In: *Proceedings Coastal Sediments '03.* 2003. CD-ROM Published by World Scientific Publishing Corp. and East Meets West Productions, Corpus Christi, Texas, USA. ISBN 981-238-422-7.

HYPOTHETICAL RELOCATION OF FIRE ISLAND INLET, NEW YORK

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Abstract: Hypothetical eastward relocation of Fire Island Inlet is examined as a thought exercise in regional sediment management. Subjects considered include morphologic behavior of the inlet, hydrodynamics of the present and hypothetical relocated inlet, collapse of the existing ebb-tidal shoal and formation of new ebb and flood shoals, sand bypassing, navigability, and stability of the beaches east and west of the inlet. The relocated inlet would be more hydraulically efficient than the present inlet, increasing tidal exchange (prism), promoting circulation in Great South Bay, and increasing sand storage in the inlet shoals. Collapse of the abandoned ebb shoal would feed the eroding beaches to the west, such as Gilgo Beach, for 50-100 years. Oak Beach would no longer experience an erosional ebb current and wave action. The east jetty would impound sediment, gradually building the width of the fragile beaches of Fire Island located to the east. Several sediment-sharing projects would benefit from the inlet relocation, a goal of regional sediment management. Potentially unacceptable negative consequences that require study, such as increased storm surge susceptibility, are identified.

INTRODUCTION

The U.S. Army Corps of Engineers has recently launched a Regional Sediment Management Research (RSM) Program to advance knowledge and develop predictive tools for the Corps and society to effectively manage water resource projects and associated sediments. Significant cost savings and reduced environmental stress are anticipated by taking a sediment-sharing system approach among multiple projects and locations. Products of the RSM Program will be focused on project design, operation, and maintenance methods that (1) minimize disruption of natural sediment pathways and processes, and (2) mediate natural processes that have adverse environmental or economic consequences. The physical processes governing regional water and sediment movement are under investigation, as well as new predictive technology at the project and intra-project level. For example, Larson et al. (2002) and Larson and Kraus (2003) describe a new type of model called Cascade that is under development and testing in the RSM Program for prediction of shoreline change at regional scale (tens to hundreds of kilometers, tens to hundreds of years) including longshore sand transport, evolution of inlet geomorphology within the domain, sand bypassing at inlets, and overwash. The former reference applied the model to the south shore of Long Island, New York, from Fire Island Inlet to east of Shinnecock Inlet, and the latter reference applied Cascade to the Delmarva Peninsula for a stretch of coast including two inlets and the beaches of three states.

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Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **2003**	2. REPORT TYPE	3. DATES COVERED **00-00-2003 to 00-00-2003**

4. TITLE AND SUBTITLE **Hypothetical Relocation of Fire Island Inlet, New York**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Army Engineer Research and Development Center,Coastal and Hydraulics Laboratory,3909 Halls Ferry Road,Vicksburg,MS,39180-6199**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
Proceedings Coastal Sediments ’03. 2003. CD-ROM Published by World Scientific Publishing Corp. and East Meets West Productions, Corpus Christi, Texas

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15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**14**	

Regional sediment management concepts are comprehensive in consideration of policy, the physical processes that need to be represented, and the predictive tools that must be developed. This paper describes a thought experiment to examine multiple projects and sediment management concerns at and around Fire Island Inlet, a moderate-sized inlet located on the Atlantic coast of New York. The experiment is designed to reveal the interacting problems to be addressed and potential benefits of regional sediment management with relocation of the inlet. The hypothesized relocation is not under consideration by the U.S. Army Corps of Engineers.

STUDY SITE SETTING AND MOTIVATION

Fire Island Inlet is one of six permanent inlets located on the south shore of Long Island, New York. It is classified as a barrier overlap inlet (Fig. 1), indicating that wave-induced sand transport dominates over transport by tidal exchange. Growth of Fire Island is a well-known example of spit elongation and owes to longshore sand transport strongly directed to the west. Westward growth of Fire Island stranded the lighthouse originally built in 1827 (rebuilt in 1854) at the eastern edge of the inlet. It is now located 8 km to the east of the present inlet entrance (Fig. 2). Geologists and engineers have studied the Atlantic shore of Long Island and associated inlets with focus on beach processes for shore preservation and on inlets for navigation and sand bypassing (e.g., Gofseyeff 1952; Saville 1960; Panuzio 1968; Kumar and Sanders 1974; Leatherman and Allen 1985; Morang et al. 1999; Smith et al. 1999; Schwab et al. 1999). Schwab et al. (1999) discuss the geology of the inner continental shelf, sediment sources and pathways, and evidence of onshore transport of sediment from the shelf toward Fire Island Inlet.

