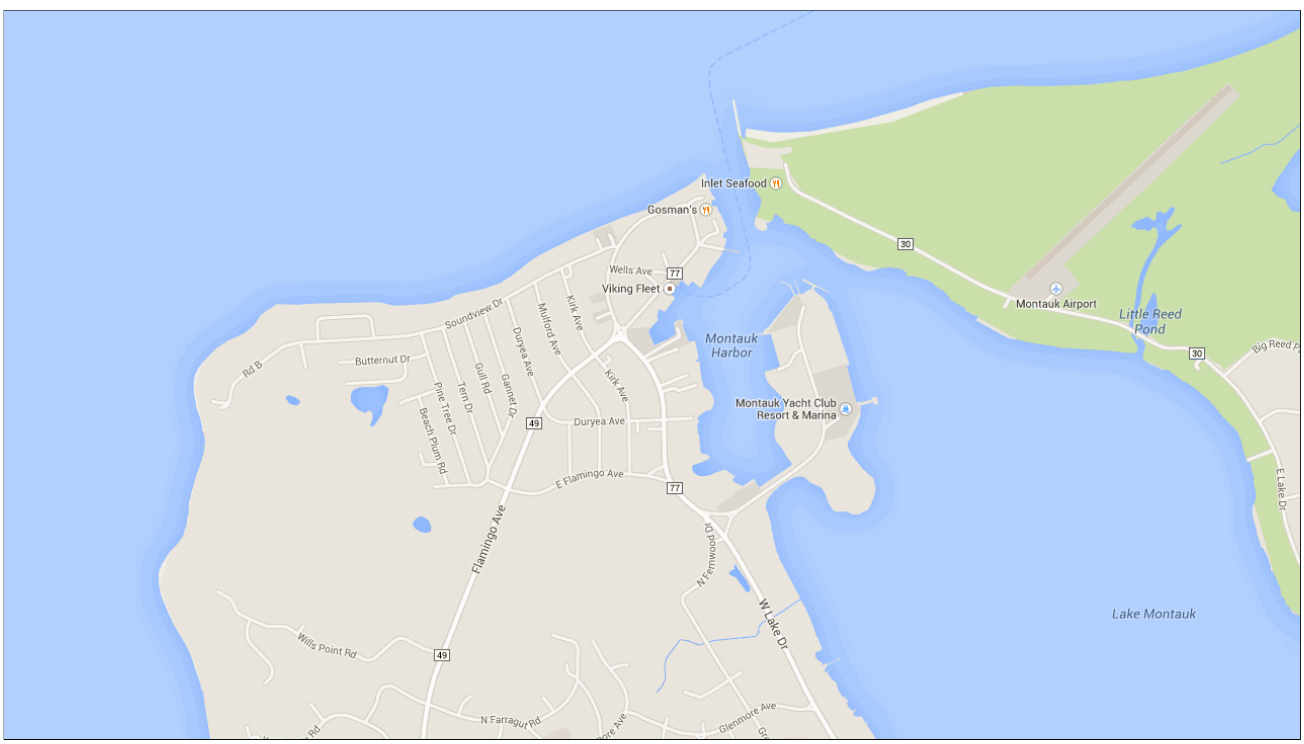


Figure 2: Project Site

Table 1: Historical Summary of Lake Montauk Harbor

Date	Historical Item/Event
1914	Private interest constructs a timber bulkhead across the inlet at Lake Montauk Harbor.
1926	Two parallel stone jetties were constructed by private interests to protect the harbor entrance. An approximately 700' long west jetty and a 750' long east jetty are separated by a distance of 500 feet.
1927	Dredging of the entrance channel and yacht basin by private interests.
1935	Section 3 of the River and Harbor Act directed a survey investigation of Lake Montauk Harbor.
1936	The Chief of Engineers authorized the survey investigation for the assessment of Federal participation in further improvements and maintenance of the privately owned Lake Montauk Harbor development.
1939	In response to a U.S. House Resolution, adopted by the Committee on Rivers and Harbors, a second report was prepared, including the results of the previous unpublished report of 1938. This report contained a favorable recommendation for the following improvements: a channel 12 feet deep at MLW, 150 feet wide, extending from the 12-foot contour in Block Island Sound to the same depth in the existing yacht basin east of Star Island; a boat basin 10 feet deep at MLW and 400 by 900 feet northwest of Star Island; and the repair and extension shoreward of the east and west jetties.
1942	Federal extension of west jetty shoreward. The work was accomplished at the request of the U.S. Navy with Navy funds. The U.S. Army Corps of Engineers supervised the work. The west jetty was extended 280 feet with crest elevation at +8 feet MLW. The total length is 981 feet.
1942-1943	Entrance Channel was dredged to -12 feet MLW, and to a width of 150 feet. The work was accomplished at the request of the U.S. Navy with Navy funds. The U.S. Army Corps of Engineers supervised the work.
1945	The River and Harbor Act of 2 March 1945 authorized the recommended Federal project.
1949	The first dredging project authorized by Congress began.
1967	General Design Memorandum for Lake Montauk Harbor, New York was prepared. The initial project was well justified with a BCR of 1.8. The benefits were primarily recreational. Work remaining from the authorized project: dredging of the boat basin, extension of the east jetty, and repairs to the east and west jetties. Modification to the plan as contained in the authorizing document includes: raising the west jetty crest elevation to +8 feet MLW during repair from present +6 feet, to match all other section of the east and west jetties, and the addition of sport fishing facilities on top of both jetties.
1968	East jetty extended shoreward 350 feet with crest elevation to +8 feet MLW. Length becomes 750+350=1,100 feet Initial dredging of boat basin to -10 feet MLW. Repair of the east and west jetties. Added jetty sport fishing facilities.
1991	U.S. Senate Resolution adopted by the Committee on the Environment and Public Works for authorization of a shallow draft navigation reconnaissance study at Lake Montauk Harbor, New York.
1995	Lake Montauk Harbor, New York Reconnaissance Report completed.
1995	Rehabilitation of East Jetty
1998	Partial Removal of Inner Harbor Shoal
1999	Advance maintenance dredging conducted by USACE for NYSDEC under Support for Others Program
2002	Lake Montauk Harbor Navigation and Storm Damage Improvement Feasibility Study Authorized with NYSDEC as Local Sponsor.
2003	Feasibility Cost Sharing Agreement (FCSA) with NYSDEC for this multipurpose coastal storm risk management and navigation study and report signed.
2013	Following Hurricane Sandy in 2012, the Lake Montauk Harbor study was identified in the May 2013 Second Interim Report to Congress in response to the Disaster Relief Appropriation Act of 2013 (PL 113-2) as a feasibility study to be completed at 100% Federal expense.

2014	The study was re-scoped to focus on coastal storm risk management as an interim response to the original congressional authorities, and a FCSA amendment was signed on 31 March 2014, with a separate response to the navigation improvement purpose to be completed in the future.
2016	The U.S. Army Corps of Engineers identified a tentatively selected plan for coastal storm risk management and coordinated with the non-Federal sponsor to obtain its support and held a public meeting.
2017	The non-Federal sponsor, by letter dated 6 April 2017, requested that this study focus on navigation improvements only. By memo dated 15 May 2017, the U.S. Army Corps of Engineers New York District responded to this request and is now completing the study to recommend navigation improvement only.
2019	A draft feasibility report and draft environmental assessment recommending a tentatively selected plan was released for a 30-day public review.

2.0 EXISTING CONDITIONS

Historical Shoreline Change

Historical shorelines from July 1892, May 1933, and October 1965 were compiled to document long-term trends prior to the construction of engineering structures. These data were particularly useful for documenting the impact of jetty construction on adjacent shoreline response since 1933 (Figure 3). Recent shoreline response was evaluated at about decadal intervals between 1965 and 2004 to observe cumulative and incremental change trends.

Shoreline positions derived from high-resolution scans of aerial photographs for October 10, 1980 and June 29, 1992 were determined by registering photographs to a common datum and coordinate system using control points extracted from 0.5 foot resolution natural color orthometric photography acquired in April 2001. Root-mean-square (RMS) photographic registration error ranged from ±2 to ±3 feet. Interpretation of the high-water shoreline position, recognized as a feature on the beach marking the boundary between wind-driven transport and that associated with waves and currents (e.g., the berm crest or a dark line marking contrast between the backshore and the foreshore), was relatively straightforward except for a few places where the beach was somewhat overexposed. The May 14, 2004 high-water shoreline was acquired using differential global positioning system (GPS) equipment to survey the position of the berm crest while walking along the beach. Uncertainty associated with shoreline position measurements was approximately ±1.6 feet.

The study results indicate that prior to construction of jetties in year 1926 shoreline recession was prevalent throughout much of the study area, with an average retreat rate of 2 feet per year west of the jetties. Although shoreline recession rates increased post-jetty construction west of the harbor from 1933 to 1965 and 1965 to 1980, shoreline change between 1980 and 2004 indicated decreased recession rates west of the entrance and shoreline advance east of the harbor jetties (Figure 4). Following jetty construction, average recession rates west of the jetties range between 4.5 feet per year (1933 to 1965) and 0.1 feet per year (1992 to 2004). Lower recession rates in recent time periods may be due to the placement of bulkheads and rubble mound structures to protect rapidly eroding beaches since 1965. Overall, post-jetty shoreline response (1933 to 2004) illustrated increased shoreline recession west of Montauk Harbor and shoreline advance east of the jetties. The average long-term erosion on the downdrift shoreline between 1933 and 2004 is approximately 3.1 feet per year. Given the reduction in recent shoreline recession rates, the historic rate of 2 feet per year was chosen for use in developing future without project conditions.

Maintenance Dredging Record

Channel maintenance dredging records indicate that approximately 532,000 cubic yards of sand was removed from the navigation channel and placed on the beach west of the entrance between 1945 and 2018, with an average shoaling rate of 7,200 cubic yards per year. Table 2 provides a time series of channel maintenance dredging and subsequent beach fill west of the entrance between initial construction and the present. The historical dredging rate was analyzed based on Table 2 and shown graphically in Figure 6. As shown in the figure, the dredging rate indicates a significant drop in the 1980-1990 periods, possibly due to over-dredging activities in the 1960-1970 periods. The projected without project future dredging rate is 8,000 cubic yards per year. The anticipated increase in shoaling rate is the result of the east sediment fillet becoming saturated and allowing more littoral material to flow around the jetty to deposit in the flood shoal inside the inlet.

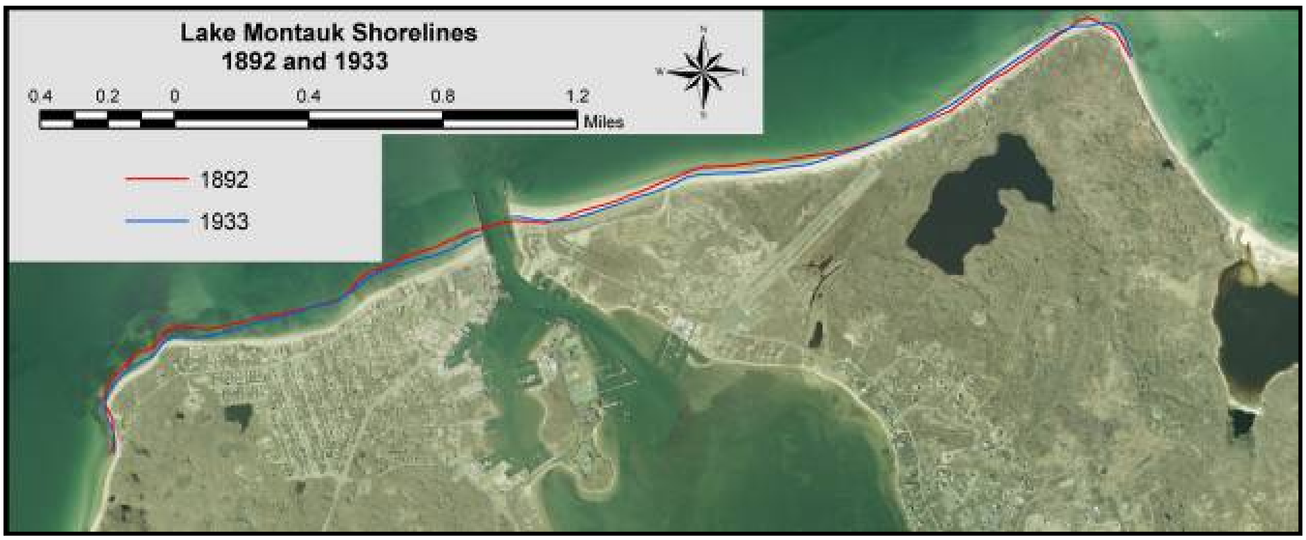


Figure 3: Pre-Jetty Construction Shorelines

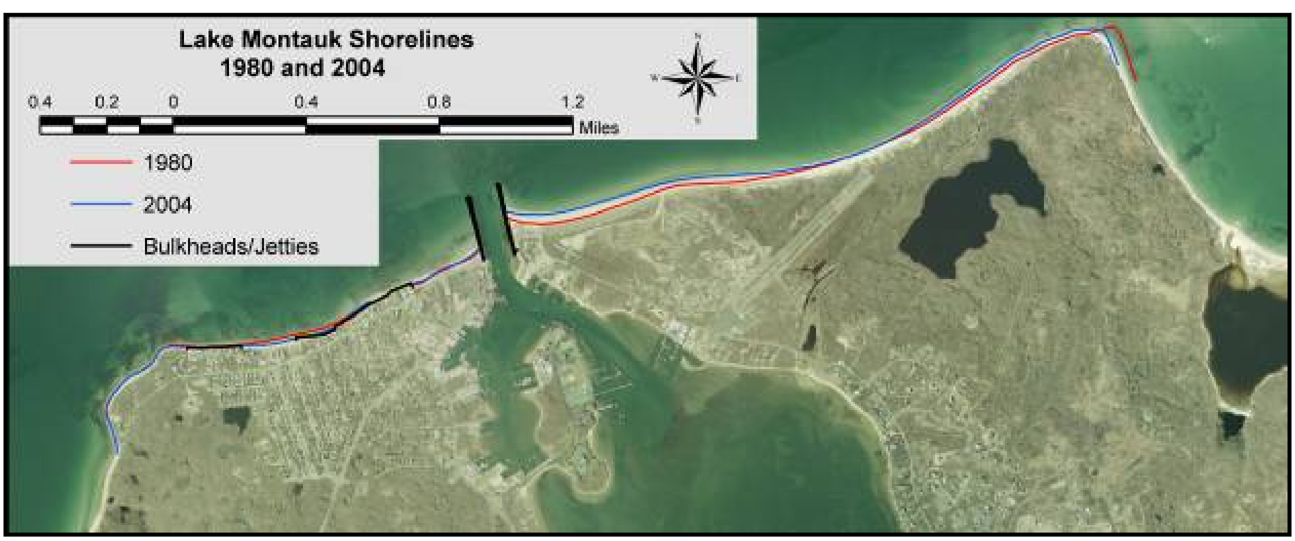


Figure 4: Shoreline Changes between 1980 and 2004

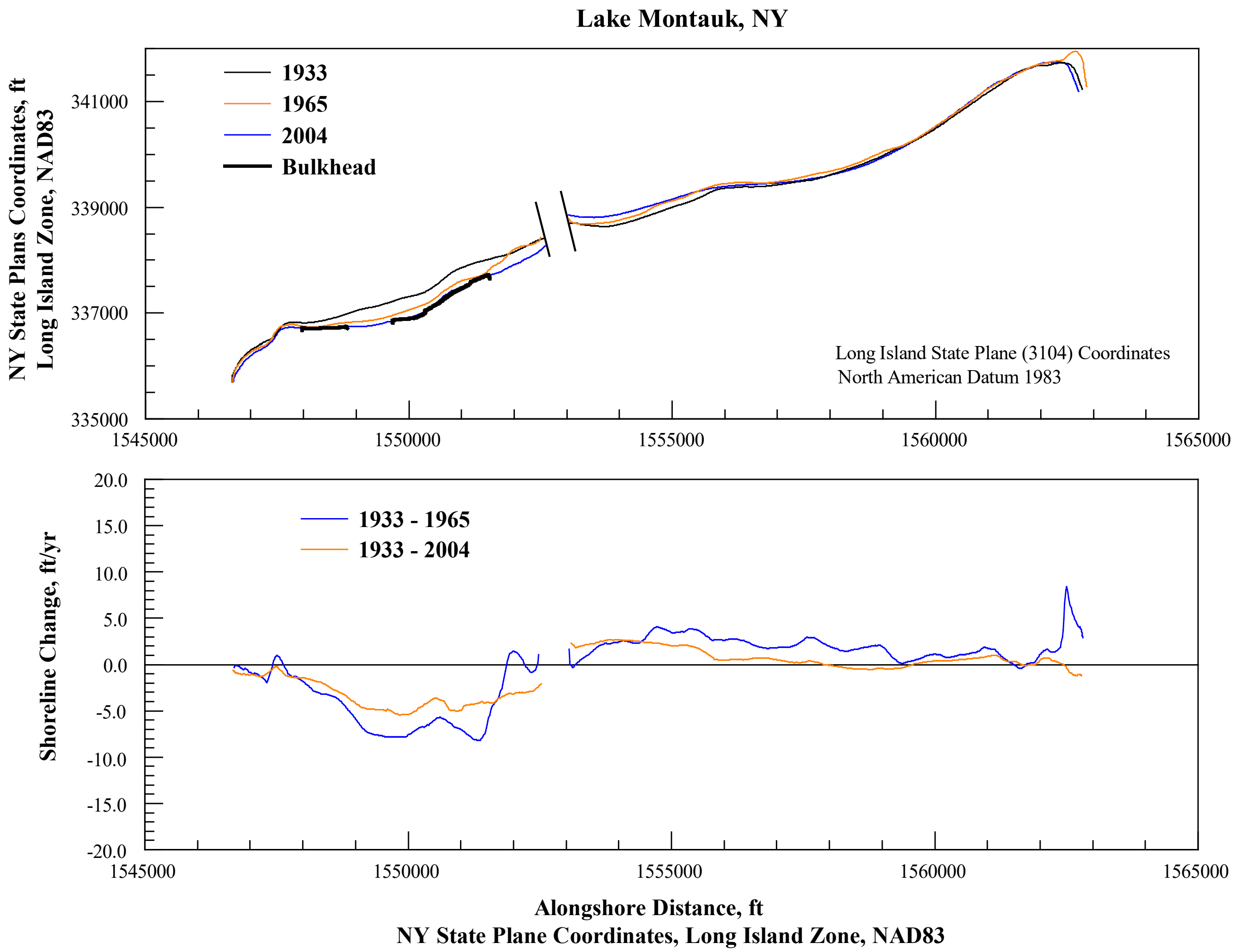


Figure 5: Long-term Shoreline Changes (1933-2004)

Table 2: Dredging Record

Lake Montauk Navigation Channel Dredging Record		
Dredge Volume (Cubic Yards)		
Dredging Period	**New Work**	**Maintenance**
Sep-Oct 1942	19,381	
Dec 1942 - Jan 1943	57,020	
1945 (Navy Funds)		14,900
Sep 1949		41,818
Jul-Sep 1955		34,546
Sep-Nov 1958		45,433
Apr-May 1962		36,205
Aug-Oct 1965		28,541
14 Aug-16 Sep 1968	110,385	
15 Jul-4 Aug 1969		41,874
5-21 Jun 1972		36,219
Jun-27 Jul 1976		25,933
9-17 Jan 1984		32,236
Oct 1991 - Apr 1992		15,307
Dec 1994-Jan 1995		46,175
Feb-Mar 2000		50,222
Oct-Nov 2004		9,350
Dec 2009		3,695
Oct-Dec 2011		11,915
12-29 Oct 2014		20,410
15 Oct 2018		37,175
TOTAL	**186,786**	**531,954**

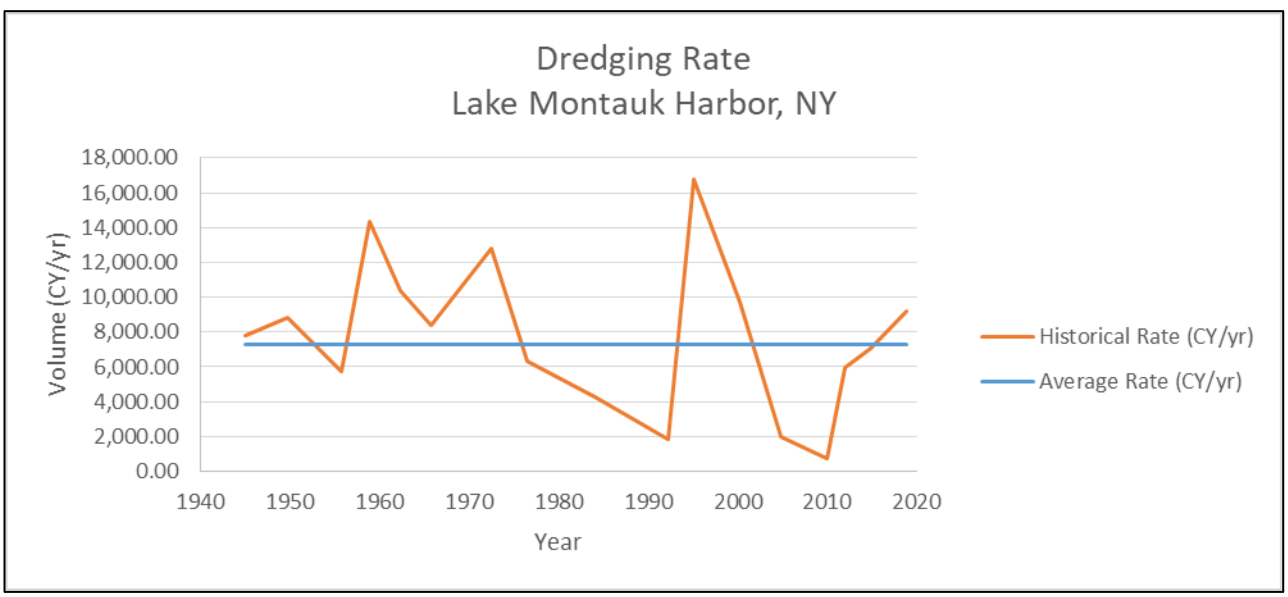


Figure 6: Historical Dredging Rates

Sediment Budget

Shoreline and bathymetry change data, as well as channel dredging quantities, formed the primary sources of information for developing a sediment budget for the periods 1892 to 1933 (41 years), and 1933 to 2004 (71 years) using the USACE Sediment Budget Analysis System (SBAS). These time periods were chosen to represent pre- and post-construction intervals relative to initial stabilization of the entrance in 1926. The post-jetty construction period was further subdivided to develop a recent sediment budget for the 1965-2004 time periods, which captures the effects of major rehabilitation of the entrance structures done in 1968. The results of sediment budget analyses are shown in Table 3, Table 4, and Table 5 and are illustrated graphically in Figure 7, Figure 8, and Figure 9. As shown in the figures and tables, net longshore sediment transport is to the west. West-directed transport quantities were determined by balancing volume change estimates derived from shoreline change results, offshore losses due to storms, estimates of sediment deposition inside the harbor, and dredging quantities placed on the beach west of the entrance harbor jetties. Channel maintenance dredging of shoaling material has been deposited as beachfill west of the jetties (bypassed) into Cell 4 since 1945. Maintenance dredging data were used to derive average annual beach fill/bypassing rates of 6,100 cubic yards per year for 1933 to 1965, 7,400 cubic yards per year for 1965-2004, and 6,800 cubic yards per year for 1933 to 2004. These channel maintenance bypassing rates are reflected in the sediment budget as inputs into Cell 4 from the east.

Pre-Jetty Construction 1892-1933

The pre-jetty construction sediment budget provides an overview of the uninterrupted shoreline evolution and sediment transport pattern from 1892-1933. As shown in Table 3 and Figure 7, the net sediment transport direction is westward. Erosion of the eastern headland at Shagwong Point provided approximately 15,000 cubic yards per year source of littoral material. The general shoreline between the two headlands (Shagwong Point to the east and Culloden Point to the west) was erosive. There were approximately 20,000 cubic yards per year net sediment transport across the inlet and approximately 30,000 cubic yards per year net transport passing Culloden Point. The majority of the littoral material passing Culloden Point continued moving offshore; creating a sub aerial spit southwest of Culloden Point as shown on the 1933 and 1999 bathymetric maps. The result was a net 10,000 cubic yards per year sediment deficit on the downstream (west of the inlet) shoreline even with a constant supply of 20, cubic yards per year littoral material from upstream shoreline across the inlet before the jetties were constructed.

Post-Jetty Construction 1933-2004

The post-jetty construction sediment budget (Table 4 and Figure 8) represents the general sediment transport pattern and can be used as a basis to predict the future without project sediment transport and shoreline condition at the project site. Based on the 1933-2004 sediment budget, the available upstream littoral source entering Cell 6 was reduced to 13,000 cubic yards per year. Approximately 5,000 cubic yards per year of that littoral material was retained in the east sediment fillet (east of east jetty) while the rest was bypassed onto the downdrift shoreline via maintenance dredging or lost permanently offshore. Even with 7,000 cubic yards per year sand being bypassing at the inlet, approximately 23,000 cubic yards per year leave the project area at Culloden Point, which results in the downdrift shoreline west of the inlet experiencing erosion at a rate of 16,000 cubic yards per year.

Recent Time Period 1965-2004

In the second half of the post-jetty period (1965-2004), due to slow-down of bluff erosion (providing littoral material source) and man-made shore protection structures, the littoral transport rates along the project shoreline have slowed down gradually (Table 5 and Figure 9). As shown in the 1965-2004 sediment budget, the downdrift erosion along shoreline west of the inlet reduced to 12,200 cubic yards per year with approximately same updrift sediment supply as in the overall 1933-2004 time period.

Predicted Future Sediment Budget

Based on the results of the pre-construction, post-construction, and recent sediment budgets, and the observation that the updrift fillet is fully saturated and can no longer impound additional material, the future without project sediment budget was estimated as follows:

- Updrift sediment source (Cell 6) to be bypassed: 10,000 – 12,000 cubic yards per year;
- Downdrift shoreline net (westward) transport at Culloden Point: 20,000 cubic yards per year;
- Net downdrift shoreline sediment deficit (after bypassing): 8,000 - 10,000 cubic yards per year;
- Majority of littoral material passing Culloden Point ends up in sub aerial spit;

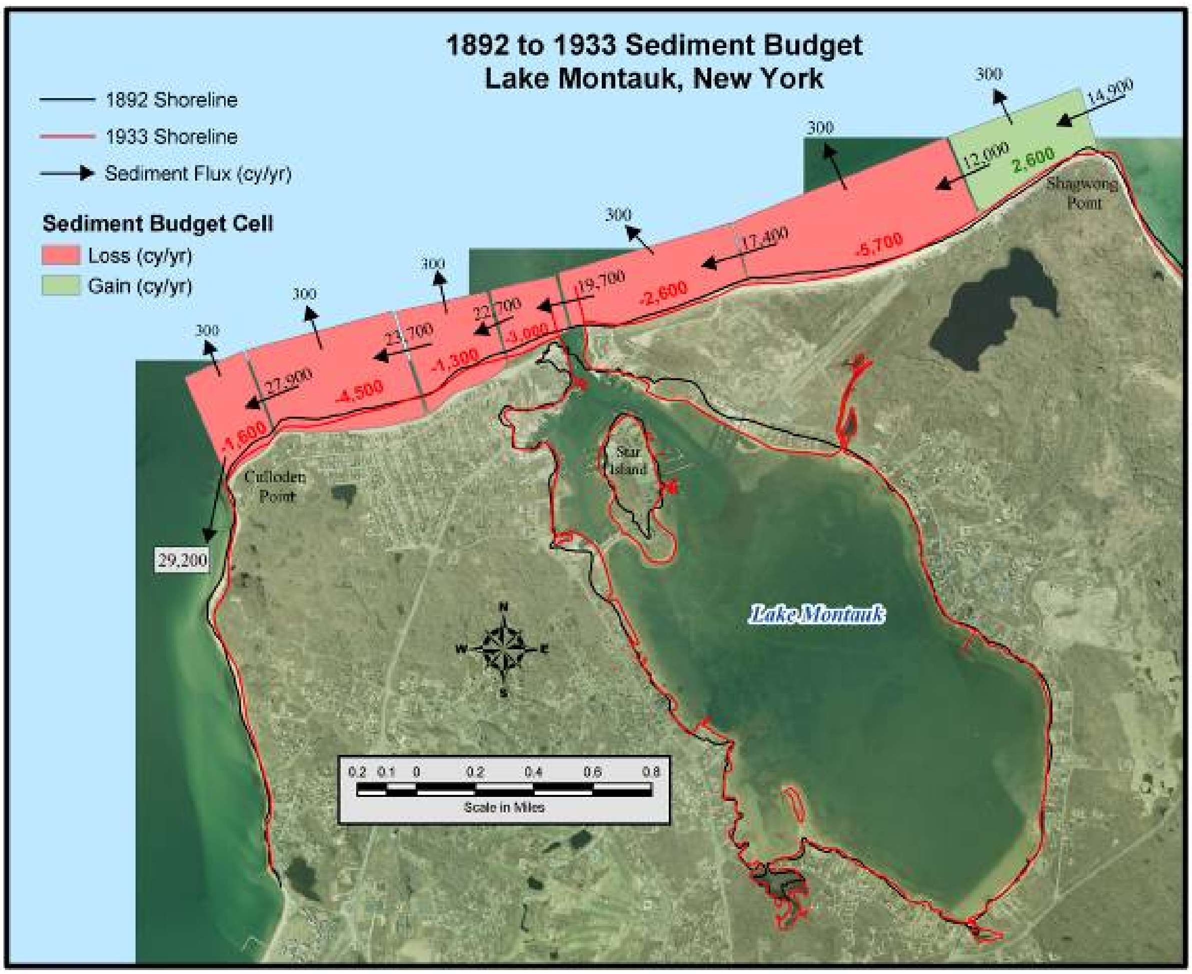


Figure 7: Pre-jetty construction sediment budget

Table 3: Lake Montauk Beach Sediment Budget, 1892 to 1933. Cells are labeled west to east.

Cell Number	1	2	3	4	5	6	7	8
Input (+)	27,900	23,700	22,700	19,700		17,400	12,000	14,900
Output (-)	29,200	27,900	23,700	22,700		19,700	17,400	12,000
Offshore	300	300	300	0		300	300	300
Residual	**-1,600**	**-4,500**	**-1,300**	**-3,000**		**-2,600**	**-5,700**	**2,600**

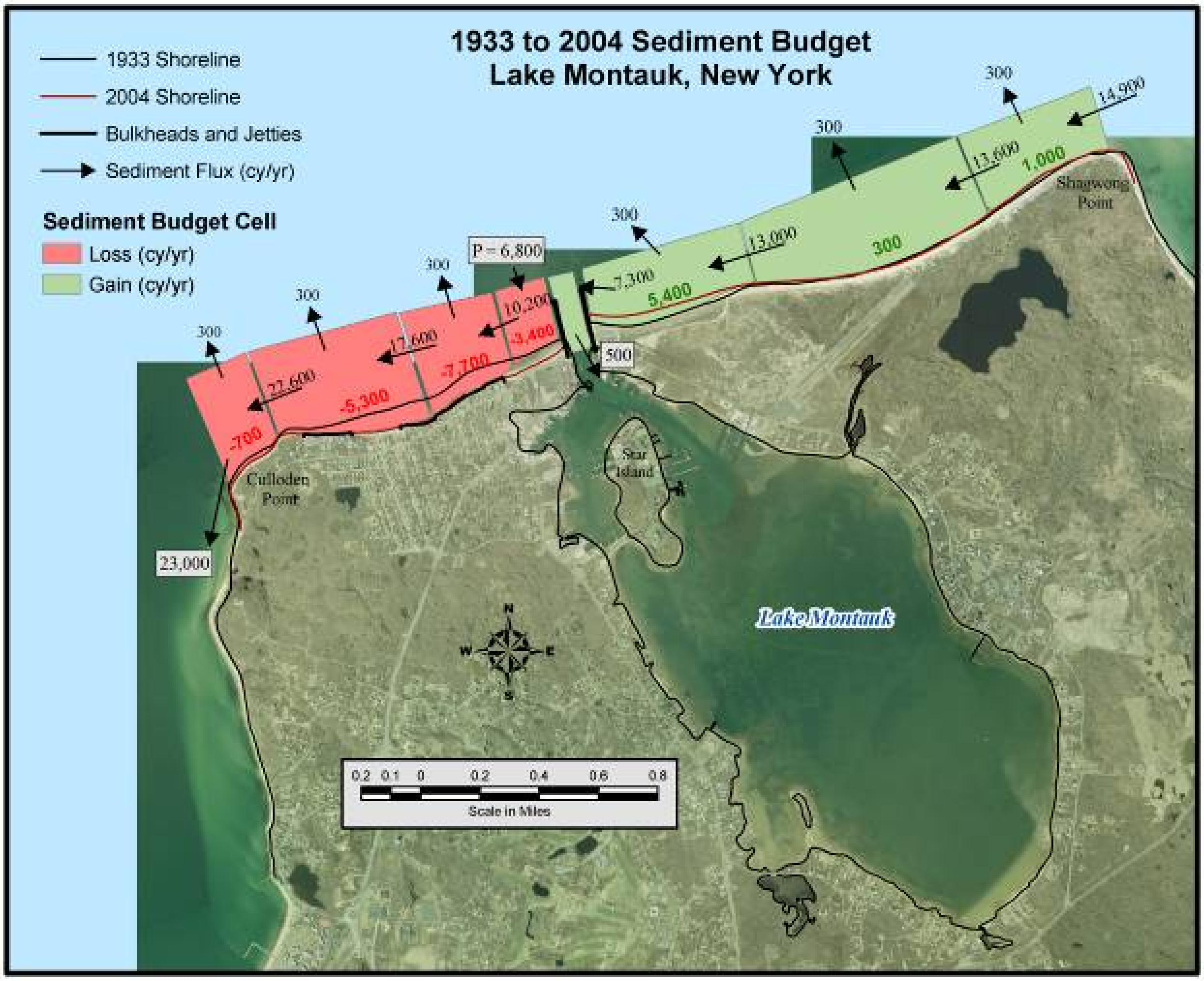


Figure 8: Post-jetty construction sediment budget

Table 4: Lake Montauk Beach Sediment Budget, 1933 to 2004. Cells are labeled west to east.