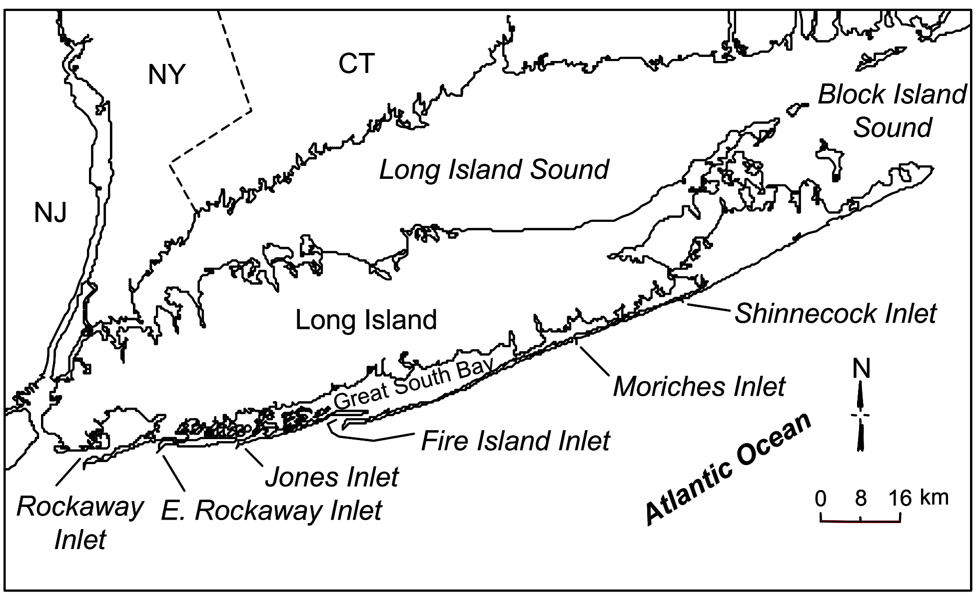

Fig. 1. Location map for the south shore of Long Island, New York

Bottom friction associated with the great hydraulic length of the inlet, presently stretching 6.5 km from the entrance to Great South Bay, weakens the tidal current and promotes shoal development and closure of the entrance. The photographic record (Fig. 3) and experience in maintenance dredging indicate that the inlet is prone to shoal, making navigation difficult. Vessels exiting the inlet must travel abeam to Atlantic Ocean waves before cutting safely south, although the finger shoals afford protection during lower water. Smith et al. (1999) documented that approximately 12.2×10^6 m^3 of sand was dredged from the entrance from 1954-1994, or about 300,000 m^3/year. That volume has increased in recent years to an annualized average rate exceeding 400,000 m^3/year, approximately equaling the total annual dredging at the other five federally maintained inlets. The present annualized cost of dredging at Fire Island Inlet, with the sand bypassed to the down-drift side, is about $5 million.

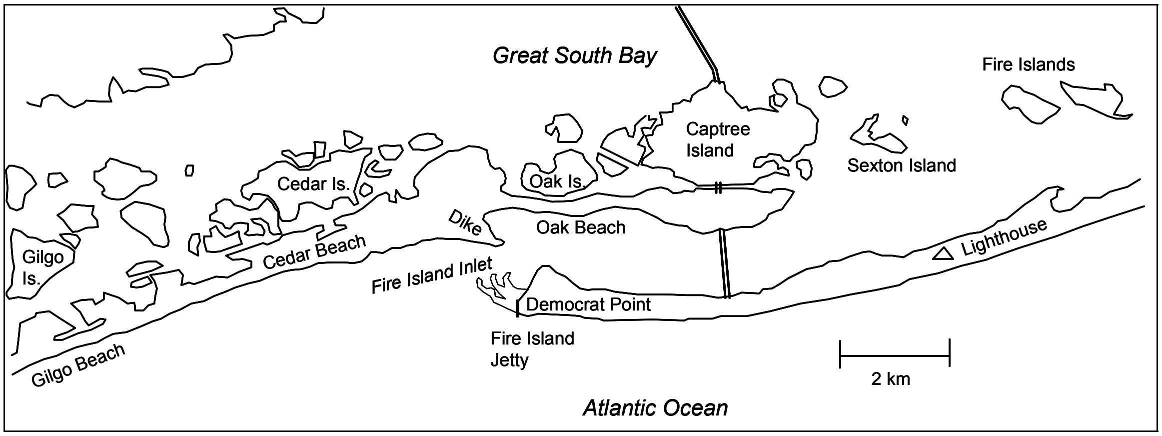

Fig. 2. Location map for Fire Island Inlet

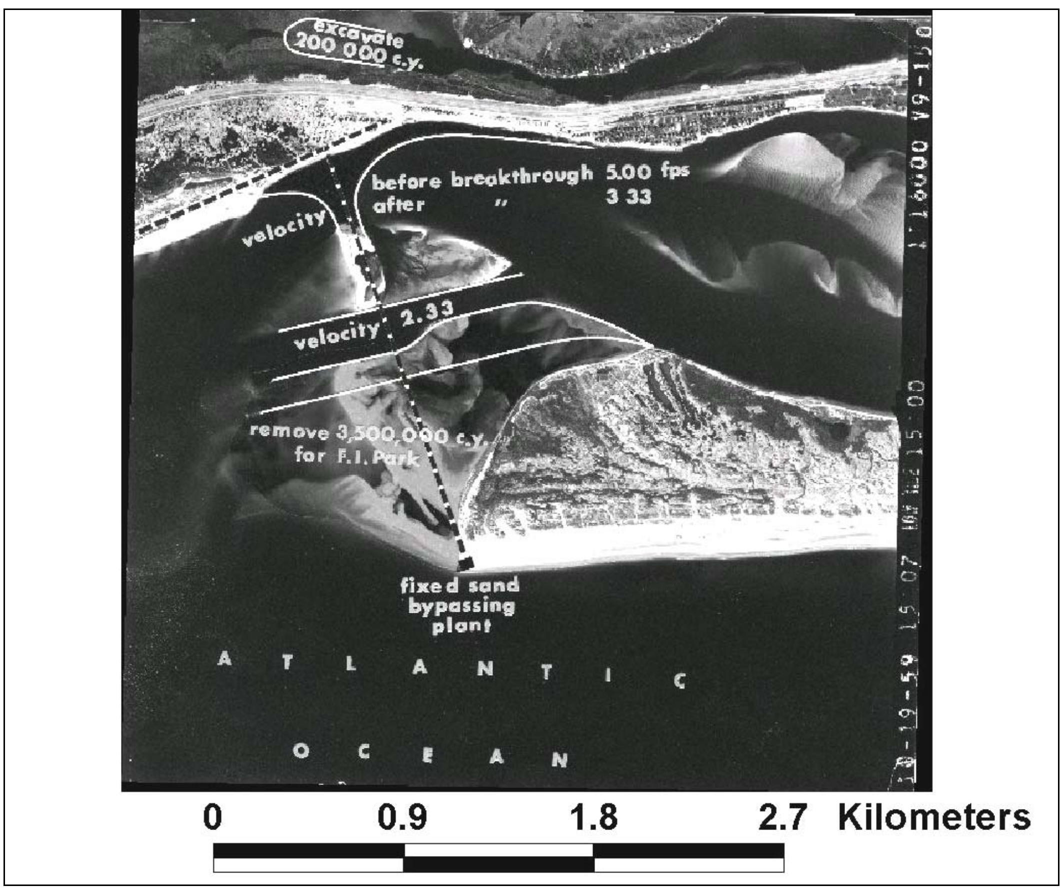

Fig. 3. U.S. Army Corps of Engineers, New York District working document photograph, Fire Island Inlet, March 1953

During 1939-1941, a jetty was constructed on the east side of Fire Island Inlet to stabilize the entrance, but by the mid-1950's it had become impounded, with finger shoals encroaching into the navigation channel. In 1959, an 800-m long sand training dike was constructed to force the ebb current away from Oak Beach. Storage of sand in the shoals has reduced bypassing capacity, contributing to chronic erosion along Gilgo Beach, located 5 km to the west of the entrance. Gilgo Beach may be in a nodal region of longshore transport created by the shadow of the combined masses of Democrat Point and the Fire Island Inlet ebb shoal and bypassing bar. Concern remains about the erosive ebb current running along Oak Beach and condition of the training dike, which is maintained by local government. Some back passing of dredged sediment is also performed to Atlantic-fronting beaches east of Democrat Point; backpassed sand is eventually transported west and re-enters the inlet.

The question can be raised – why not relocate the inlet back to its early 19th century position and construct dual jetties to eliminate or greatly reduce problems associated with the present inlet configuration in a regional sediment management approach? What direct and indirect consequences, positive and negative, would emerge as a result of the relocation? This paper examines, at scoping level, functional designs and regional sediment management considerations of hypothetical relocation of Fire Island Inlet.

HYPOTHETICAL FUNCTIONAL DESIGN OF RELOCATED (NEW) INLET

Numerous physical processes, as well as political and socio-economic issues, must be addressed in considering inlet relocation in an urban area. If Fire Island Inlet were to be relocated 8 km to the east (and the old entrance closed or allowed to close), the existing ebb shoal having an estimated volume of about 30 million m^3 would migrate shoreward to the western beaches. Under an estimated annual-average net westerly transport rate of 300,000 m^3/year, Cedar Beach, Gilgo Beach, and beaches to the west would be supplied with sand for close to a century. The existing jetty might be shortened gradually to hold the beach along the terminus of Fire Island (Democrat Point), minimizing formation of a cape to the west. Such considerations of various regional sediment and physical processes are discussed here.

As a hypothetical regional sediment management alternative, the inlet is relocated 8 km to the east, back to its position in 1827, with the east jetty of the relocated inlet placed 150 m west of the lighthouse. The jetties are constructed 330 (1,000 ft) apart and extend to the 6-m (20-ft) contour (mean sea level, MSL). Approximately 500 m of barrier island is dredged to create the inlet. Assuming an average barrier island elevation of 4 m above MSL, the total volume removed to create the relocated inlet is about 1.6×10^6 m^3. This material could be (1) placed offshore to form a nascent ebb shoal and promote natural sand bypassing, (2) pumped west to plug the old inlet, or (3) stockpiled for various uses such as for wetland creation, and for beach nourishment and breach filling during a storm. Inlet dimensions were chosen to approximate the natural cross-sectional area of the existing inlet and provide reliable navigation. The 6-m depth MSL is almost equivalent to the authorized depth of 4.27 m mean lower low water (MLLW).

The dual jetties of the hypothetical relocated inlet are aligned 11 deg to shore-normal and at a NE-SW orientation to shelter vessels from larger waves out of the SE and to direct the flood tidal plume away from Sexton Island and the two small "Fire Islands" in Great South Bay (see Fig. 2). The flood current of the relocated inlet might tend to erode these islands, which are environmental resources. The relocated inlet will create both an ebb shoal and a flood shoal. Other processes and possible consequences are discussed below.

MORPHOLOGIC AND HYDRODYNAMIC PROCESSES

Westward Growth of Democrat Point and Relation to Neighboring Beaches

Fire Island Inlet has migrated to the west since at least 1824, when a lighthouse was built close to its eastern bank. Its rapid migration is a textbook example of spit growth and has been well documented (Gofseyeff 1952; Saville 1960; Panuzio 1968; Kumar and Sanders 1974; Leatherman and Allen 1985; Morang et al. 1999; Smith et al. 1999). Shoaling in the inlet tends to drive the navigation channel to the north. Erosion on Oak Beach was attributed to the close proximity of the natural ebb channel to shore, and a training dike was constructed in 1959 to move the channel southward (Figs. 2&3) and limit erosion. Property owners along Oak Beach are concerned about opening Fire Island Inlet wider or aligning the channel more in a north-south orientation that might expose the beaches to greater wave action. Cedar Beach has accumulated sediment, whereas Gilgo Beach further to the west of the inlet experiences chronic erosion and is a Demonstration Site in the National Shoreline Erosion Control Development and Demonstration Program (http://limpet.wes.army.mil/sec227/Demosites/gilgo.htm). Beaches to the east of Fire Island Inlet are also experiencing erosion, and back passing of dredged material is performed. Most dredged material is placed off Gilgo Beach. Historically, westward growth of Democrat Point modified the islands to the north and west, as well as abandoned flood shoals to the east. Examination of historic U.S. Coast and Geodetic Topographic Sheets (T-Sheets) suggests that Sexton Island and the Fire Islands of Great South Bay may be the remnants of the distal end of the Oak Beach barrier that has disintegrated by erosion during the barrier overlap process.

To investigate the westward movement of Democrat Point, T-Sheets were obtained in digital format from the National Oceanic and Atmospheric Administration's Coastal Services Center. The T-sheets included survey dates between 1834 and 1924. Historical aerial photographs covering 1941 through 2000 were obtained from the U.S. Army Engineer District, New York archives and from the Beach Erosion Board archive at the U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, and digitized at high resolution. The digital T-sheets, which included benchmark information referenced to NAD 1927, were imported into ArcView™ and referenced to NAD 1983 with the ArcView™ Projection Utility. The aerial images were imported into ArcView™ as image analysis themes and referenced to the local plane coordinate systems (NY State Plane NAD 83) using USGS Digital Ortho Quarter Quadrangle images (DOQQ's). The approximate position of the mean high water line was then mapped with the Beachtools ArcView™ Extension (Hoeke et al. 2001).

The analysis is summarized in Fig. 4. The approximate 8-km extension of Fire Island mapped from the sequence of T-Sheets and aerial photographs shows the response of the Oak Beach barrier to the overlap process. A narrow tidal inlet (Oak Island Inlet) is noted in the 1851 configuration. By 1873, the east end of Oak Beach was fragmented. Shortening of Oak Beach continued to at least 1924, and by 1941 the east end of Oak beach was nearly in its present location. The inlet entrance was narrow by the early 1950's (Fig. 3) due to shoal building, and thinning of the Oak Beach barrier became severe from erosion by tidal currents within the inlet channel. At this point in time it seems likely that a major storm would have to cut a new inlet across a narrow portion of Oak Beach just to the west of Oak Island and Captree Island. The impoundment of sand and deflection of tidal currents by the sand dike constructed in 1959 may have prevented breaching of a new inlet. The impacts of sand impoundment, sand bypassing, and shoal growth are evident in the 1960 to 2000 shoreline sequence.