Cell Number	1	2	3	4	5	6	7	8
Input (+)	22,600	17,600	10,200	6,800	7,300	13,000	13,600	14,900
Output (-)	23,000	22,600	17,600	10,200	6,800	7,300	13,000	13,600
Offshore	300	300	300	0	0	300	300	300
Residual	**-700**	**-5,300**	**-7,700**	**-3,400**	**500**	**5,400**	**300**	**1,000**

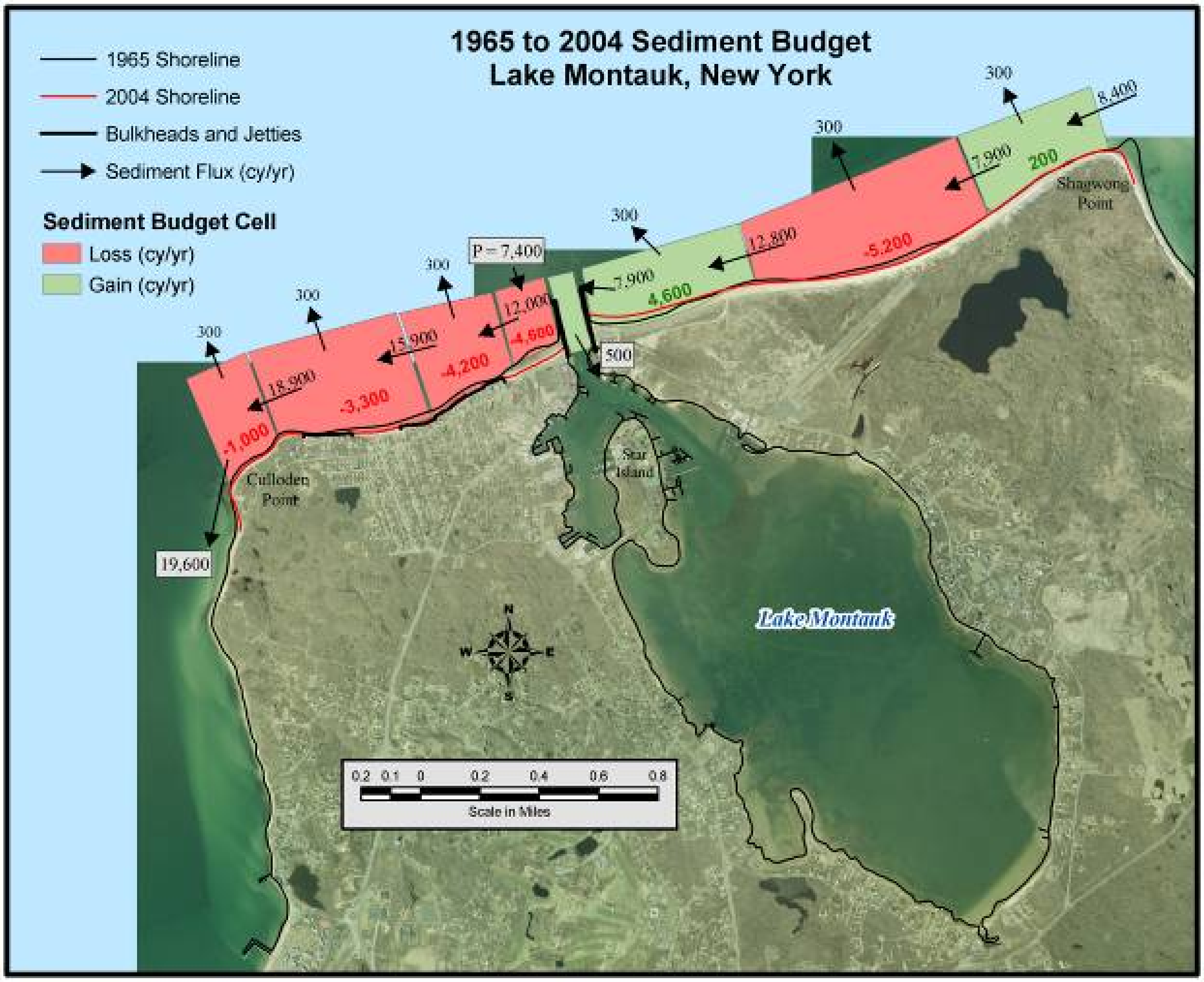


Figure 9: Recent sediment budget

Table 5: Lake Montauk Beach Sediment Budget, 1965 to 2004. Cells are labeled west to east.

Cell Number	1	2	3	4	5	6	7	8
Input (+)	18,900	15,900	12,000	7,400	7,900	12,800	7,900	8,400
Output (-)	19,600	18,900	15,900	12,000	7,400	7,900	12,800	7,900
Offshore	300	300	300	0	0	300	300	300
Residual	**-1,000**	**-3,300**	**-4,200**	**-4,600**	**500**	**4,600**	**-5,200**	**200**

Coastal Process

Temperature

The climate at the study area is characterized by long, cold winters and short, warm summers. The mean annual temperature for this region is approximately 53ºF (degrees Fahrenheit). The normal temperature during the winter months ranges from 31ºF to 35ºF, and during the summer months ranges from 65ºF to 72ºF.

Precipitation

Annual rainfall for this region is approximately 42 inches. The maximum 24-hour rainfall based on a 32-year record was 6.6 inches, which occurred in September. The mean annual snowfall for the eastern Long Island region is about 21 inches.

Storms

Most hurricanes, which reach Long Island, approach from a southerly direction after re-curving east of Florida and skirting the Mid-Atlantic States. These hurricanes start their journey with a forward speed of about 10 miles per hour and after re-curving toward Long Island may increase their speed to 20 to 30 miles per hour and even up to 40 to 60 miles per hour as they reach colder water temperatures. The most destructive winds in a hurricane occur east of the eye, where the spiral wind movement and forward motion of the storm combine. Northeasters (extra-tropical storms) develop near the Atlantic Coast of North America and can occur any time of the year, but most frequently in the winter and spring months. Even though the maximum sustained winds and wind gusts of an extra-tropical storm are typically not as strong as a hurricane, the high winds of a northeaster can last for up to five tidal cycles, causing higher return tides. The long exposure of shorelines to high water combined with high waves can reach further inland and cause severe damage on the beach and properties behind. Table 6 is a summary of historical storms affecting New York area.

Winds

The mean annual wind speed in the area is 9.2 knots (10.6 miles per hour) with a predominant direction of southwest. The maximum speed, based on 32 years of record, is 78 knots East Southeast. Extreme winds were determined for the site on the basis of ANSI-A58.1. The extreme wind speeds are expressed in fastest mile vs. return period and tabulated in Table 7.

Waves

Normal waves reaching the site of study area include both the locally generated short period wind waves and long period sea swells generated in the deep ocean. The local wind wave direction statistics were predicted based on the methodology outlined in the Shore Protection Manual (USACE 1984) and the Automated Coastal Engineering System (ACES) (Leenknecht, Szuwalski and Sherlock 1992). Due to the sheltering effect and shoreline orientation of the project shoreline, only waves from WSW clockwise to ENE will affect the site. The predominant wind waves are from the northwest with the majority of wave heights in the range from 1.0 to 1.5 feet (USACE 1995). Ocean swells and deep-water waves are partially sheltered by Block Island and Montauk Point to the east. Refraction of these waves however provide the potential energy for net littoral transport westward. Storm waves were determined based on extreme winds from the NNW, which generate the most critical waves for beach erosion and coastal structures. The storm wave height-frequency at the project site is shown in Table 8.

Currents

Nearshore currents at the study site are predominantly tidal. The average maximum current speeds at the harbor entrance are 1.2 knots flood and 0.6 knots ebb based on published NOAA, NOS tidal current tables (USACE 1995). Littoral currents along the shoreline are predominantly induced by wind and waves and are weak most of the time

Table 6: Historical Storms Impacting New York Area

Hurricane		**Northeaster**	
Date	Name	Date	Name
14 Sep 1904	-	03 Mar 1931	-
08 Sep 1934	-	17 Nov 1935	-
21 Sep 1938	-	25 Nov 1950	-
14 Sep 1944	-	06 Nov 1953	-
31 Aug 1954	Carol	11 Oct 1955	-
02 Sep 1954	Edna	25 Sep 1956	-
05 Oct 1954	Hazel	06 Mar 1962	-
03 Aug 1955	Connie	05 Nov 1977	-
12 Sep 1960	Donna	17 Jan 1978	-
10 Sep 1961	Esther	06 Feb 1978	-
20 Aug 1971	Doria	22 Jan 1979	-
14 Jun 1972	Agnes	22 Oct 1980	-
06 Aug 1976	Belle	28 Mar 1984	-
27 Sep 1985	Gloria	09 Feb 1985	-
19 Aug 1991	Bob	30 Oct 1991	-
08 Oct 1996	Josephine	01 Jan 1992	-
07 Sep 1999	Floyd	11 Dec 1992	-
01 Sep 2006	Ernesto	02 Mar 1993	-
28 Aug 2011	Irene	12 Mar 1993	-
29 Oct 2012	Sandy	28 Feb 1994	-
		21 Dec 1994	-
		05 Jan 1996	-
		06 Oct 1996	-
		02 Feb 1998	-
		14 Apr 2007	-
		15 Nov 2009	Nor'Ida
		13 Mar 2010	-
		17 Apr 2011	-

Table 7: Extreme Wind Frequency

Return Period (Years)	**Fastest Mile Wind Speed**	
	mph	**knots**
5	62	54
10	70	61
25	82	70
50	90	78
100	100	87

Table 8: Storm Wave Height-Frequency

Recurrence Period (Years)	Wave Condition	
	Deep Water Wave Height (ft)	Wave Period (sec)
5	6.5	4.5
10	7.2	5.0
25	8.0	5.3
50	8.9	5.6
100	9.8	5.8

Tide Elevations

The site is subject to semi-diurnal tides (two highs and two lows per day). A tabulation of the astronomical tide elevations based on the tide tables is shown on Table 9 with datum referenced to MLLW. The National Geodetic Vertical Datum in 1929 (NGVD29), established by the U.S. Geological Survey as mean sea level datum in 1929 is used in many official survey monuments, and is also referenced. NGVD29 is used as reference datum throughout the study. The North American Vertical Datum 1988 (NAVD88) at the project site is approximately 1 foot above NGVD29.

Table 9: Astronomical Tide Elevations

Tide	Elevation		
	(ft, MLLW)	(ft, NGVD29)	(ft, NAVD88)
Mean Higher High Water (MHHW)	+2.46	+1.66	+0.66
Mean High Water (MHW)	+2.17	+1.37	+0.37
North American Vertical Datum (NAVD)	+1.80	+1.00	0.00
Mean Sea Level (MSL)	+1.17	+0.37	-0.63
National Geodetic Vertical Datum (NGVD)	+0.80	0.00	-1.00
Mean Low Water (MLW)	+0.17	-0.63	-1.63
Mean Lower Low Water (MLLW)	0.00	-0.80	-1.80

Source: NOAA VDatum

Geomorphology

The main body of Long Island divides into two branches at the head of Great Peconic Bay. The backbone of the Island in the main body consists principally of two moraine ridges of Pleistocene age, the Harbor Hill Moraine and the Ronkonkoma Moraine. The moraine and outwash accumulations, associated with the glacial or recent epochs, constitute the greater portion of both the surface and underlying materials throughout the entire island.

An examination of these data shows that sand or sand and gravel predominates to depths of over

100 feet. At Montauk Point, to the east of the study site, the shoreline is characterized by a series of bluffed headlands formed by erosion of the face of the Ronkonkoma Moraine, with some nearly vertical bluffs rising to a height of almost 70 feet above sea level. The shoreline from this point westward to Fort Pond Bay, the western limit of the study area, is a succession of wave-formed beaches. The beaches are backed by sand dunes with widths ranging from 20 to 50 feet and heights ranging from 10 to 25 feet above mean sea level. At most parts of the shoreline west of the inlet, a mild, narrow foreshore slope backed by a steep dune characterizes the beach profile. About 60% of the shoreline from the east jetty to Culloden Point is reinforced with bulkhead.

Storm Surge

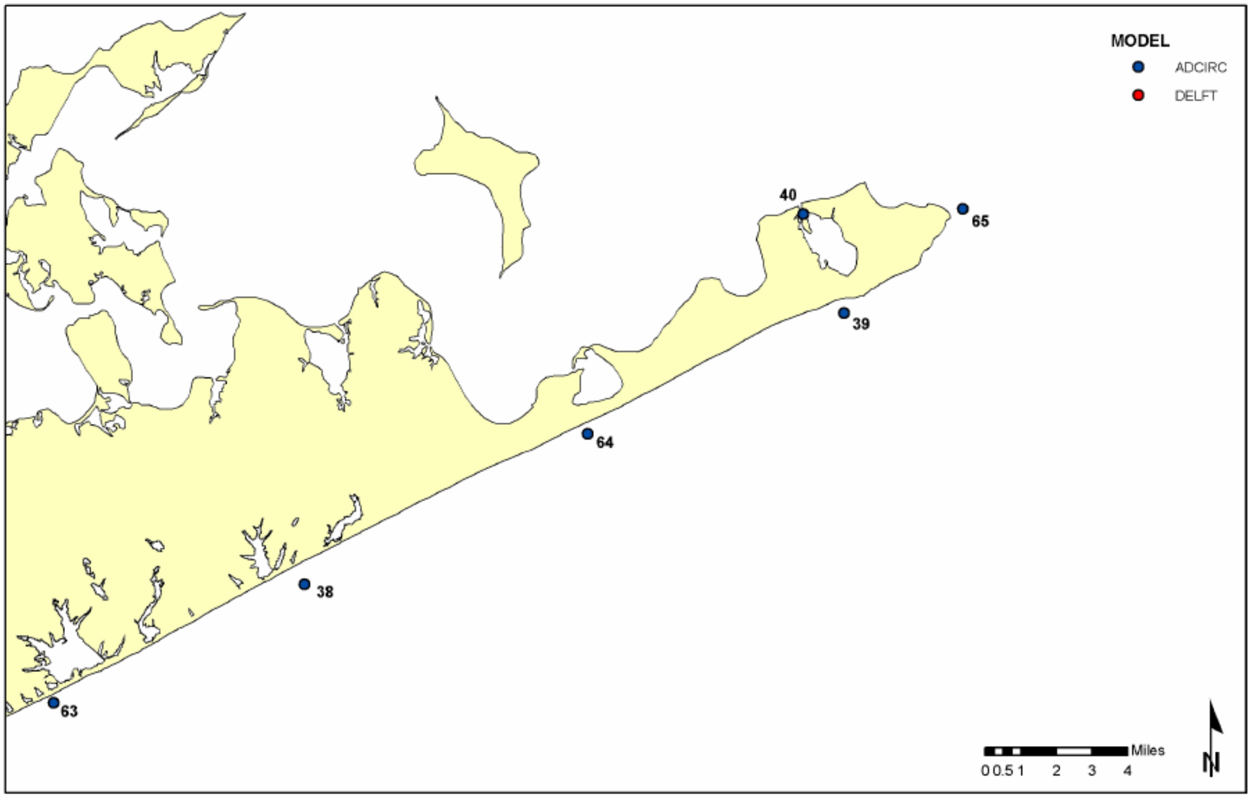
Storm surge is the rise above normal water level on the open coast due to the action of wind stress on the water surface. Storm surge due to hurricanes also includes the rise in water level due to atmospheric pressure reduction and that due to wind stress. The storm surge elevations for this study were determined based on analysis of data from various studies conducted by the Waterways Experiment Station, now called the US Army Engineer Research and Development Center (ERDC), Federal Emergency Management Agency (FEMA) Flood Insurance Studies, USACE Fire Island to Montauk Point (FIMP) Studies in the 1980’s and in 2005, and the data used for the reconnaissance study. The stage frequency curves based on all available data sources were used to guide the storm recession damage modeling effort. See Appendix C Economics Lake Montauk Harbor for a more detailed discussion. The existing stage-frequency data are:

Lake Montauk Reconnaissance Study, 1995

The storm surge elevations for this study were determined from various studies conducted by ERDC, Federal Emergency Management Agency (FEMA) Flood Insurance Studies, and Frederic R. Harris, PC storm surge predictions for the New York District Corps of Engineers.