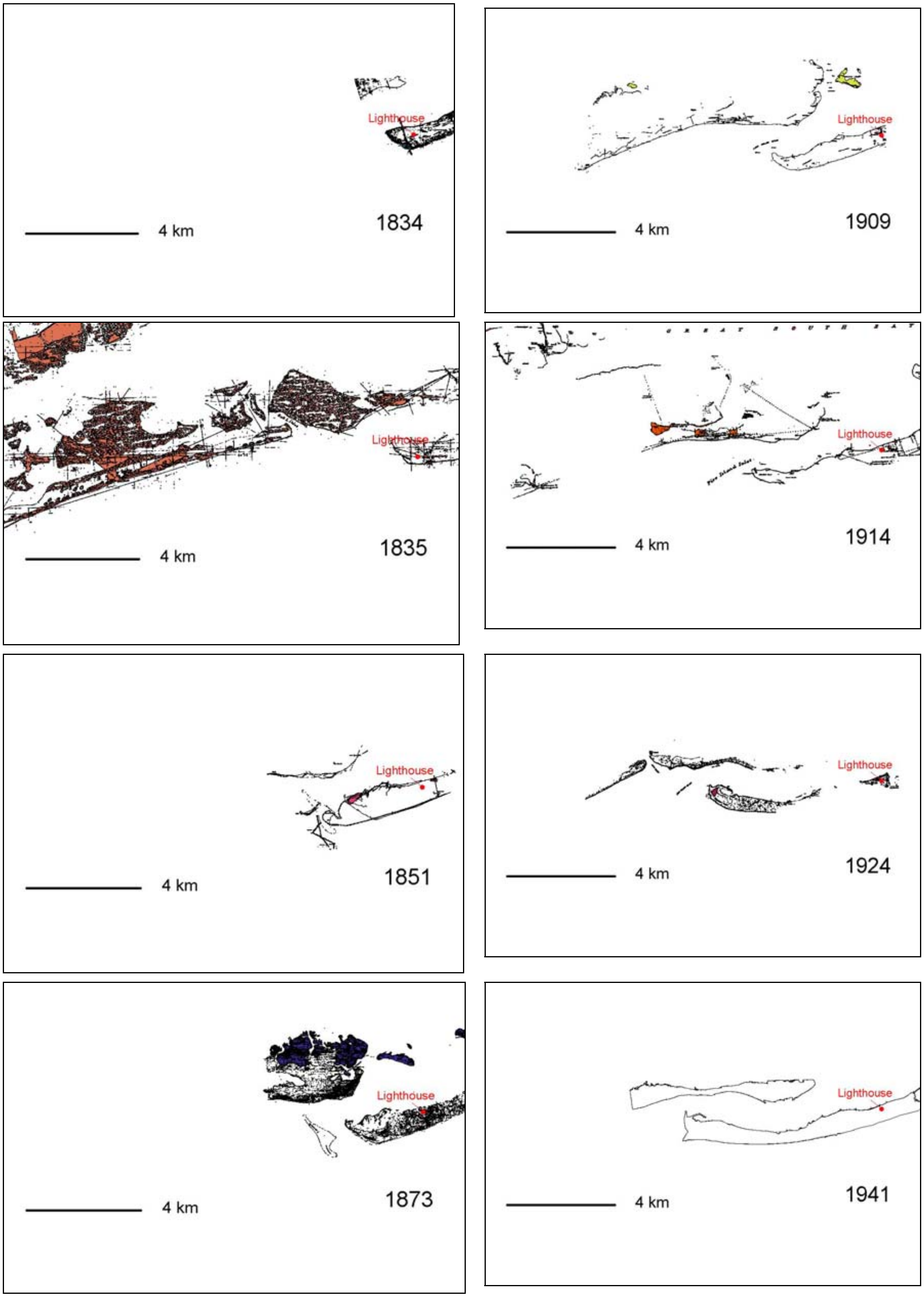

Fig. 4. Westward growth of Fire Island from lighthouse (figure continued next page)

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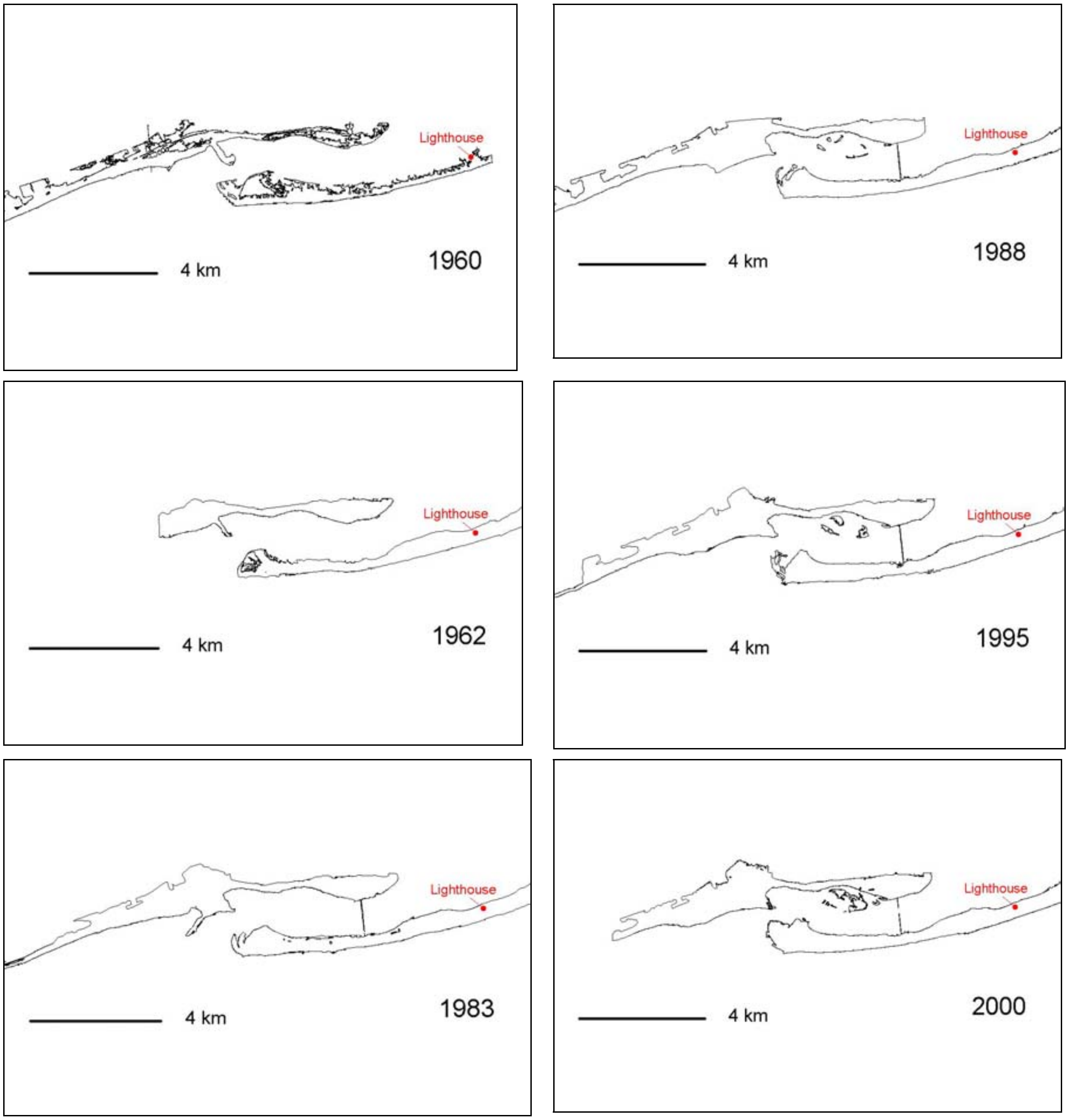