New York District FIMP ADCIRC/EST, 2005

A storm surge model was performed for the FIMP reformulation study. In all, 22 historical extratropical and 14 historical tropical events were selected for storm surge modeling. Each of the historic events was simulated in ADCIRC, over a computational domain spanning the northeastern Atlantic Ocean, using state-of-the-art input meteorological fields. The one-dimensional EST methods developed for the FIMP study were employed to generate a stage-frequency relationship. The EST is a nonparametric approach which re-samples from a single data set. The predicted storm surge frequency covered the study area with data available at model output station 40, Montauk Harbor (Figure 10).



Storm water level output stations (continued).

Figure 10: NAN-FIMP ADCIRC/EST Model Output Stations

FEMA Suffolk County FIS Map Published in 2009

Federal Emergency Management Agency (FEMA) updated the Federal Insurance Rate Map (FIRM) for the Suffolk County, NY area around year 2009 based on earlier storm surge-frequency study results. Transects used to map the flood zones are shown in Figure 11. Based on the transect descriptions, the surge elevations can be grouped in two categories:

- Back bay area including Fort Pond Bay, Lake Montauk inner shore (181, 182, 184-87)
- Block Island Sound front shoreline (183,188, 189)

Since the project area is facing the Block Island, the sound front data was used.

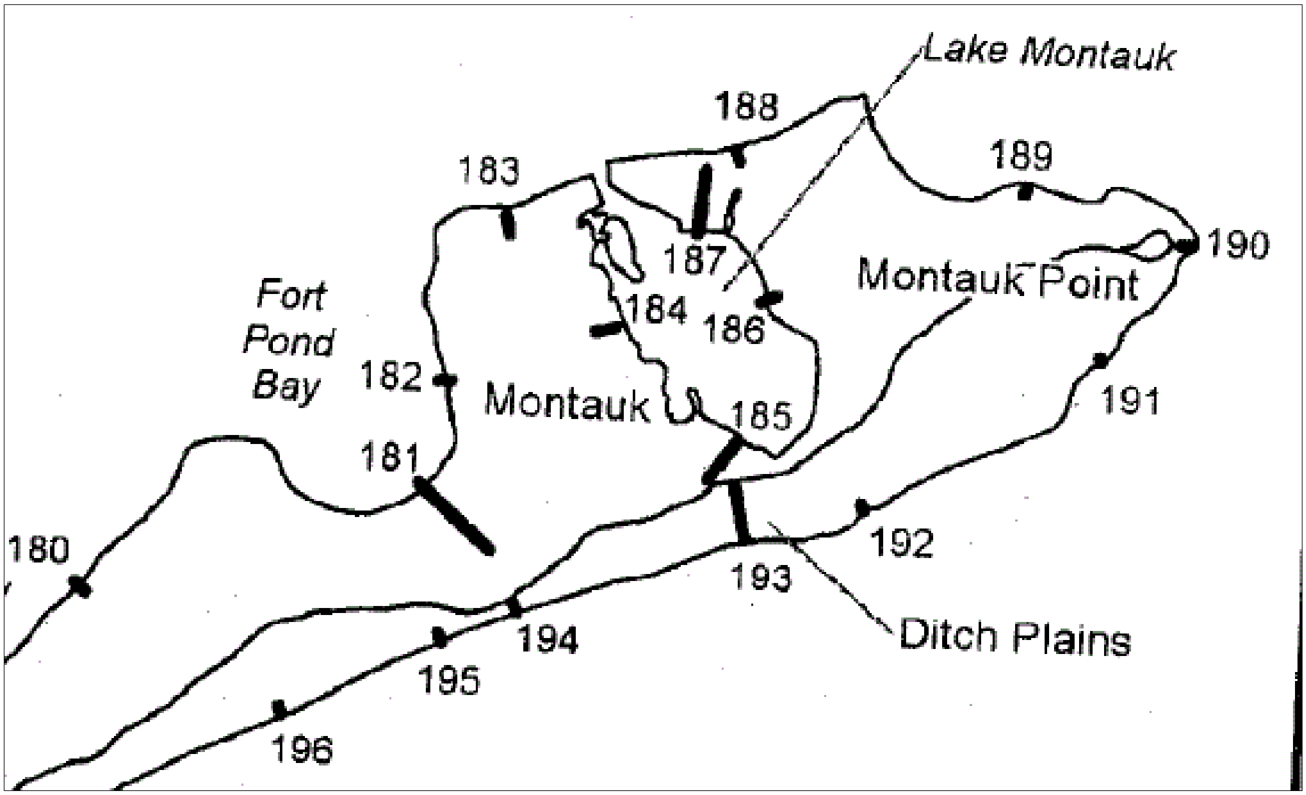


Figure 11: FEMA FIS Map Transects in the Project Area

Surge Data Comparison

The storm surge-frequency data from the reconnaissance study was compared with the 2005 FIMP storm surge modeling results (based on ADCIRC and EST modeling) and the FEMA FIS mapping. Note that the FEMA and Lake Montauk Reconnaissance Study data were interpolated and extrapolated to include the full range of recurrence period from 5 years to 500 years for comparison purpose (Table **10** and Table **11**). The surge-frequency data were plotted for both with and without wave setup (Figures 12 and 13 respectively). For surge-frequency with wave setup, assume the setup component is approximately 20% of the predicted deep water wave height. Although North Atlantic Coast Comprehensive Study (NACCS) statistical storm data was available at the time of this report and provides more up to date statistics for storm events and return periods, the data will not change design or design calculations for the channel. Under keel clearance does not account for extreme events as vessels are typically at sea avoiding the storm or in port taking refuge during storm event.

Table 10: Stage-Frequency Comparison (w/o Wave Setup)

Annual Exceedance Probability	Surge Elevation w/o Wave Setup (feet NGVD)			
	Recurrence Period (years)	Lake Montauk Recon Study	FIMP ADCIRC 2005 Modeling	FEMA Published 2009
0.200	5	4.5	4.7	4.6
0.100	10	5.0	5.6	5.3
0.040	25	5.8	7.0	6.5
0.020	50	6.8	8.5	7.5
0.010	100	7.6	9.8	8.3
0.005	200	8.7	11.0	9.5
0.002	500	10.2	12.9	10.8

Notes:
1. Conversion from NGVD to NAVD Datum is -1.0 feet
2. FEMA Flood Insurance Study surge data is straight line fit for comparison purposes
3. Lake Montauk Recon. Study data is extrapolated to 0.002 AEP
4. 0.3 feet of sea level rise is included in FIMP Study to reflect year 2000 levels

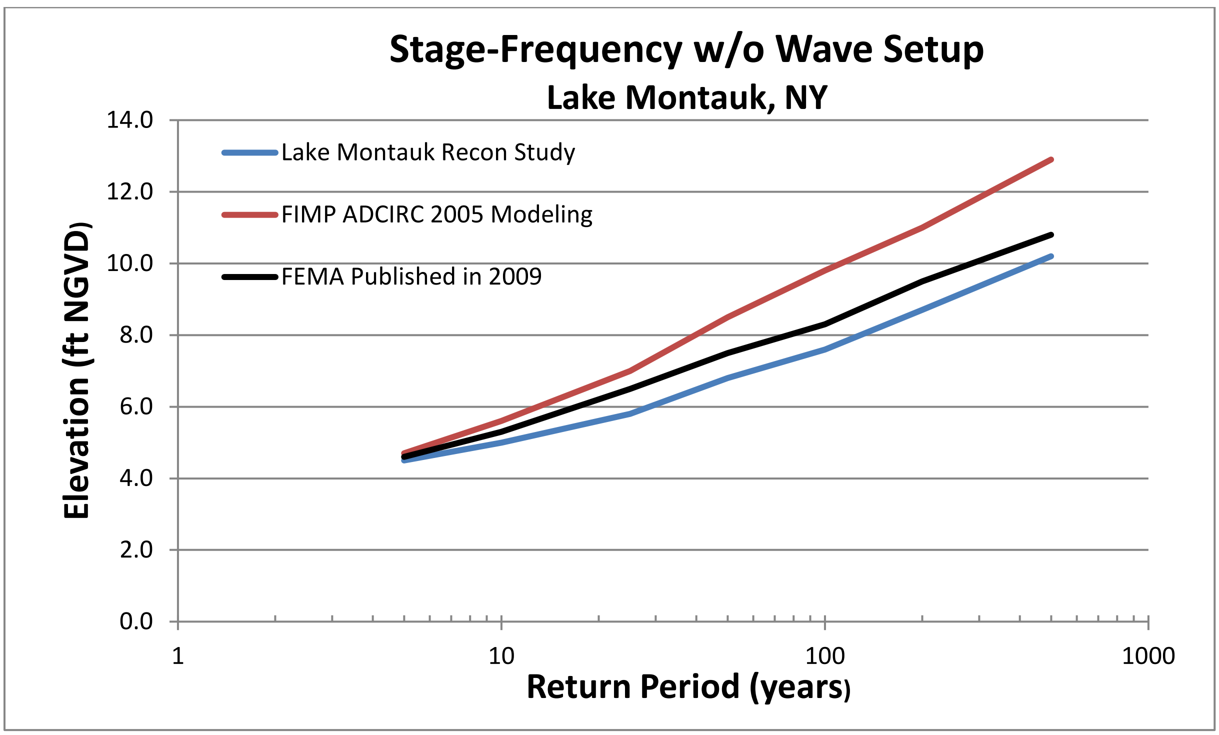


Figure 12: Stage-Frequency Comparison (w/o Wave Setup)

Table 11: Stage-Frequency Comparison (with Wave Setup)

Annual Exceedance Probability	Surge Elevation with Wave Setup (feet NGVD)			
	Recurrence Period (years)	Lake Montauk Recon Study	FIMP ADCIRC 2005 Modeling	FEMA Published 2009
0.200	5	5.8	6.0	5.9
0.100	10	6.4	7.0	6.7
0.040	25	7.4	8.6	8.1
0.020	50	8.6	10.3	9.3
0.010	100	9.6	11.8	10.3
0.005	200	10.8	13.1	11.6
0.002	500	12.6	15.3	13.2

Notes:
1. Conversion from NGVD to NAVD Datum is -1.0 feet
2. FEMA Flood Insurance Study surge data is straight line fit for comparison purposes
3. Lake Montauk Recon. Study data is extrapolated to 0.002 AEP
4. 0.3 feet of sea level rise is included in FIMP Study to reflect year 2000 levels

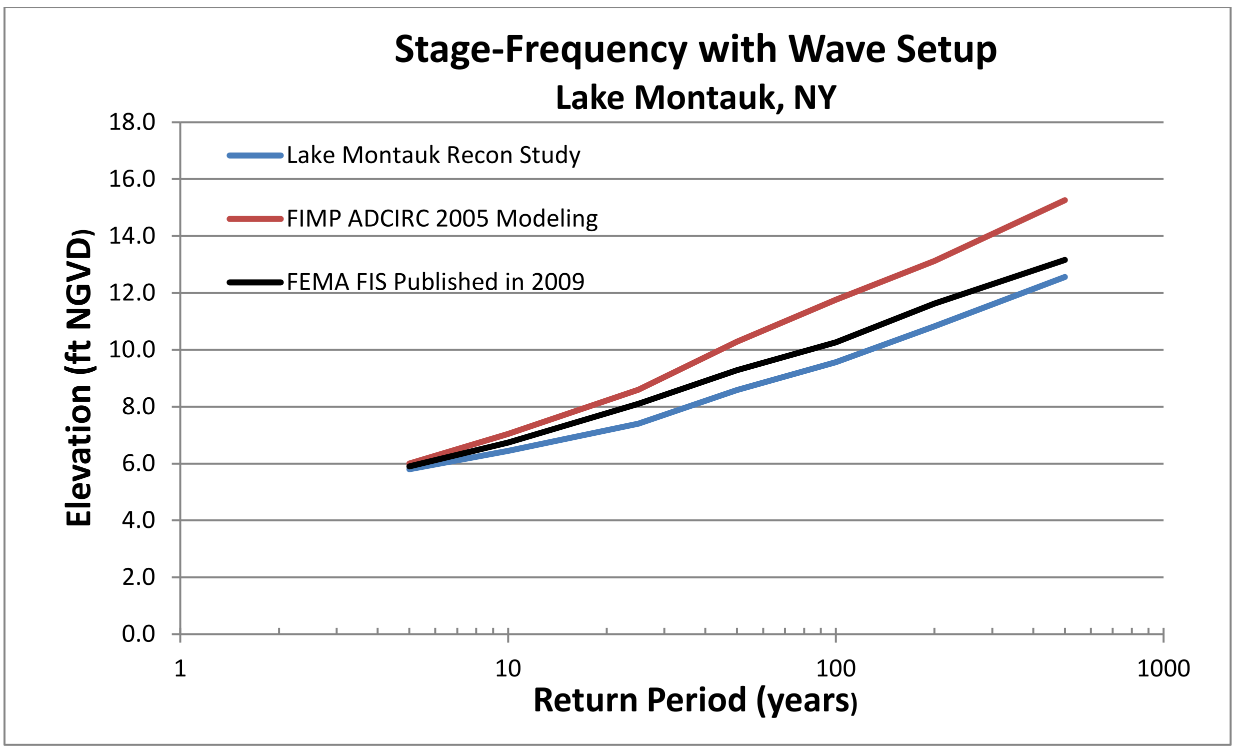


Figure 13: Stage-Frequency Comparison (with Wave Setup)

Sea Level Rise

In accordance with 1100-2-8162, three sea level change curves are provided in Figure 14 for the 50-year period of analysis and the 100-year adaptation horizon. Sea level change will not significantly affect the navigation project as the channel depth is referenced to a tidal datum. Sea level change may result in a seaward response to the cross-shore profile of the updrift beach, however the longshore currents are not strong enough to impact dredging requirements. The dredging record detailed in Table 2 and Figure 6 show no significant increase in dredging volumes which reflect the effects of sea level change on longshore sediment transport over the period of record dating back to 1942. Values for the sea level change (SLC) curves for the project length and 100-year adaptation horizon in feet relative to NAVD88 are shown in Table 12. It is assumed that waterfront structures will be maintained and adapt to rising sea levels as necessary. Specifically the east and west jetties will need to be maintained to ensure stability of the main navigation channel. It is anticipated that an additional layer of armor stone could be added to the structures should they be in danger of becoming a submerged or limited visibility hazard as water levels rise. The current crest elevations of the jetties are approximately +7 feet NAVD88 (USACE 1995). When added, a second layer of ten ton armor stone would increase crest elevations three to four feet, bringing the top of the structures to +10 to +11 feet NAVD88. Assuming intrepid captains currently use the inlet up to events with an AEP of 0.10 (10 year recurrence period) they would be piloting their vessels through surge elevations of +5.4 to +6.0 feet NAVD88 (Table 11, includes wave setup and adjustment from NGVD). This condition would put the current crests of the structures between 1 and 1.6 feet above water level depending on the surge elevation study referenced (see section on Storm Surge). Assuming a second armor layer has been placed this similar limited structure visibility condition would occur by the years 2090 and 2050 for the USACE intermediate and high sea level change projections respectively. In order to ensure the safety of intrepid captains and structure visibility throughout the project life and the 100-year planning horizon it is anticipated the placement of the second layer of armor stone would need to occur by the year 2070 for the intermediate sea level change projection. Should the rate of sea level change be more aggressive then adaptation measures would need to be in place by 2040. If the USACE low sea level change projection is realized than no adaptation measures will be necessary during the 100-year planning horizon.

Littoral Materials

Littoral material on the study shoreline is predominantly sand with some gravel. Two sediment samples were collected at the east and west sides of the inlet in October 1994, representing typical beach sand sizes in the study area. The median sand size at the east shoreline is approximately 0.02 inches (0.4 millimeter). The median size at the west shoreline is approximately 0.01 inches (0.24 millimeter). The finer sediment size at the west shoreline is believed to be material from channel dredging.

Dredged Material

The dredged material in the channel and boat basin is predominantly comprised of fine to medium sand with traces of silt. Figure 15 and Figure 16 show the sampling plan and results of testing performed in support of the fall 2018 operation and maintenance dredging of the Inlet.

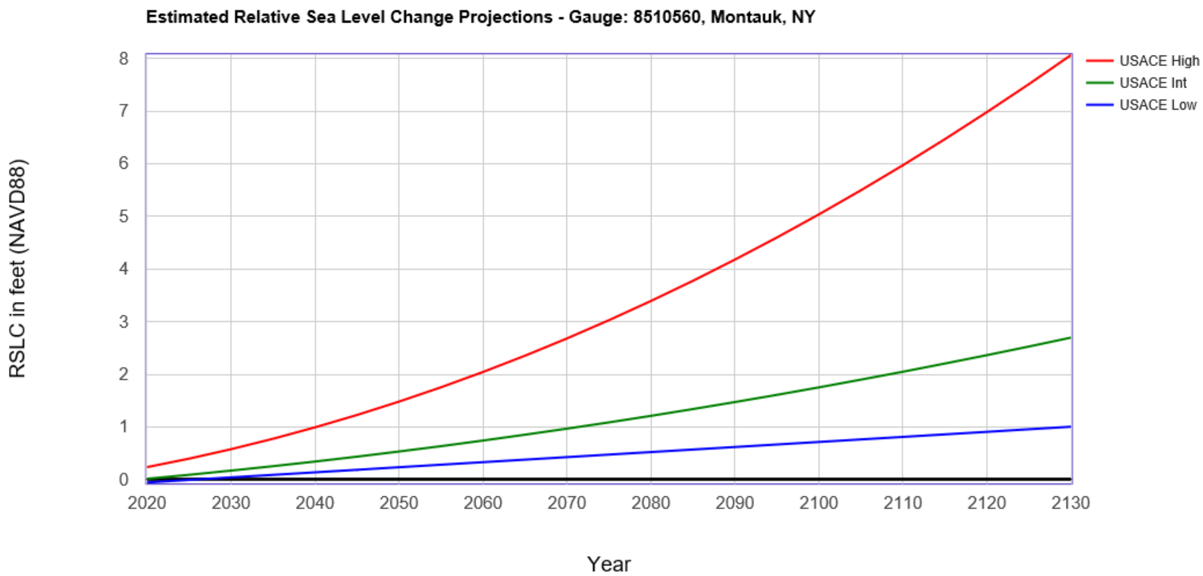


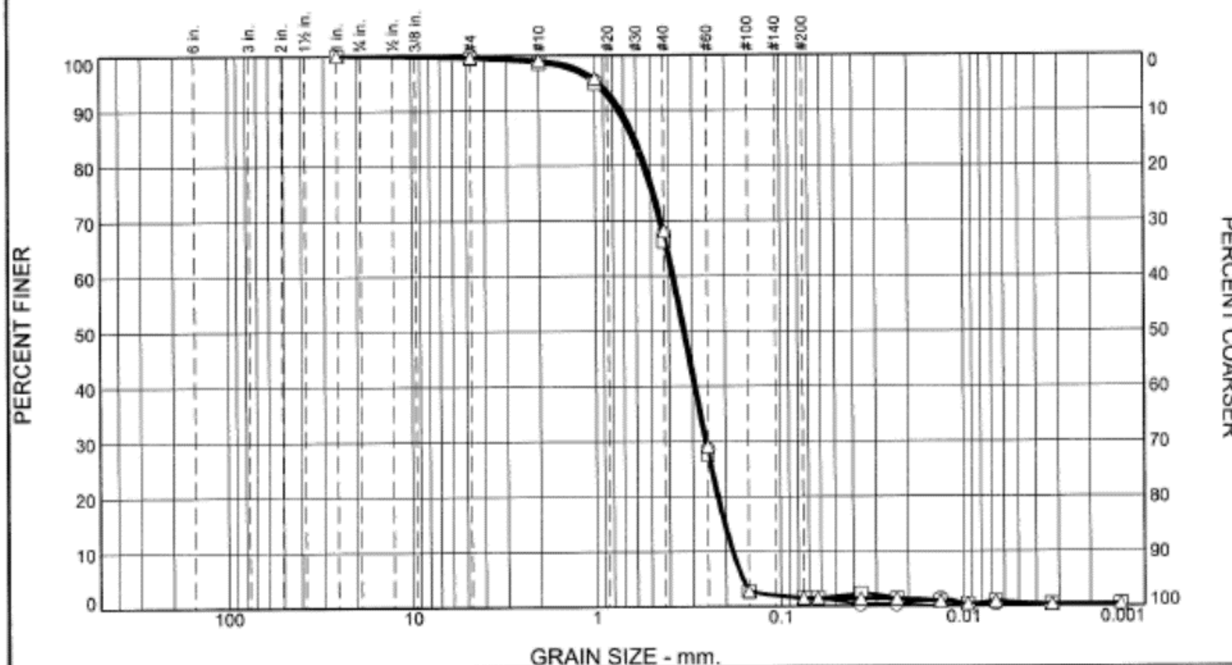
Figure 14: Relative Sea Level Change at Montauk, NY.

Table 12: SLC Values for Lake Montauk Harbor

SLC values expressed in ft relative to NAVD88							
	USACE				USACE		
Year	**Low**	**Int.**	**High**	**Year**	**Low**	**Int.**	**High**
2020	-0.08	-0.01	0.22	**2080**	0.47	1.16	3.34
2025	-0.03	0.07	0.38	**2085**	0.52	1.29	3.73
2030	0.02	0.14	0.55	**2090**	0.56	1.42	4.12
2035	0.06	0.23	0.75	**2095**	0.61	1.55	4.54
2040	0.11	0.31	0.96	**2100**	0.66	1.69	4.98
2045	0.15	0.4	1.2	**2105**	0.7	1.84	5.44
2050	0.2	0.5	1.45	**2110**	0.75	1.98	5.91
2055	0.25	0.6	1.72	**2115**	0.79	2.14	6.4
2060	0.29	0.7	2	**2120**	0.84	2.29	6.91
2065	0.34	0.81	2.31	**2125**	0.88	2.46	7.44
2070	0.38	0.92	2.64	**2130**	0.93	2.62	7.99
2075	0.43	1.04	2.98				

Figure 15: Lake Montauk Sediment Sampling Plan.

Particle Size Distribution Report



	% Boulders	% +3"	% Pebbles	% Granules	% Sand V. Crs.	% Sand Crs.	% Sand Med.	% Sand Fine	% Sand V. Fine	% Silt Crs.	% Silt Med.	% Silt Fine	% Silt V. Fine	% Clay
○	0.0	0.0	0.2	1.0	3.4	18.7	48.0	26.4	0.7	1.2				0.4
□	0.0	0.0	0.6	0.8	3.7	19.5	47.8	25.3	0.7				1.6	
△	0.0	0.0	0.4	0.5	3.3	18.6	48.1	26.8	0.8	0.1	0.2	0.5	0.2	0.5

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			0.6119	0.3789	0.3313	0.2547	0.2019	0.1831	0.93	2.07
□			0.6327	0.3869	0.3375	0.2586	0.2041	0.1847	0.94	2.09
△			0.6044	0.3762	0.3290	0.2530	0.2007	0.1822	0.93	2.06

Material Description	USCS	AASHTO
○ Sediment		
□ Sediment		
△ Sediment		

Project No. 38-058 **Client:** ACOE-NYD
Project: Lake Montauk Harbor
○ **Source of Sample:** Lake Montauk Composite **Sample Number:** 20180276
□ **Source of Sample:** Lake Montauk Composite **Sample Number:** 20180276 dup
△ **Source of Sample:** Lake Montauk Composite **Sample Number:** 20180276 trp

Remarks:

Aqua Survey, Inc.
Flemington, NJ

Figure

Tested By: L. Horn **Checked By:** C. Hall

CH

Figure 16: Grain Size Distribution Curve Lake Montauk Composite Sample.

Inlet Circulation and Sediment Transport Modeling due to Inlet Modification

A two-dimensional circulation and sediment transport model was applied to the harbor in order to provide information on tide-induced and tide- plus wave-induced velocities and sediment transport patterns for the existing condition and 5 channel-improvement alternatives. A reconnaissance-level modeling approach was taken in which an approximately 9-day simulation was conducted on a high-resolution grid. This approach provides details of velocity and transport patterns, as well as depth change over a representative tide cycle, a typical situation at the study site.

Modeling was conducted with the two-dimensional finite-difference model M2D. This model was selected for the Lake Montauk channel dredging evaluation because it is fast and easy to set up and has proved reliable and robust in numerous project applications for a wide range of coastal environments. M2D calculates water level and two horizontal components of velocity on a rectilinear grid, and also computes sediment transport rates and changes in depth over time. M2D operates within the Corps of Engineers Surface water Modeling System (SMS), where project applications can be set up, modified, launched, post-processed and visualized.

Model Development

Model development for Lake Montauk was based upon the channel configuration and condition surveys. The data included beach profiles along the east and west beaches surveyed by Offshore Coastal Technologies Incorporated (OCTI) in 2004, jetty sections surveyed by OCTI in 2004, a post-dredge survey in 2003, and topographic data dated 2004. The M2D computational grid was developed over a navigation chart which supplemented the bathymetric survey data. The domain included all of Lake Montauk, the navigation channel, jetties, adjacent beaches, and part of the nearshore area extending to approximately 60 feet of water.

Six navigation improvement alternatives, including the existing condition, were developed for analysis of shoaling and erosion patterns in the navigation channel, flood shoal, and ebb shoal. Each of the action alternatives required removal of material from the inlet or boat basin, but no changes to the jetty or shoreline configuration.

Table 13 describes the alternatives. Each alternative was evaluated for forcing by tide and by a combination of tide and waves. Wave input to M2D was obtained by simulation of wave transformation and breaking with the steady state wave model STWAVE.

Results

Evaluation of the six alternatives is conducted by examining the changes and general pattern of flow rates, velocities, and transport rates for the situations of tide only and tide combined with waves. Areas and considerations are: hydraulic, sediment transport and environmental (change of flow pattern) due to navigation channel improvements. The results are summarized as follows:

1. Changes of peak flood and ebb flow rates through inlet range from 5 to 7% for all alternatives, therefore, there would be minimal impact due to water quality changes;
2. Flood and ebb currents remain consistent for all alternatives;
3. Flood current speeds (2.4 to 2.8 feet per second) dominate the ebb currents (1.6 to 1.9 feet per second), implying general trend of flood shoal formation;
4. Onshore transport is skewed to the east channel and offshore transport is skewed to the west channel. Cross-shore transport is weak during normal tidal flow, therefore, natural sediment bypassing is negligible.

Table 13: Bathymetric configurations for design model alternatives

Alternative	Description
Existing Condition	Inlet and navigation channel bathymetry specified from survey data.
A1	Widen channel by 50 feet to depth of -17 feet MLLW on its eastern side for the length of the channel from the inlet to the inshore end of the east jetty. Remove the shoal feature located at inner base of east jetty.
A2	Widen channel by 100 feet to depth of -17 feet MLLW on its eastern side for the length of the channel from the inlet to the inshore end of the east jetty. Remove the shoal feature located at inner base of east jetty.
A3	Widen channel by 50 feet to depth of -17 feet MLLW on its eastern side and 50 feet on its western side for the length of the channel from the inlet to the inshore end of the east jetty. Remove the shoal feature located at inner base of east jetty.
B1	Deepen channel between the jetties to -17 feet MLLW and the portion of the channel inside the bend to -14 feet MLLW, transitioning between depths at the bend. Boat basin depth specified as -10 feet MLLW.
C1	Remove shoal located at inner base of east jetty.

Existing Navigation Conditions

Federal Navigation Channel

The existing channel at Lake Montauk Harbor is 150 feet wide and 0.7 miles in length. The authorized channel begins at the 12-foot contour line in Block Island Sound and extends to the same depth in the basin east of Star Island. The project depth of the channel is -12 feet MLLW with side slopes of 1 vertical on 3 horizontal. The channel has two bends into the basin ending next to the eastern shoreline of Star Island. The area beyond the Federal Authorized channel is maintained by the Town of East Hampton.

Navigation Aides

The existing navigation aids include the following: one lighted floating buoy at the channel entrance, a daybeacon, and two lighted towers on both jetty heads. The daybeacon is approximately 700 feet south of the channel entrance on the western edge of the channel.

Boat Basin

The United States Coast Guard uses Lake Montauk Harbor all year round as a base for patrol boats, the largest of which is part of the 87 foot long Marine Protector Class (USCG 2016). The basin was created in 1927 along with the entrance channel that was 15 feet deep and 1300 feet long. In 1943, the boat basin was dredged to its current layout that is 400 feet wide, 900 feet long and located northwest of Star Island. The area offers a protected location even in times of strong winds and storms. The boat basin was initially dredged in August-September 1969 to a depth of -10 feet below MLLW, allowing for a maximum commercial design vessel with a draft of 9 feet, length of 110 feet, and beam of 20 feet. The design depth includes an allowance of one foot under the keel of the deepest vessel to provide for pitching and rolling during adverse weather conditions. The design basin side slopes are 1 vertical on 3 horizontal for dredging. The mooring basin was designed for 200 recreational boats and 15 commercial fishing vessels. During winter months, commercial fishing boats from nearby harbors transfer their operations to Lake Montauk Harbor. The mooring basin continues to be maintained at -10 feet below MLLW.

Shoaling

Channel shoaling occurs along the entire channel and boat basin due to tidal currents carrying littoral drift into the channel and sand leaching into the channel due to both the buildup of the east sand fillet and the deteriorated condition of the east jetty. The most significant shoaling source is at the shoreward end of the east jetty believed to be originating from the leaching of the east fillet and the migrating southeast shoal. The southeast shoal is formed by sand migrating through the channel and around the east jetty. The sand fillet is migrating westward toward the channel south of the jetty threatening the inner channel that provides access to Star Island. In addition, there is shoaling at the entrance to the channel mainly along the east jetty that migrates from the seaward end of the channel toward the harbor. Shoaling has affected the usable width of the navigation channel along the east jetty.

Marinas

Lake Montauk Harbor can accommodate recreational craft, fishing boats, and other small commercial craft with lengths up to approximately 200 feet. There are currently 18 marinas and five temporary docking and ramp facilities within the Lake Montauk Harbor as listed below. The marinas have a total of approximately 1,235 dockside slips. The largest slip is 70 feet long.

1. Uihlein's Boat Rental & Marina
2. Montauk Marine Basin
3. Offshore Sports Marina
4. The Landing
5. Captain's Cove Marina
6. Westlake Fishing Lodge & Marina
7. Snug Harbor Motel & Marina
8. Montauk Yacht Club Resort
9. Star Island Yacht Club & Marina
10. Montauk Lake Club & Marina
11. Gone Fishing Marina
12. Inlet Marina
13. Darenberg Marine
14. Diamond Cove Marina
15. Montauk Sportman’s Dock
16. Rick’s Crabby Cowboy Café
17. Viking Dock
18. West Lake Fishing Lodge and Marina

Temporary Dock and Ramping Facilities:

19. Sport Fishing Charter Service
20. Salivar Dock
21. Viking Fleet
22. East Hampton Launching Ram
23. Gosman's Dock

Fishing, Ferry, and Charter Boat Slips (Docks)

A few of the marinas have slips designated for transient boats and fishing, ferry and charter boats. Lake Montauk Harbor has two town docks, one named Star Island and the other Montauk Dock with 23 and 17 slips, respectively. All these docks slips are all currently occupied.

Vessel Fleet

The heavy volume of vessel traffic using the entrance channel consists primarily of pleasure craft and commercial fishing boats. The inlet channel is used by an average of about 500 boats per day, during the warmer seasons. In 1967, the vessels using the Lake Montauk Harbor and its existing facilities as a home port number 400 individually owned recreational boats, 160 publicly used recreational boats, 25 commercial fishing boats using two commercial docks, and 14 marinas and mooring facilities. The number, length, and draft of these vessels are shown in Table 14.