Ebb Tidal Shoal and Inlet Stability

Moffatt & Nichol Engineers (MNE) (2002) compiled recent hydrodynamic and morphology conditions for Fire Island Inlet. They found a minimum cross-sectional area at the throat of 2.1×10^3 m^3, average depth to MLLW of 4.4 m, tidal prism of 8.7×10^7 m^3, and a measured ebb-shoal volume of 3.1×10^7 m^3. The measured volume of the ebb shoal may be an underestimate owing to limited survey coverage. An empirical predictive relation by Walton and Adams (1976) for the volume of an ebb-tidal shoal as a function of its tidal prism gives a calculated volume of 3.8×10^7 m^3. Therefore, the ebb shoal at Fire Island Inlet is at about 80 % of its theoretical equilibrium volume, although some uncertainty exists in the theoretical value.

As noted by MNE (2002), the recent value of the tidal prism is greater than those reported in the past (e.g., in Jarrett 1976), whereas the minimum cross-sectional area is less than measured in the past. However, the nearly annual dredging of the entrance makes conclusions difficult to reach about trends in channel cross sectional area. The Escoffier closure curve for Fire Island Inlet as calculated by MNE indicates the inlet is only marginally stable, likely the result of (1) large amounts of littoral sediment transport entering the inlet, and (2) great length of the inlet, which makes it hydraulically inefficient.

In summary, Fire Island Inlet in its present state is tending to close, which increases dredging requirements because the navigation channel through the inlet is only marginally self-scouring. Also, at least 30 million cubic meters of sediment are available in the ebb shoal. Assuming net westward longshore transport rate of 300,000 m^3/year, the inlet ebb shoal contains approximately a 100-year supply of sediment.

Circulation Modeling

A regional circulation model established for Long Island (Militello et al. 2000) was run to examine the circulation for the existing condition. Although the model had been calibrated for Shinnecock Inlet, for the present work no calibration or grid refinement was done for Fire Island Inlet and Great South Bay. However, calculated values of water level compared well with recent measurements in Great South Bay and Fire Island Inlet. Figs. 5 and 6 show contours of current speed (shading) and direction of the current (arrows) at peak ebb and peak ebb and peak flood tide for the existing inlet and hypothetical relocated inlet, respectively. The existing inlet was closed for the simulation with the hypothetical relocated inlet.

For the existing inlet (Fig. 5), the calculated ebb current is strong along Oak Beach and near the seaward end of the dike, which is known to experience erosion at its tip. There is also a strong ebb current along the NW side (backside) of Democratic Point, an area that has required revetting to stop erosion. The flood current, and to a lesser extent, the ebb current is relatively strong between Sexton Island and Captree Island. The ebb and flood current seaward of the entrance of the existing inlet spreads widely and weakens because of the wide opening of the inlet. Therefore, the transport capacity of the current is greatly reduced at the entrance, only being strong at the narrowest constriction between the dike and backside of Democrat Point.

The calculated ebb and flood currents for the hypothetical relocated inlet are much more constricted due to the presence of the jetties than for the existing inlet. The ebb shoal that would form at the relocated inlet would be farther offshore than the finger shoals (Fig. 3) that comprise much of the ebb shoal of the existing inlet. The flood and ebb currents in the vicinity of Sexton Island and Fire Islands are much weaker than for the existing condition, so once the island configurations adjust to the new inlet currents, there would be less potential for sediment to be removed from them as compared to the existing condition. Based on the horizontal flow pattern in Fig. 6B, a flood shoal would be created southeast of Sexton Island. The tidal current in the former inlet and along Oak Beach would be greatly reduced.

REGIONAL SEDIMENT MANAGEMENT CONSIDERATIONS

This section collects and organizes information and concepts, as well as introduces new considerations, for evaluation of the hypothetical relocation of Fire Island Inlet from a regional sediment management perspective. Not all issues can be introduced in this short paper, and those discussed are prominent or obvious ones that serve the purpose of illustrating a "system-wide approach" to sediment management as discussed in the Introduction.

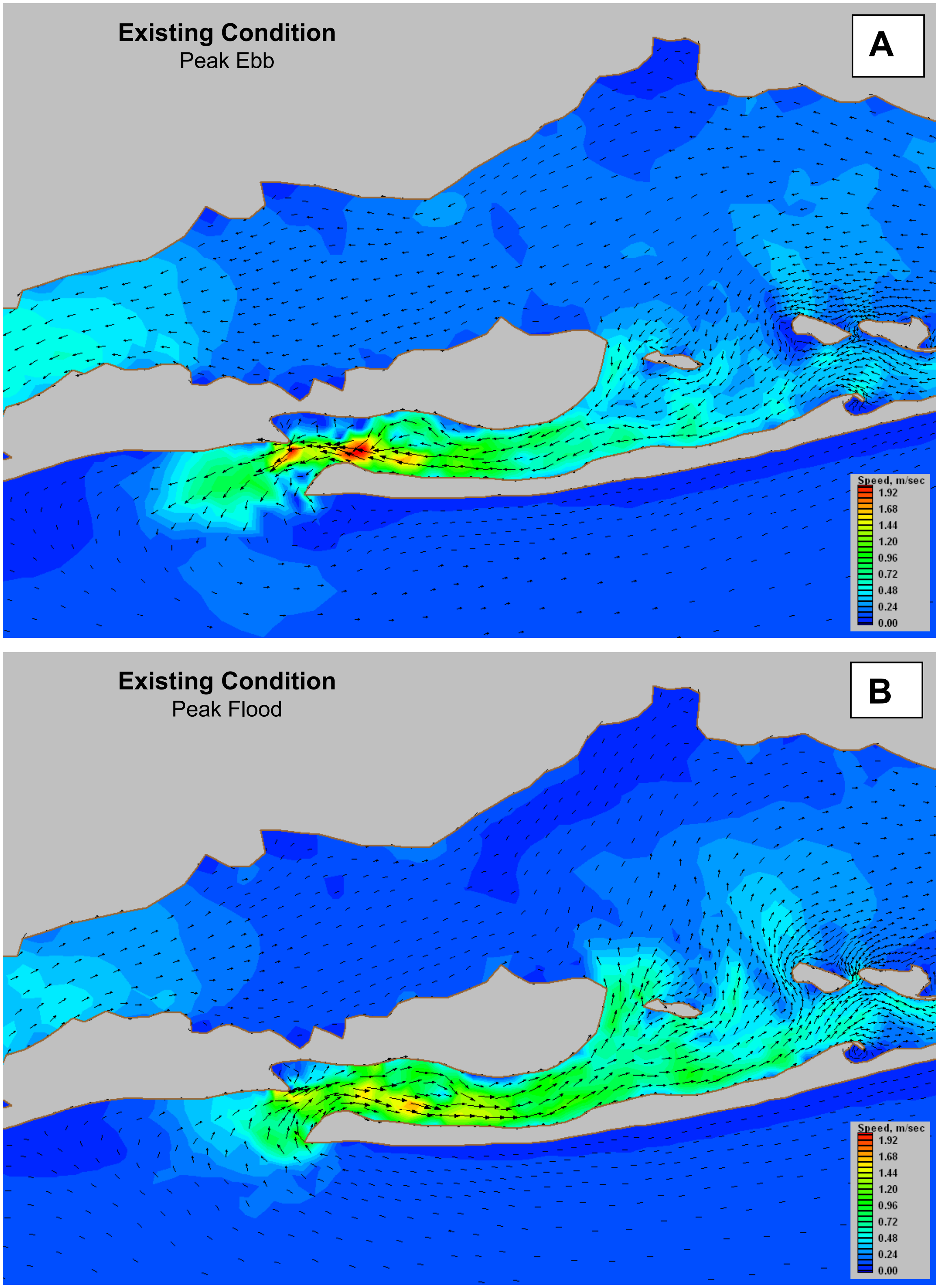

Fig. 5. Existing Fire Island Inlet: calculated (A) peak ebb current, and (B) peak flood current at the entrance

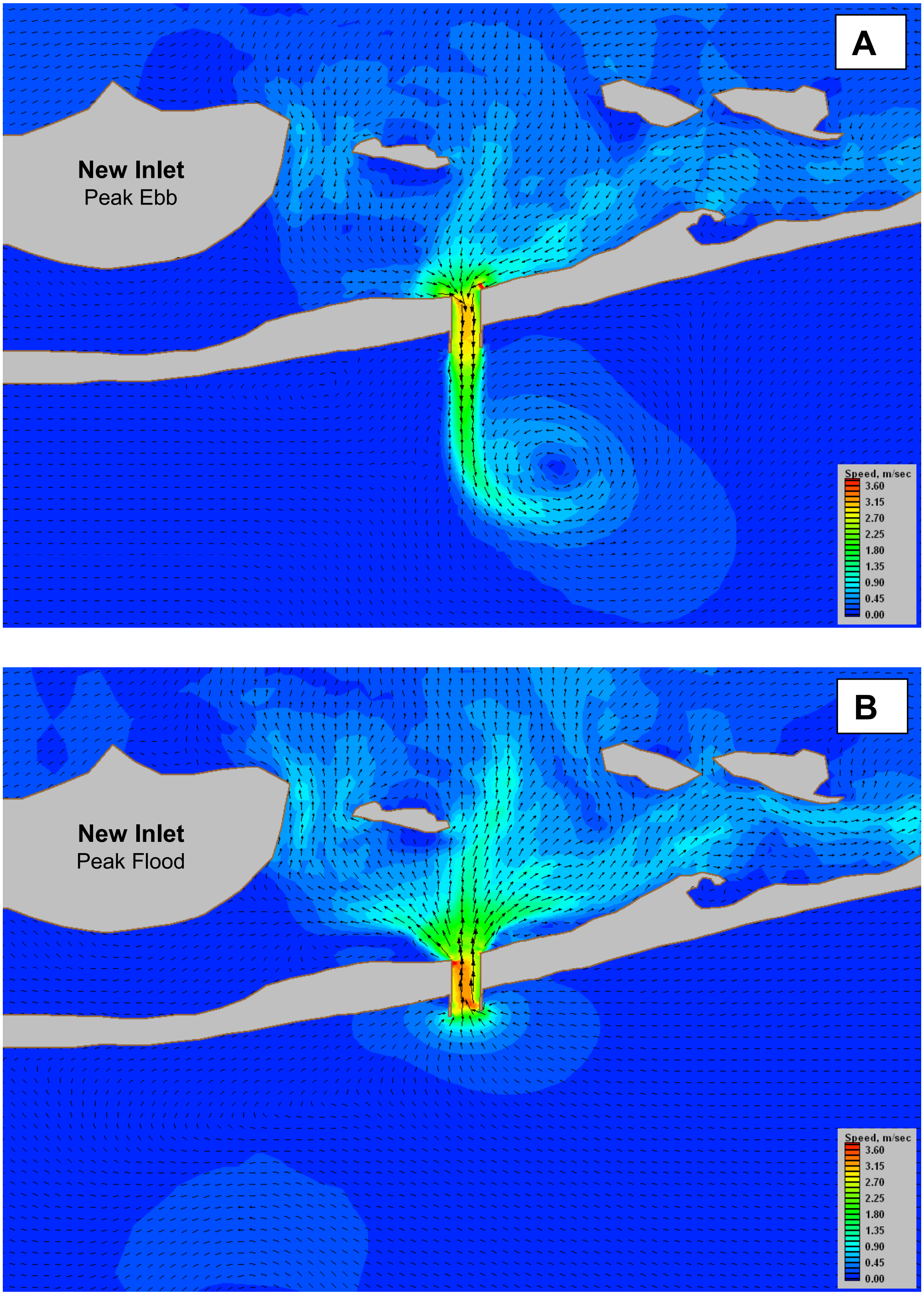

Fig. 6. Hypothetical relocated Fire Island Inlet: calculated (A) peak ebb current, and (B) peak flood current at the entrance