Table 14: Recreational Vessels Using Lake Montauk Harbor as Home Port in 1967

VESSELS USING LAKE MONTAUK HARBOR AS A HOME PORT IN 1967			
CLASS OF BOATS	**No. of Boats**	**Length (Ft.)**	**Draft (Ft.)**
I. Individually Owned Boats			
1. Outboards	70	14-21	1½-2
2. Inboards	30	16-25	1½-2
3. Cruisers	80	16-25	1½-2
4. Cruisers	200	26-32	2½-4
5. Cruisers	20	36-50	3-5
TOTAL	400	14-50	1½-5
II. Publicly used Recreational Boats			
1. Party Fishing Boats	30	35-50	4-6
2. Charter Fishing Boats	30	35-40	4-6
3. For Hire Boats			
3a. Row Boats	50	10-22	½-1
3b. Outboards	20	14-21	1-2
3c. Inboards	10	16-25	1½-2
3d. Cruisers	10	16-25	1½-2
3e. Cruisers	10	26-32	2½-4
TOTAL	160	10-50	½-6
III. Commercial Fishing Boats			
TOTAL	25	30-110	4-13

Table 15: Dimensions of Commercial Vessels Using Lake Montauk as a Home Port in 2005

Length (ft.)	Beam (ft.)	Unloaded Draft (ft.)	Load Draft (ft.)
70	20	9	11
72	20	10	12
95	25	13	15
50	18	8	9
86	23	10	13
90	24	12	13-14
85	22	8	10
65	20	8-9	10-11
85	22	8	10
73	24	13.5	16
50	23	8	10
70	20	9	11
45		5-6	
102	30	13	16
94	24	12.5	15

About 400 additional moorings are used by transients during the summer. The demand for moorings during the summer is greater than the availability by 200 moorings. Most of these transient vessels, who are unfamiliar with the local conditions, may require special design consideration and parameters that will require further study.

Lake Montauk is an important commercial fishing center and has an extensive and varied fleet. Although subject to turnover and change, the fleet has at times comprised as many as 44 ground fish trawlers, 12 inshore and 7 offshore lobsters boats and 53 long liners including as many as 32 transients boats from other areas of the east coast (Reference: A.T. Kearney Development of a commercial fisheries industry for the state of N.Y. 1989). The number of commercial vessels has increased by 578% since 1967. There are currently 148 vessels in the fleet according to the National Marine Fisheries Service in East Hampton. The composition of the commercial vessel fleet using Montauk Inlet is as follows:

5 Tile Boats - approximately 75 feet in length
30 Transient Sword Boats - approximately 40-90 feet in length
8 Tuna & Swordfish longliners based in Montauk
40 Trawler (Draggers) - approximately 35-100 feet in length
15 Lobster Boats - approximately 20-45 feet in length
20 Baymen
30 Rod & Reel

The summary of the increase in commercial vessels using Lake Montauk Harbor is shown in

Table 16. The population of vessels has increased significantly since its initial design and the trend of vessels size is to larger, deeper draft boats.

Table 16: Number of Commercial Vessels by Year

COMMERCIAL VESSELS			
Year	**No. of Boats**	**Length (Ft.)**	**Draft (Ft.)**
1967	25	30-110	4-13
1992	51	26-86	4-12
1993	91	25-95	4-13
1994	128	30-95	4-15
2004	148	45-102*	5-16**

* Danielle & Jason under Construction in 2011; currently operational.
** Fully loaded draft

The total annual U.S. commercial landings for Lake Montauk Harbor for 1990, 1991, 1992 and 1993 were 14.2, 14.3, 14.3 and 12.5 million pounds, respectively.

Vessel Traffic
The vessel traffic in Lake Montauk consists of commercial vessels, sport fishing vessels, and pleasure craft. The traffic volume varies considerably with time of year, being heavier in the warmer months due to the increase in transients. The channel can accommodate the existing two-way vessel traffic with the maintenance of the original design width.

Existing Navigation Requirements

Introduction
The goal of the navigation design requirements is to provide a safe, efficient and an economical channel with an emphasis on social and environmental impacts.

Design Vessel
The design vessels are selected for their various dimensions and maneuverability. These parameters include the length, beam, draft and type of vessel. The design vessel for the channel is a fishing vessel that has a length of 85 feet, beam of 25 feet, and a draft of 13 feet based on the number of commercial vessels currently using the channel. This design draft is based on analysis conducted in 2011, further analysis will be required for design drafts of 16 feet. Current economic analysis supports a design draft of 13 foot. The design vessel for the boat basin is 10 feet, based on the maximum sailboat draft and the larger number of recreational vessels in comparison to the limited number of commercial vessels using the boat basin. Draft is the depth of water the design vessel draws when fully loaded to the load line while stationary in mean summer salt water. The channel design parameters are summarized as follows:

Channel Alignment
The channel should be aligned to provide navigation that does not require difficult maneuvers or subject the vessel to strong crosscurrents. Consideration of littoral drift and shoaling and physical factors affect the alignment.

Channel Width
Sufficient channel width to allow safe and efficient passage of the vessel fleet is required. The channel

width is usually measured at the toe of the side slopes or at the design depth. The channel width depends upon the following factors: (a) the beam, speed and maneuverability of the design vessel, (b) whether the vessel is to pass another vessel, (c) the channel alignment and whether the channel is in a restricted or wide waterway, d) the stability of the channel banks, and (e) the winds, waves, currents and crosscurrents in the channel.

The recommended channel width is a percentage of the design vessel beam for the vessels' steerage capability. These widths may increase in adverse wind, wave and current conditions, or high traffic volumes. One-way traffic should have three to four and a half times the beam of the design vessel. Two-way traffic should have five to six times the beam of the design vessel. The existing channel project width is adequate for two-way traffic with six times the beam width of the design vessel.

Interior channels generally need less width than the entrance channel because wind, waves, and currents are less severe due to sheltered conditions but was maintained at the same width as the entrance channel. The channel bends at Lake Montauk are not significant, therefore, the entrance width is adequate through the channel.

Depth
Channel depths should be adequate for vessel draft and squat, wave conditions, and safety clearances. Channel depths are usually measured from a suitable low-water datum. Additional depth is allowed in construction due to dredging inaccuracies. Overdepth dredging may also be included as an advance maintenance procedure. The design channel depth can be designed to either accommodate all vessels during all stages of the tide or only at higher stages of the tide. Interior channel depths are normally not as deep as entrance channels because the wave action adjustment is normally less.

Squat - Density
Squat for small recreation craft moving at reasonable speed in entrance channels is generally taken to be one foot. Squat at low speed in interior channels, moorage areas, and turning basins is about 0.5 of a foot. Squat depends on several factors, including the speed of the vessel, characteristics of the channel and vessel, and interaction with another vessel. The amount of squat increases as a vessel departs from the centerline of the channel. The squat for the design vessel is 1.6 feet and was calculated in accordance with EM 1110-2-1615, Hydraulic Design of Small Boat Harbors.

Trim
Often a vessel is not loaded to an even keel in an attempt to improve its steering ability. The vessel is usually set down at the stern approximately 3 inches for every 100 feet. When the vessel is in motion, the trim can change, though the change is variable. The trim for the design vessel is negligible.

Wave Conditions – Allowance
Channel depth increase for wave action is generally one-half the design wave height. The wave height allowance is 0.5 feet.

Safety Clearance
A clearance minimum range from 1 to 2 feet is needed for channels with soft bottoms, such as sand or silt. Safety clearance is 2 feet.

Water Density and Effect of Freshwater
Considering brackish water at half salinity at Lake Montauk Harbor a ship with 13.0 foot draft would be increased to 0.17 feet.

Boat Basin
The existing boat basin was designed for staging and berthing vessels that dock within the Lake Montauk Harbor. The U.S. Coast Guard uses the channel and basin year-round.

Design Depth Summary
Taking into consideration the design vessel draft, squat, wave allowance, and safety clearance, the required and recommended depth is summarized in Table 17. Economic analysis indicated that net National Economic Development benefits maximized at -17 feet MLLW (See Economics Appendix and Main Report for more details).

Table 17: Design Depth Summary

DESIGN DEPTH SUMMARY	
Design Vessel Draft	13.00
Squat	1.60
Wave Allowance	0.50
Dynamic Trim	0.00
Safety Clearance	2.00
Water Density- Freshwater effect	0.17
Total Required Depth (feet)	17.27
RECOMMENDED PROJECT DEPTH (Feet)	**18**

* This design draft is based on analysis conducted in 2011.

Future Navigation Requirements

Vessel Fleet
Based on comparisons of vessel fleet records, the currently maintained depth is inadequate for the vessels that use the channel and boat basin. In 1993 there were 32 vessels with a loaded draft of 12 to 13 feet as opposed to 12 vessels in 1992. Lake Montauk Harbor is experiencing an increase in the dockings of larger vessels which require a deeper channel and basin to operate, without having to time their entrances and exits into the harbor with the tides.

Channel
For the entrance channel, the recommended improvement design requires a design depth of –18 feet MLLW. Due to the limited amount of boats with larger drafts than the design, those vessels will time their entrance and exit from the harbor with the tides. Recommended project widths and depths are summarized in Table 18.

Table 18: Recommended Navigation Project Width and Depth

RECOMMENDED PROJECT WIDTH AND DEPTH				
Reach	**Width (ft.)**		**Depth (ft. MLLW)**	
	Existing	**Recommended**	**Existing**	**Recommended**
Channel	150	150	12	18

3.0 WITHOUT PROJECT FUTURE CONDITIONS

Navigation

The 0.7 mile Federal channel will be maintained at 12 feet MLLW depth and 150 foot width with a 50 foot deposition basin. The recreational, charter and party boat traffic will remain generally unchanged. The commercial fishing fleet is not projected to expand; however, the future trend of the commercial fishing industry would lean toward larger, deeper draft, more efficient vessels. With the Federal channel depth unchanged, loaded fishing vessel will need to wait for high tide or maneuver through deeper channel sections, resulting in wasted operation time and inconvenience.

Operation and Maintenance

The U.S. Army Corps of Engineers New York District, Operations Division is currently providing maintenance dredging periodically when condition surveys indicate channel shoaling above the project depth. The historical dredging record (see Figure 6) showed an average 7,100 cubic yards per year maintenance dredging rate with dredging operation carried out every 4 to 5 years. The channel shoaling rate is expected to increase as the east jetty sediment impounding capacity becomes saturated, allowing more littoral material to deposit in the channel. The continued growth of the flood shoal located south of the east jetty base also triggers more frequent maintenance dredging as the side slope of the shoal encroaches into the channel. It is expected that, without project, the shoaling rate would increase and the dredging period would be more frequent.

Western (Downdrift) Shoreline Protection

Without the downdrift placement of dredged material, the western shoreline will continue to erode, endangering the remaining dune system, timber bulkheads, and landward properties during storms. The without project shore erosion scenario is discussed below:

- Long term erosion and storm induced erosion will endanger the road, West Lake Drive, part of which runs parallel to the 1,200 ft section of shoreline immediately west of the western jetty;
- Continued shore erosion will lower the toe protection of approximately 3,000 feet of timber sheet pile bulkhead, leading to scour, increased wave overtopping, and eventual bulkhead failure with property damage;

4.0 ALTERNATIVES SCREENING

Navigation improvement alternatives were developed, evaluated, screened, and selected. The following section details all potential improvement alternatives considered. The first step in the plan formulation process is to identify possible plan components or features, which would meet the opportunities, needs, objectives and constraints. A discussion of the purpose of each potential component in relation to these criteria is presented below. For clarity, Figure 17 identifies and shows the location of specific elements of the alternative plans described.

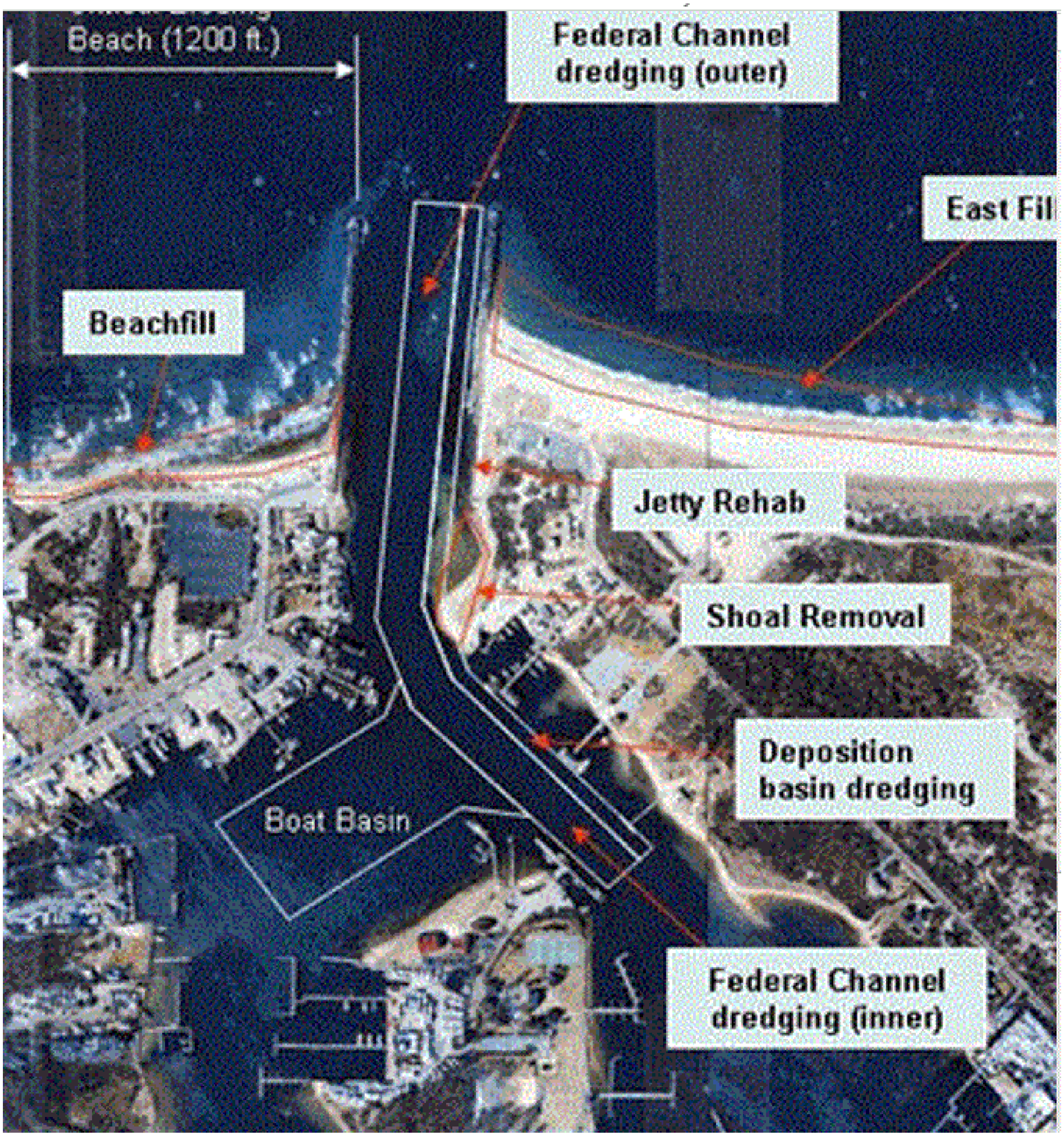


Figure 17: Navigation Channel Improvement Alternatives.

Navigation Improvement Alternatives

1- Unconventional drafts. Use of larger vessels with shallower drafts was considered, but this is not the present trend. It is not projected that the commercial fishing fleet at Lake Montauk Harbor will deviate from the general trend of using larger, deeper draft vessels. This measure was not practical with regard to the objectives of the project because it would imply implementation of a plan which is not realistic or up to date. It would not meet the specified needs and concerns of the public within the study area. The recommendation would not be flexible to adapt to changing economic, social and environmental patterns and changing technologies. This measure was not considered further.

2- High water transit; Waiting for high tide to traverse the inlet for deeper draft vessels. Astronomical tides in the study area are semi-diurnal, flooding and ebbing twice a day. The mean and spring tides range from 2.0 to 2.4 feet. Waiting for the tide leads to costly delays for commercial fishing vessels, estimated by local fishing captains. The U.S. Coast Guard reports that potentially unsafe navigation practices result from the limited channel depth. Scheduling all departures and arrivals through the channel imposes an undue rigidity. This measure is not in compliance with good, sound engineering practice, and should only be used for special cases and not considered a standard navigation procedure. This alternative was not developed further.

3- Relocation of the Existing Fleet. Relocating the existing commercial fishing fleet was not considered as an option. The nearest major commercial fishing fleet is at Shinnecock Inlet. The limited facilities at Shinnecock could not accommodate the Montauk fleet, and the limited shelter from storms at Shinnecock would make relocation undesirable. The local community has made very large investments in the existing marine facilities and the commercial fishing industry. Such a measure would have an adverse impact on the economic and social development of the entire area. This measure would not be cost effective and was not considered further.