Existing Condition and Other "Local" Project Alternatives

The existing condition presently involves about $5 million a year in dredging on average, bypassing to the chronically eroding Gilgo Beach, the threat of erosion along Oak Beach, occasional back passing of sand to Fire Island Beaches to the east and, a nearly unstable inlet and navigation channel. Based on an informal estimate of $100 million dollars to relocate the inlet, including construction of the dual jetties, and reduced cost of maintenance and bypassing at the new entrance of $250,000 annually (same order of magnitude as for other south shore inlets), cost savings for the relocated inlet would begin to accrue sometime after 20 years, given the increased cost of future dollars and that bypassing would likely not be necessary at the relocated inlet for a number of years. The need for back passing would be minimal because of the impoundment functioning of the new east jetty. Therefore, an order-of-magnitude cost estimate indicates the hypothetical relocation alternative is cost effective and justified. Societal, environmental, and other physical process issues remain, some of which are discussed below.

"Local" or project-specific alternatives for reducing costs and providing a more reliable channel have been identified by MNE (2000), compiled based upon deliberations by a technical committee with members drawn from state and federal agencies as well as a local university. Among project-specific alternatives are those that (1) extend the existing jetty, (2) reconfigure the training dike, and (3) optimize (if possible) the channel and deposition basin configurations. The project-specific alternatives do not addresses regional sediment considerations and have limitations in being short-term and in bringing relatively small incremental improvement. It is noted that the MNE (2000) compilation includes inlet relocation as discussed here, but gives it a low rating due primarily to judged high risk of creating a new inlet.

Selected Regional Sediment Issues Associated with Inlet Relocation

In this section, selected regional sediment management issues are identified, and the possible performance of two alternatives are examined and compared. The two alternatives are (1) maintaining the existing condition (or implementing some small modification of the existing condition), and (2) relocating the inlet and constructing dual jetties as described above. The selected issues and comparison are summarized in Table 1.

Navigation Reliability. Navigation reliability (safe navigation for greatest possible sea state for the given design vessel) is expected to be better for the relocated inlet. Vessels can exit heading into the incident waves, and they will be protected by the jetties while crossing the surf zone under mild to moderate (navigable) wave conditions.

Cost of Channel Maintenance Dredging. The relocated inlet is expected to have maintenance requirements similar to the other five federally maintained channels on the south shore of Long Island, meaning 1/5 to 1/10 the dredging cost of the existing inlet. Less channel sediment shoaling during storms is expected, meaning less potential for costly emergency dredging.

Sediment Sharing with Adjacent Beaches (Bypassing and Backpassing). Collapse of the ebb shoal at the existing inlet will provide sand to the downdrift (western beaches), including Gilgo Beach, for 50-100 years after inlet relocation. The beaches will widen and increase in volume, reducing or completely eliminating the erosion threat to infrastructure. Bypassed material associated with maintenance dredging of the relocated inlet will enter the littoral stream to reach the downdrift beaches. Consideration would need to be given for gradual removal of the old jetty to allow Democrat Point to realign with beaches to the west, eliminating a sharp, cape-like turn west of the inlet. Backpassing to the east of the relocated inlet will likely not be necessary because of impoundment at the east jetty and gradual increase in width of the eastern beaches.

Table 1. Regional Sediment Management Issue and possible performance of alternative.		
Sediment Management Issue	**Existing Inlet performance**	**Relocated Inlet performance**
1. Navigation channel reliability	Relatively difficult and costly as compared to other LI inlets	Expected to perform similarly as other LI inlets, and at much reduced cost as compared to present
2. Erosion at Gilgo Beach and westward beaches, with road endangered during storm	Erosion threat at Gilgo Beach and western beaches continues, butis reduced by periodic bypassing of dredged sand	Eliminates erosion at Gilgo Beach and westward beaches for ~ 50-100 years through collapse of existing ebb shoal and building of wide beaches
3. Sand bypassing accompanying dredging	Continue existing practice	Likely not necessary for many years west of inlet; east of inlet, between old jetty and new west jetty, monitor and bypass as necessary. Probably best not to allow new inlet east jetty fully impound – bypass from the impoundment fillet.
4. Erosion, strong current, and possible wave action along Oak Island Beach	Erosion threat continues	Erosion, strong current, and direct wave impact eliminated
5. Erosion on beaches to east of Fire Island Inlet	Erosion threat continues, reduced by occasional sand backpassing	Impoundment at east jetty will create wider beaches to east
6. Maintenance of sand dike	Dependent on state and local decisions	No longer necessary
7. Erosion on back (northwest) side of Democrat Point	Monitor existing revetment	Bayside erosion possible at ends of new jetties; protective measures need to be incorporated in design
8. Storm surge in Great South Bay	No change	Will likely not be greater than existing condition for slow-moving northeasters, but surge may rise more rapidly for fast-moving tropical storms. Needs to be calculated for quantification. The relocated inlet would release bay waters to the ocean more rapidly than existing inlet
9. Increased tidal range in Great South Bay	No change	Will increase tidal range; preliminary calculations show the lows to become lower, not the highs to become notably higher, but more accurate calculations are necessary. The relocated inlet would improve circulation in Great South Bay
10. Formation of flood shoal	No change of tendency for flood shoal growth off Oak Beach	New flood shoal would form, covering existing bay bottom.

Development of Ebb and Flood Shoals at Relocated Inlet

The volume of the flood shoal that will form at the relocated inlet can be estimated by an empirical predictive formula found by Carr de Betts (1999) in terms of the tidal prism, giving 4.6 x 10^6 m3, about 25% larger than the flood shoal at Shinnecock Inlet. The Reservoir Model (Kraus 2000) allows estimation of the time history of re-establishment of natural bypassing and growth of ebb- and flood-tidal shoals. Based on an equilibrium ebb shoal volume of 15 x 10^6 m^3, downdrift bypassing bar equilibrium volume of another 15 x 10^6 m^3, and flood shoal equilibrium volume of 4.6 x 10^6 m^3, 50% and 90% inlet natural bypassing would occur in 60 and 200 years, respectively, for a gross input longshore sand transport rate of 300,000 m^3/year, which assumes that little sand comes from the west. Mechanical bypassing during channel dredging would augment natural bypassing. The maintenance-dredging requirement is expected to be similar to that of the other south shore inlets, yielding the savings justification to construct the jetties in a long-term regional sediment management plan.

Storm Surge, Water Level, and Circulation. The much smaller hydraulic length of the relocated inlet (~ 1 km) as compared to the existing inlet (~ 6.5 km) will improve water exchange between the ocean and Great South Bay. Preliminary calculations show an increase in tide range of 5 to 6 cm. The increased efficiency will improve circulation in the vicinity of the relocated inlet. Slow-moving storms will fill the bay about equally for the existing and relocated inlet, but fast-moving storms will fill the bay faster for the relocated inlet. On the other hand, bay filling by heavy precipitation will be more rapidly discharged to the ocean through the relocated inlet. Such processes can be reliably calculated with tidal circulation and wave propagation numerical models as part of a feasibility study. Great South Bay involves a multiple inlet system, and examination of a major inlet modification should include all the inlets.

CONCLUDING DISCUSSION

This paper has explored regional sediment management considerations through a thought-experiment case study of hypothetical eastward relocation of Fire Island Inlet, Long Island, New York. Emphasis was on the physical processes and sediment redistribution and handling. Simple calculation of the cost of relocation indicates the new inlet would begin yielding cost savings in about 20 years while providing greatly improved shore protection to adjacent (downdrift, updrift, back bay) beaches for on the order of a century or more.

Some negative consequences, both certain and probable, were identified. The new flood shoal at the relocated inlet would cover existing bay bottom and remove sand from the littoral system. Slightly increased tidal range may be a concern for wetland health under normal weather conditions, but most likely would be offset by improved circulation in the bay. Bay filling during fast moving tropical storms is a real concern that must and can be evaluated.

Environmental, socio-economic, and political issues were not considered. Numerous stake-holders and interested parties would have to come together at the regional sediment management table to identify issues that need addressing to assure that a system-wide approach anticipated all direct and indirect consequences of inlet relocation. The authors believe that the knowledge and technology exist to make reliable decisions and arrive at a properly performing design.

ACKNOWLEDGEMENTS

We appreciate the assistance of Dr. Andrew Morang for locating and digitizing the Beach Erosion Board photographs and of Ms. Lynn Bocamazo for locating photographs at the U.S. Army Corps of Engineers, New York District. This paper, developed as an activity of the Coastal Morphology Modeling Work Unit of the Regional Sediment Management Research Program, benefited from review by Ms. Julie Dean Rosati. Permission was granted by Headquarters, U.S. Army Corps of Engineers, to publish this information. This paper concerned a hypothetical alternative studied to examine concepts in regional sediment management; results and conclusions should not be construed as a position on any action by the U.S. Army Corps of Engineers for maintenance and operation of the federal navigation project at Fire Island Inlet.

REFERENCES

Carr de Betts, E.E. 1999. An examination of flood deltas at Florida's tidal inlets. MS thesis, University of Florida, Gainesville, Florida, 125 pp.

Gofseyeff, S. 1952. Case history of Fire Island Inlet, N.Y. *Proc. Third Conf. Coastal Eng.*, Council on Wave Research, 272-305.

Hoeke, R.K., Zarillo, G.A., and Synder, M. 2001. A GIS based tool for extracting shoreline positions from aerial imagery (*BeachTools*). Coastal and Hydraulics Engineering Technical Note CHETN-IV-37, U.S. Army Engineer Research and Development Center, Vicksburg, MS. *http://chl.wes.army.mil/library/publications/chetn/*

Jarrett, T. 1976. Tidal prism – inlet area relationships. GITI Rep. 3, U.S. Army Eng. Waterways Expt. Station, Vicksburg, MS.

Kraus, N.C. 2000. Reservoir model of ebb-tidal shoal evolution and sand bypassing. *J. Waterway, Port, Coastal, and Ocean Eng.*, 126(6), 305-313.

Kumar, N., and Saunders, J.E. 1974. Inlet sequence: a vertical succession of sedimentary structures and textures created by the lateral migration of tidal inlets. *Sedimentology*, 21, 491-532.

Larson, M., and Kraus, N.C. 2003. Modeling regional sediment transport and coastal evolution along the Delmarva Peninsula, USA. *Proc. Coastal Sediments 03*, World Sci. Press, in press.

Larson, M., Kraus, N.C. and Hanson, H. 2002. Simulation of regional longshore sediment transport and coastal evolution – the "Cascade" model. *Proc. 28th Coastal Eng. Conf.*, World Sci. Press, in press.

Leatherman, S.P., and Allen, J.R. (editors). 1985. Geomorphic analysis: Fire Island Inlet to Montauk Point Long Island, New York. Final Report, Reformulation Study, for U.S. Army Corps of Engineers, New York District.

Militello, A., Kraus, N.C., and Brown, M.E. 2000. Regional coastal and inlet circulation modeling with application to Long Island, New York. *Proc. 13th Annual National Conf. on Beach Preservation Technology*, FSBPA, Tallahassee, FL, 191-201.

Moffatt & Nichol Engineers (MNE). 2002. Fire Island to Montauk Point Reformulations Study, Inlet Modifications. Draft Interim Report submitted to the U.S. Army Engineer District, New York, December 2002.

Morang, A., Rahoy, D.S., and Grosskopf, W.G. 1999. Regional geologic characteristics along the south shore of Long Island, New York. *Proc. Coastal Sediments '99*, ASCE, 1,568-1,583.

Panuzio, F.L. 1968. The Atlantic coast of Long Island. *Proc. 11th Coastal Eng. Conf.*, ASCE, 1,222-1,241.

Saville, T. 1960. Sand transfer, beach control, and inlet improvements, Fire Island Inlet to Jones Beach. *Proc. 7th Coastal Eng. Conf.*, ASCE, 785-807.

Schwaab, W.C., et al. 1999. Geologic mapping of the nearshore area offshore Fire Island, New York. *Proc. Coastal Sediments '99*, ASCE, 1,552-1,567.

Smith, W.G., et al. 1999. Historic geomorphology and dynamics of Fire Island, Moriches and Shinnecock Inlets, New York. *Proc. Coastal Sediments '99*, 1,597-1,612.

Walton, T.L., Jr., and Adams, W.D. 1976. Capacity of inlet outer bars to store sand. *Proc. 15th Coastal Eng. Conf.*, ASCE, 1,919-1,937.