4- Channel Extension East and West of Star Island. Extending the channel into the former yacht basin area, east of Star Island, was also given consideration. The use of the area, maintained by the Town of East Hampton, for purposes including a turning basin for transient vessels and for access to southern portions of the Lake, was investigated. The presence of sea grass beds and productive shellfish areas in the shallow portions of Lake Montauk, south of Star Island, would require a detailed evaluation of potential environmental impacts associated with such extension. The option would likely be less cost effective than other viable plans as there is no advantage for the large fishing boats to transit further into the harbor. Generally, only recreational vessels would benefit from a channel extension and Corps projects cannot be formulated with recreation as a purpose. The Federal Government is restricted from participating in maintenance of private marinas, berthing areas, and access points. In addition, extending the Federal channel into the Coonsfoot Cove area, west of Star Island, was given consideration. However, the large percentage of silts and clays in the sediment would make this material unsuitable as beach fill and would require further environmental testing. This measure is not considered further due to potential environmental considerations.

5- Channel Widening. The present authorized channel width of 150 feet was determined to be sufficient for two-way vessel traffic clearances at a depth of 12 feet. Given the fact that channel deepening (assuming a cut slope of 1 vertical to 3 horizontal) would result in a wider navigational area at the same 12 foot depth, this option was not given further consideration.

6- Channel Realignment. Any major shift in the authorized channel due to its large initial costs would likely be not feasible. Shifting the outer channel west of its present position would temporarily improve the present shoaling condition resulting from east jetty leakage, but this plan would not solve the deeper draft requirements of the larger vessels. It also would not provide a long-term safeguard against shoaling because, without jetty rehabilitation, sand bars would begin to form again. This option was not considered as an effective use of resources, and it was not considered further.

7- Deepening of Boat Basin. Sediment sample analyses indicated the presence of many silts and clays in this area, which is currently authorized at -10 feet MLLW. This may be a disposal hindrance, pending further testing. The area is currently used primarily by shallow draft recreational craft. Based on boating survey conducted in 2005, there are not enough transient vessels or turning basin needs to deepen the existing depth. As a result, this option was not considered further.

8- Sand-Bypassing. Based on the results of sediment budget analysis, there is an approximately 12,800 cubic yard per year sediment supply from the updrift (east) shoreline. Of the total supply, approximately 7,000 cubic yards per year is bypassed to the downdrift beach via channel dredging and approximately 800 cubic yards per year is lost to deep water offshore. The remaining 5,000 cubic yards per year continues to accumulate to the east of the inlet. The east sediment fillet is close to saturation and the accumulated sediment is shoaling the entrance channel both around the east jetty and by migration into the inner channel via gaps in east jetty. The accumulated updrift sediment fillet could be bypassed to the downdrift beach via trucking or hydraulic pumping across the channel to reduce future channel shoaling and maintenance dredging costs. Due to the small bypassing rate, temporary hydraulic pumping equipment or trucking would be more cost-effective than using a fixed bypassing plant which requires a high investment cost (close to $1,000,000) and annual operation, maintenance, and equipment depreciation, which may double the unit trucking cost of $15 to $20 per cubic yard to $30 to $40 per cubic yard.

9- Jetty Rehabilitation. Rehabilitation of the eastern jetty could play an essential role in improving the navigation through the channel for the vessel fleet. A large portion of the shoaling material that enters the channel results from leakage through the eastern jetty. Accordingly, this plan component could reduce the future Operation and Maintenance Costs for the navigation channel. The without project future condition would mean continued deterioration of the eastern jetty and a mandate for more frequent dredging (shorter dredging cycles). Since the shoal that results from leakage tends to be localized but quite intrusive at certain channel points, this component could help enhance navigation maneuverability. The U.S. Army Corps of Engineers New York District, under a separate Operations and Maintenance Authority, rehabilitated a section of the eastern jetty from Station 5+55 to 9+55 together with a tie-in at the inshore end in year 1999. Despite this, it is projected that seepage of sand into channel through the voids of the east jetty would continue without further rehabilitation.

10- Deepening of the Federal Navigation Channel. There is a trend toward larger, deeper draft commercial fishing vessels. In 1993, there were 24 vessels overall with a loaded draft of 12 to 13 feet that listed Lake Montauk Harbor as a homeport. According to local fishing captains who were recently interviewed, there are approximately 15 large fishing vessels that operate out of the harbor. The vessels range from 50 to 100 feet in length with loaded drafts of 10 to 16 feet. When considering squat requirements, wave allowance requirements, and safety clearances, deepening would be necessary under present guidance and would meet concerns of local interests. Deepening would improve navigation through the channel for the existing and future fleet and would enhance navigation maneuverability. This measure is considered further.

11- Removal of shoal at the inshore end of the East Jetty. A large sand shoal has been developing near the inshore end of the eastern jetty, just northeast of Star Island. It has been infringing upon the authorized channel width. In 1995, 2000, 2004, 2009, 2011, and 2014 the U.S. Army Corps of Engineers New York District removed part of this shoal during maintenance dredging. Local interests have indicated however that it has already begun to shoal in again because the jetty has not been rehabilitated enough to prevent further leakage into this area. However, due to the construction of a bulkhead, complete removal of the shoal will result in flanking of the structure. Deepening of the navigation channel (Alternative 10) however will widen the area to be dredged and as a consequence reduce the size of the shoal.

12- Deposition basin outside the current authorized channel limits. Over the past several dredging cycles (1991, 1995, 2000, 2009, 2011, 2014, and 2018), advanced maintenance dredging measures have been employed. Essentially, for a length of channel approximately equal to the existing east jetty length, an additional 50 feet (outside and to the east of the existing channel) is dredged. This additional cut serves as a deposition basin to protect the authorized channel. This is also done for economic reasons because removing larger quantities is more efficient, given the high dredging mobilization and demobilization costs. This practice could be authorized and extended around the bend and into the inner channel, approximately an additional 1,800 foot length. The width of the deposition basin could be extended from 50 feet to 100 feet to increase the capacity. This measure is carried forward for further consideration.

5.0 SCREENED ALTERNATIVES AND VOLUME ESTIMATES

Screened Alternatives

Based on the preliminary screening, five navigation improvement alternatives are short listed and developed in further detail for consideration and selection. The navigation alternatives are examined to meet navigation requirements and minimize channel maintenance dredging operations throughout the 50-year project life. A

Alternative 1: Continue Existing Navigation Plan

This alternative includes dredging of existing 150 foot wide federal channel and additional 50 foot deposition basin to the authorized depth at -12 feet MLLW for both outer and inner channels. The estimated initial volume available for beach placement will be approximately 26,400 cubic yards (Table 19).

Based on past practice, the dredged material will be placed as stockpile located west of the west jetty and spread downdrift with bulldozer naturally to the downdrift. The estimated maintenance dredging period is approximately 4 years when the channel shoals above the authorized Federal depth.

Alternative 2: Deepening up to -18 feet at Existing Channel Width and 50 foot Deposition Basin

This alternative includes dredging of existing 150 foot wide federal channel and additional 50 foot deposition basin up to -18 feet MLLW authorized depth for the channel. The estimated initial volume available for beach placement will be approximately 51,800, 83,200, 109,000, 135,400, and 163,000 cubic yards for -14 foot, -15 foot, -16 foot, -17 foot and -18 foot depths respectively.

The dredged material will be placed as stockpile located west of the west jetty and spread downdrift naturally or with bulldozer to the eroded downdrift shoreline. There will be no scheduled future nourishment period or quantity. The estimated maintenance dredging period is approximately 4 years as the channel shoals above the authorized federal depth (Table 19).

Alternative 3: Deepening up to -18 feet at Existing Channel Width and 100 foot Deposition Basin

This alternative includes dredging of existing 150 foot wide federal channel and additional 100 foot deposition basin up to -18 feet MLLW. The estimated initial volume available for beach placement will be approximately 83,200, 117,300, 145,800, 174,900 and 205,300 cubic yards for -14 foot, -15 foot, -16 foot, -17 foot and -18 foot depths respectively (Table 19).

The dredged material will be placed as stockpile located west of the west jetty and spread downdrift naturally or with bulldozer to the eroded downdrift shoreline in accordance with current operations and maintenance practices. The estimated maintenance dredging period is approximately 7 years as the channel shoals above the authorized federal depth.

The post-construction jetty slope stability will be analyzed based on U.S. Army Corps of Engineers' slope stability manual (EM 1110-2-1902) guideline during the preconstruction, engineering and design phase of the project. Based on the historical pre- and post- channel dredging condition survey records, the equilibrium channel side slope are at a range of 1 vertical on 5 to 7 horizontal, with steeper slopes and deeper toe depths near the jetty entrance. The proposed channel configuration design was based on the assumption of jetty toe depths beyond -10 feet MLLW at both the east and west jetties with a 1 vertical on 5 horizontal channel equilibrium side slope for sand material (Figure 18). Based upon these assumptions, the tentatively selected plan does not result in any impacts to jetty stability. However, in preconstruction, engineering and design phase the post-construction jetty stability shall be confirmed based on the most recent jetty condition survey, geotechnical investigations, and slope stability analysis results. Specifically to ensure the long term equilibrium side slope of the channel, which may be more gradual than the initial cut slope does not impact the structure. Based upon the more detailed jetty stability analysis, consideration may be given to modify the recommended plan if deemed necessary.

Alternative 4: East Fillet Mining

The east jetty impoundment offers an additional source of sand for the project. The potential borrow region extends east from the inlet approximately 1000 feet and out to a depth of approximately -10 feet NAVD88 (Figure 19). It was assumed the fillet would be mined back to the baseline with a final slope of 1 vertical on 12 horizontal down to a depth of -10 feet NAVD88. Composite profiles were constructed from recent LIDAR and long range profiles from 2004 (Figure 20). Applying an average area end method to the data assuming 100% mining efficiency led to an Initial estimate of 56,000 cubic yards of sand.

Originally it was thought a cutter head dredged would be used to mine the fillet out from a depth of -17 feet NAVD88 up to the baseline, creating a construction slope of 1 vertical on 3 horizontal that would gradually evolve to a final slope of 1 vertical on 12 horizontal. Field work (Mattituck Inlet) in 2014 indicated this is not a viable option for mining any appreciable volume of material. An alternative mining method of beach scraping and trucking of the subaerial portion of the fillet was considered but this would yeild a significantly smaller volume of material (~ 7,000 to 10,000 cubic yards of sand). The rate at which this sand would be replenished to the fillet was estimated to range between 8 and 11 years. This was constructed using the most recent sediment budget for the region, assuming equal distribution of sand within the transport cell and along the profile, and constraining the mineable area to the subaerial portion of the fillet. The gradual impoundment on the beach face and berm east of the jetty will reduce shoaling rates within the channel and deposition basin by roughly 3 to 5 percent, increasing the maintenance cycle to 4.2 years when combined with Alternatives 1 or 2 and 7.6 years when combined with Alternative 3.

This measure was removed from further consideration because the use of trucking and/or hydraulic dredging would not be cost effective, or provide a significant volume of sand to appreciable extend the maintenance cycle of the main navigation channel.

Alternative 5: Jetty Rehabilitation

The rehabilitation of the eastern jetty in conjunction with the mining of the east fillet was considered in Alternative 5. Some of the sand depositing in the main channel and deposition basin enters from leakage through the eastern jetty. It is estimated that decreasing the porosity of the structure may reduce overall shoaling by 5 to 7 percent, increasing the maintenance cycle to 5 years when combined with Alternatives 1 or 2 and 8 years when combined with Alternative 3.

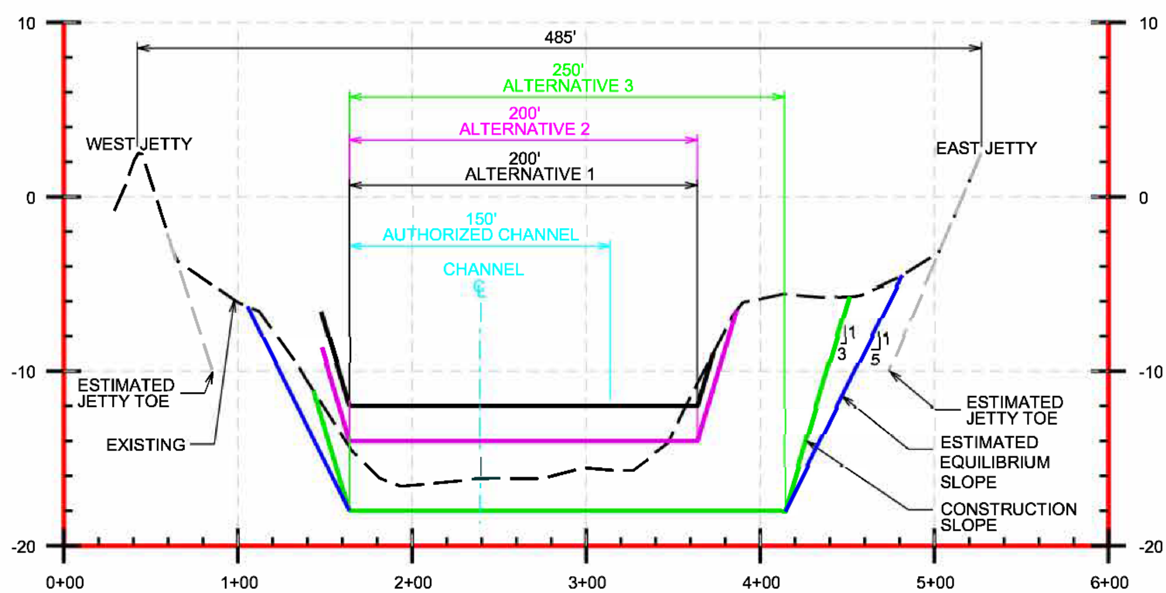
The rehabilitation of the east jetty is estimated to cost approximately $10 million. This is based on recently completed stone work at Long Beach, NY. The remoteness of the site, length of structure and water depth at the jetty head significantly impact construction costs. Even if the rehabilitation efforts defer two maintenance dredging cycles (~$1.6 million) the cost saving would not be justifiable. This measure was removed from further consideration as the analysis shows that it would not be cost effective in reducing the need for navigation maintenance.

Table 19: Alternatives Summary

		Alternative 1	Alternative 2	Alternative 3
Channel Width	ft	150	150	150
Deposition Basin (ft)	ft	50	50	100
Authorized Depth	ft MLLW	-12	-14/-16/-18	-14/-16/-18
Initial Dredged Volume (cy)	-14 ft	26,400	51,800	83,200
	-15 ft	N/A	83,200	117,300
	-16 ft	N/A	109,000	145,800
	-17 ft	N/A	135,400	174,900
	-18 ft	N/A	163,000	205,300
Maintenance Dredging		4	4	7
Period (years)				
Maintenance Volume (cy)		32,000	32,000	56,000

Notes:

1. Initial dredged volume includes 2 ft overdredge tolerance;
2. Dredged depth = Authorized Depth + 2 ft;



NOTES:

1. DEPTHS ARE IN FEET AND ARE REFERENCED TO MEAN LOWER LOW WATER (MLLW).
2. SURVEY WAS CONDUCTED IN MARCH 2019.
3. VERTICAL AXIS IS SCALED 10 TIMES.
4. ALTERNATIVE 1: 150 + 50D = 200 W @ -12 MLLW
5. ALTERNATIVE 2: 150 + 50D = 200 W @ -14 TO -18' MLLW
6. ALTERNATIVE 3: 150 + 100D = 250 W @ -14 TO -18' MLLW

Figure 18: Typical Alternative Dredged Sections

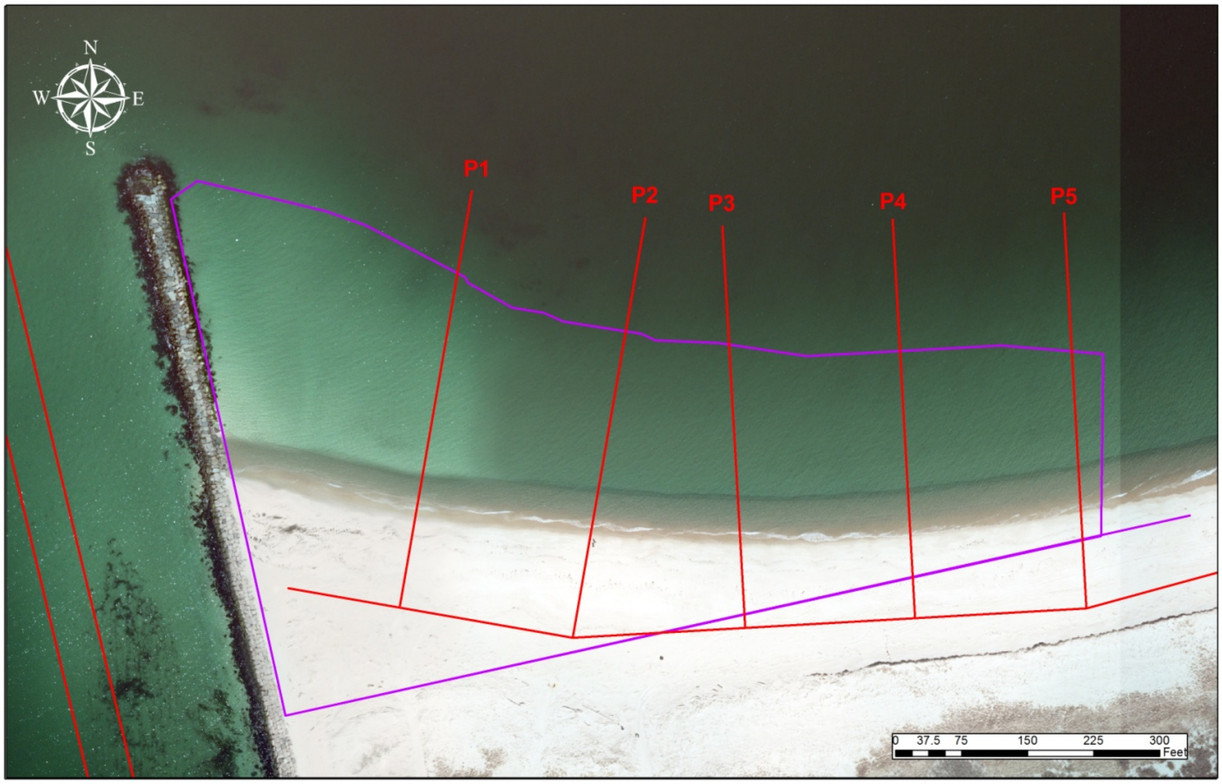


Figure 19: East Fillet Mining Region and Profile Locations

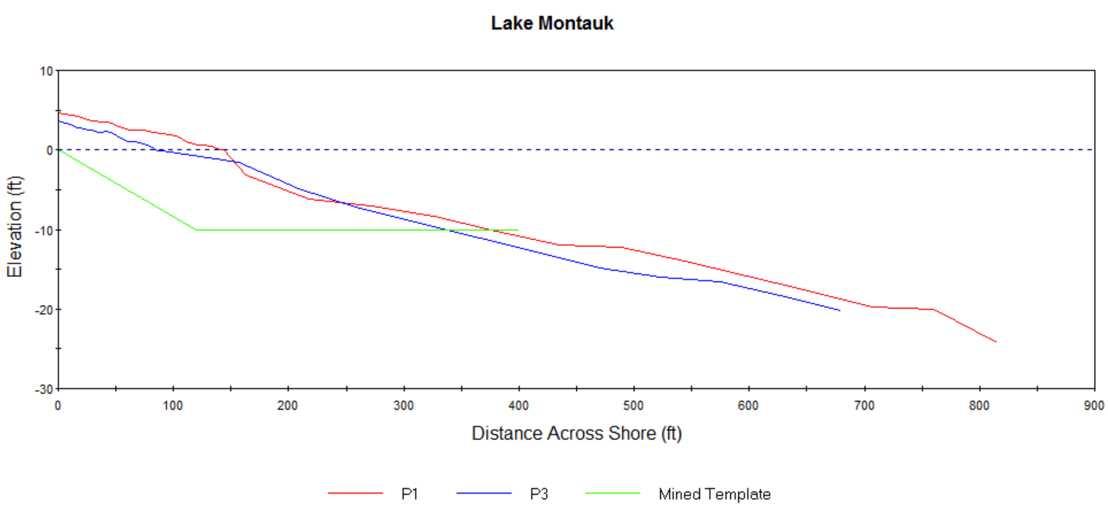


Figure 20: Typical Fillet Profiles and Mined Template.

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ATTACHMENT 1

AVAILABLE DREDGED VOLUME ANALYSIS

Date: December 13, 2019

Technical Memo: Volume Estimate for Lake Montauk Harbor Feasibility

Summary: This technical memo briefly describes the local sand sources, methodology and data used to estimate the potential volume of material readily available for the Lake Montauk project. The primary borrow area includes the main navigational channel and deposition basin (Figure 1). Analysis of the most recent bathymetric and topographic data collected in 2018 suggests that approximately 26,000 to 205,000 cubic yards of material can be mined from the channel and deposition basin, depending on the alternative that is selected. A detailed description of the alternatives, volume calculations, data and methodology is listed below.

Navigation Channel: Three dredging options for the channel and deposition basin were considered for this analysis. These options include: 1) dredging of the 150 foot wide channel to authorized depth only (-12 feet MLLW), 2) uniform dredging of the 150 foot wide channel and 50 foot wide deposition basin to depths of -14 feet through -18 feet MLLW, and 3) widening of the deposition basin to 100 feet coupled with uniform dredging to depths of -14 feet through -18 feet MLLW. Table 1 provides a volume summary for each alternative. All calculations assume a cut slope (construction slope) of 1 vertical on 3 horizontal and 2 feet overdredge tolerance. Proposed dredging depths and concern for submerged aquatic vegetation (SAVs) limit the extent of the deposition from STA 0+00 to STA 13+00 (Figure 1).

For Alternatives 1 and 2, surfaces were constructed of each configuration and compared to the most recent survey data collected on April 16, 2018 using INROADS. Volumes for each option and depth level are reported in Table 1, values are listed in cubic yards. The additional volume associated with widening the deposition basin to 100feet (Alternative 3) was calculated using the most recent survey data and the average area end method.

Table 1: Volume Calculations for Alternatives 1, 2, and 3.

	Dredge Depth (ft, MLLW)					
Alternatives	**A -12 ft**	**C -14 ft**	**D -15 ft**	**E -16 ft**	**F -17 ft**	**G -18 ft**
1 Authorized Channel Depth with 50 ft Deposition Basin	26,409	NA	NA	NA	NA	NA
2 Channel Deepening with 50 ft Deposition Basin	NA	51,780	83,170	108,950	135,440	162,980
3 Channel Deepening with 100 ft Channel-Deposition Basin	NA	83,170	117,280	145,750	174,940	205,340

**values reported in cu.yd.*

Dredging Interval: An estimate of required maintenance dredging was calculated for each Alternative. The estimate assumes dredging is initiated when the channel shoals, the historical shoaling rate of roughly 7,000 cubic yards per year is constant and applies primarily to the outer channel (Station 2+00 through Station 10+00). Recent surveys of the extent of the outer shoal were analyzed in order to compute the volume of material that would be required to trigger a dredging event for each alternative. Representative profiles and alternatives are shown in Figures 2, 3 and 4. Maintaining the authorized channel (Alternative 1) requires a 2 year cycle. Deepening the channel with a 50 foot deposition basin (Alternative 2), would maintain a dredging cycle of 4 years. Deepening the channel with a 100 foot deposition basin (Alternative 3), would lengthen the maintenance dredging cycle to approximately 7 years.

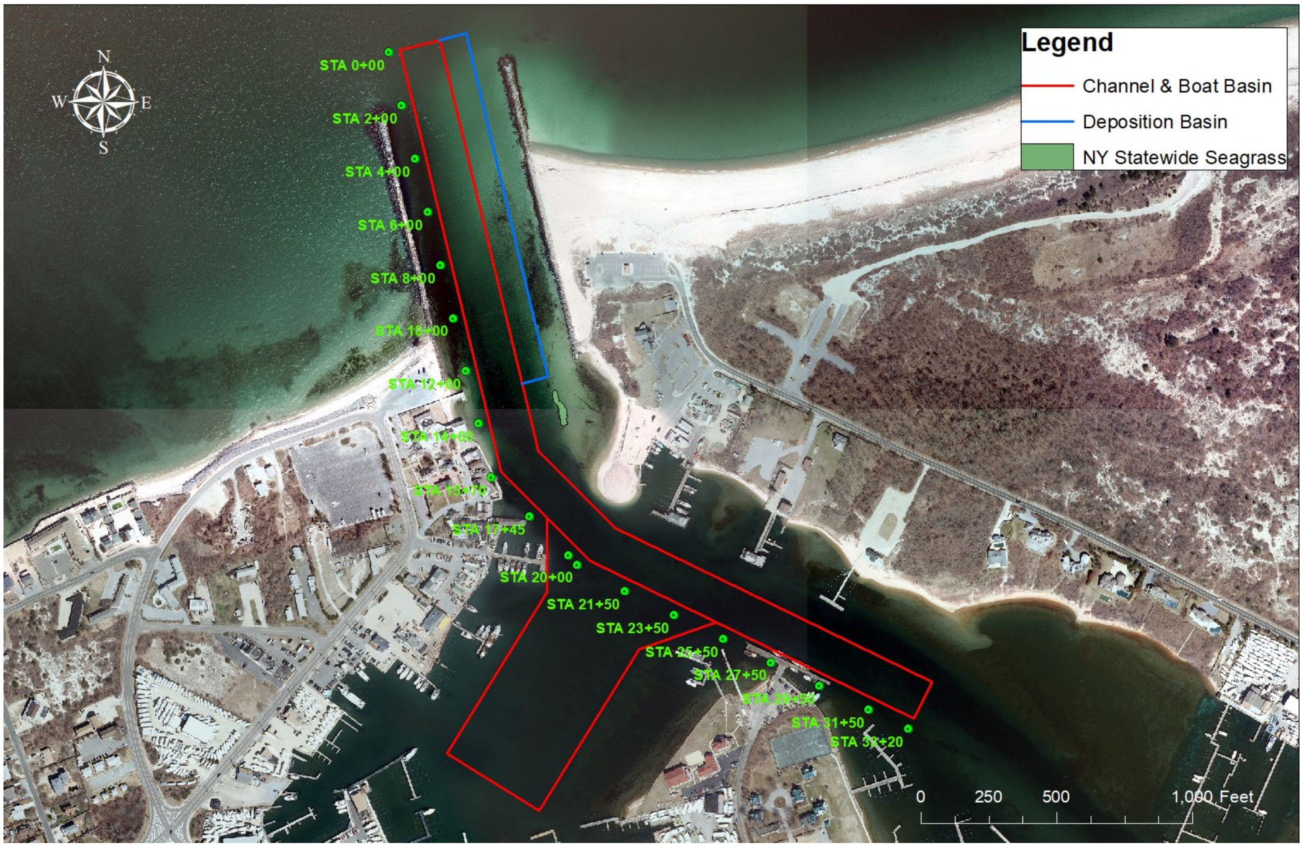

Figure 1: Lake Montauk Harbor. 150 foot navigation channel and boat basin are shown in red. Eastern 100 foot deposition basin (Alternative 3) is shown in blue.

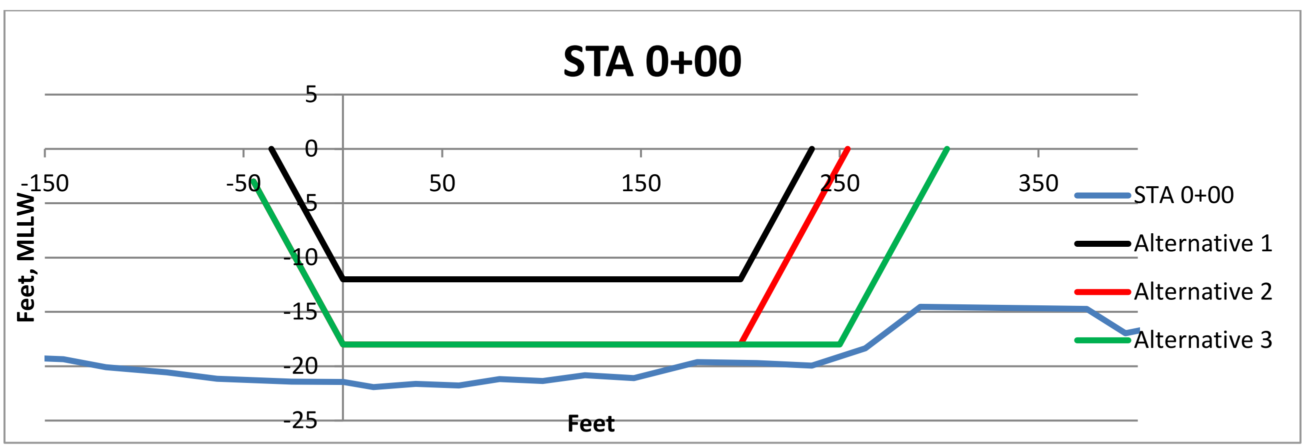

Figure 2: Select Channel Alternatives at Station 0+00. All channel construction slopes are 1V:3H.

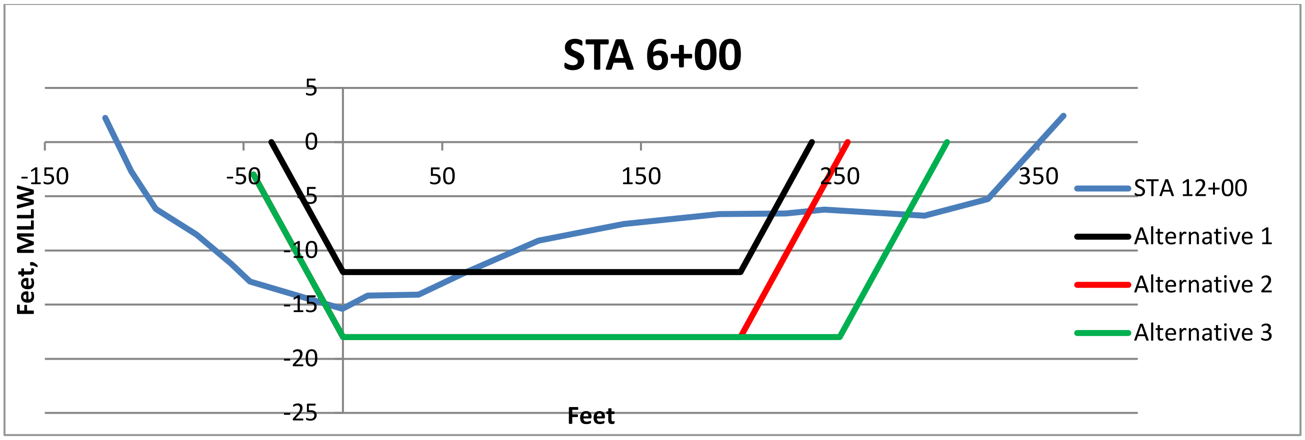

Figure 3: Select Channel Alternatives at Station 6+00. All channel construction slopes are 1V:3H.

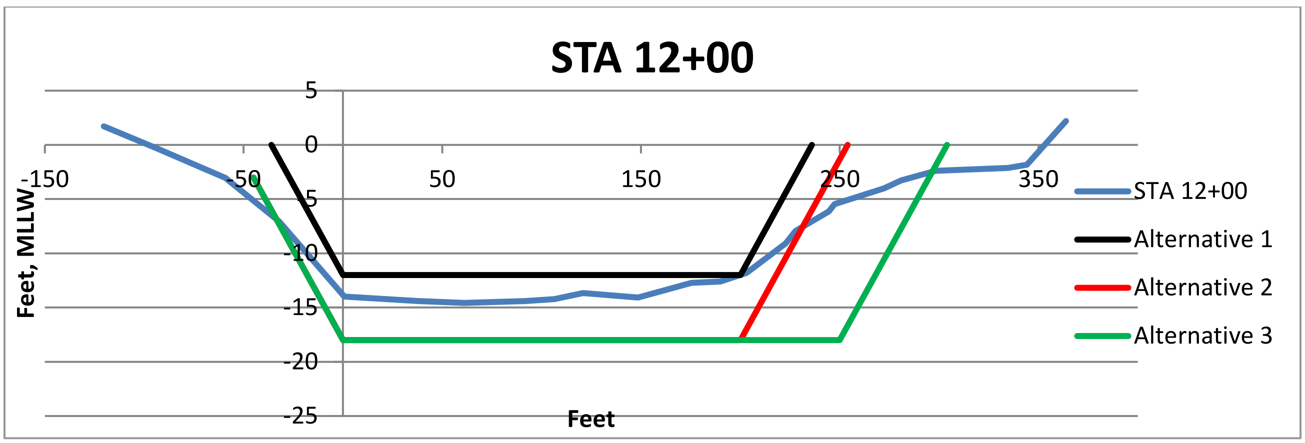

Figure 4: Select Channel Alternatives at Station 12+00. All channel construction slopes are 1V:3H.