# CHAPTER TWO HUNDRED ONE

### SEDIMENTATION PATTERNS IN A TIDAL INLET SYSTEM MORICHES INLET, NEW YORK

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# ABSTRACT

A detailed study of the historical development of Moriches Inlet, Long Island (New York), was completed to determine the morphodynamic interaction of tidally influenced processes and the effects of man-made alterations on the inlet channel and affiliated flood and ebbtidal deltas. The south shore of Long Island in the vicinity of Moriches Inlet is a microtidal, wave-dominated (mixed-energy) environment. Characteristic of this setting, the inlet bisects a low-lying barrier island backed by an open bay and has a prominent flood-tidal delta.

In this study, bathymetric charts of the inlet, bay, and barrier nearshore zones were contoured for analysis. Using a polar planimeter, the areas between isobaths from mean high water to the bottom surface were measured. This information was used to determine the volumetric distribution of sediment and water in the system. In addition, harmonic analysis was applied on digitized bay-tide records to ascertain the relationships of the semidiurnal overtide constituents. From the results, mean rise/fall duration differences, related to the conservation of mass, were calculated.

The results of the quantitative spatial analysis indicate that Moriches Inlet was flood-dominant from breach in 1931 until closure in 1951. After reopening in 1953, the inlet became ebb-dominant as a result of inlet stabilization and extensive dredge-and-spoil operations in the inlet and bay. Good correlations exist between net sedimentation in the inlet with (1) bay-surface area change, (2) water storage capabilities of the flood-tidal delta, and (3) the cross-sectional area of the inlet. The relationship among these variables suggests that there is a system-wide response to the change in the hydrodynamics caused by man-made alterations, resulting in ebb dominance.

# INTRODUCTION

Research in coastal processes and geomorphology has recognized the relationship between the scope and distribution of morphologic features and the hydrodynamic regime of the environment. The interaction of the morphology with tidal and wave energy, or the morphodynamics of a system, involves continual change toward an equilibrium condition. Through detailed examination of an environment, process/ response models have been developed to help understand this interaction.

This study focuses on the morphodynamics controlling the tidally influenced sedimentation patterns in a tidal inlet/bay system at Moriches Inlet, Long Island (New York). Through modifications of the inlet and bay configurations, the hydrodynamic adjustment resulted in a reversal in tidal dominance. In order to quantify this reversal and to identify the controlling factors of tidal dominance in the system, an historical analysis of the evolution of the inlet and associated depositional bodies was completed. Detailed bathymetric charts of the entire inlet system that document the morphological changes, supplemented with bay-tidal records, comprise the data base for this study.

### INLET DYNAMICS

The dynamics of flow in an inlet/bay system can be described by two governing principles: (1) the equation of motion (or conservation of momentum) and (2) the continuity equation (or conservation of mass). Assuming that the velocity in the inlet is constant (i.e., local acceleration is neglected) and that the tidal wave is much longer than the inlet length, the one-dimensional equation of motion can be integrated to yield:

$$g(h_{o} - h_{b}) = L \frac{du}{dt} + \frac{1}{2}(1 + \frac{2r}{h}L)ulul$$
 (1)

where g is the acceleration of gravity, h is the ocean water-surface elevation, h is the bay water-surface elevation, L is the entrance length, u is the average inlet velocity, h is the water depth in the inlet, and r is the square law friction coefficient defined as:

 $r = \sigma/\gamma u^2$ 

where  $\sigma$  is the bottom shear stress and  $\gamma$  is the density of water. This equation represents the difference in bay and ocean water levels as proportional to the flow velocity squared, through a channel of a given geometry based on its length, depth, and the effects of inertia.

The equation of continuity can be stated as:

$$UA_{A} + Q = A_{b} [dh_{b}/dt]$$
(2)

where A is the cross-sectional area of the inlet, A is the bay surface area, and Q is discharge from river flow or sources other than the inlet. This equation relates the velocity to (1) the rate of change of the bay water level and (2) the ratio of the bay surface area over the inlet cross-sectional area. As A and A vary over a tidal cycle, the peak ebb and flood velocities. as well as their duration will differ.

### STUDY AREA

Moriches Inlet is located on Fire Island, off the south shore of Long Island, New York (Fig. 1). One of five inlets on the south shore, Moriches Inlet connects Moriches Bay and the Atlantic Ocean. The inlet is 80 miles (mi), by water, east of The Battery (New York





FIGURE 1. Location map of Long Island, New York, and Moriches Inlet on the south shore.

Citv) and is 52 mi west of Montauk Point. The inlet separates Great South Beach (Fire Island) on the west and Cupsogue Spit, or Pike's Beach (eastern end of Westhampton Beach), on the east.

Moriches Bay is 12.8 mi long, including the adjacent Narrow Bay. The width of the bay varies from 0.75 mi to 2.5 mi, whereas Narrow Bay, which connects Moriches Bay to Great South Bay to the west, has widths of 1,000 to 4,000 feet (ft). The total water surface area of the combined bay is approximately 20 square miles (mi<sup>2</sup>). Moriches Bay also connects with Shinnecock Bay to the east through Quantuck and Quogue Canals. The largest streams which drain into Moriches Bay are the Forge River and Seatuck Creek; a total of 60 mi<sup>2</sup> of land area drain into the bay.

The astronomic tides at Moriches Inlet are semidiurnal with a mean range of 2.9 ft. The mean spring and neap tidal ranges are 3.5 ft and 2.1 ft, respectively. Visual observations of the nearshore wave climate were compiled by the Coastal Engineering Research Center from June 1970 to May 1973. The average breaker height, based on these observations, was 2.25 ft, and the average breaker period was 7.9 seconds.

# GEOMORPHIC/HYDRAULIC HISTORY

The geomorphic and hydraulic history of Moriches Inlet and Bay from 1931 to 1967 can be described by two phases: (1) an initial post-breach period during which the inlet system was relatively natural and eventually shoaled closed, and (2) a period beginning after the inlet was stabilized and artificially reopened--characterized by human manipulation of the inlet and bay. The apparent contrast in sedimentation patterns between these two periods provided the basis for this study on tidal inlet dominance.

#### 1931-1951

The modern Moriches Inlet was breached on 4 March 1931 by a severe extratropical storm. A July 1931 survey shows an initial configuration of the inlet 800 ft wide and 1,500 ft long with channel depths up to 18 ft. A prominent flood-tidal delta with an intertidal perimeter existed landward of the inlet. A line of breakers indicated on the sheet suggest that an ebb-tidal delta had formed also. The bay tidal range was measured at 0.4 ft.

From the breach in 1931 to 1940, the inlet migrated westward a distance of 3,500 ft from its original breach position. During this time, the inlet/bay system was a sediment trap, as net sedimentation continued on both the ebb- and flood-tidal deltas. The morphology and the hydraulics of the inlet adjusted to the tidal flow demonstrated by a small increase in the bay tidal range as well as an increase in the inlet length and width. These processes were probably enhanced by the impact of storms in 1934, 1938, and 1940.

In 1947, a jetty was constructed on the west side of the inlet in an attempt to stop its westward migration. The construction was

performed in conjunction with channel dredging to the west of the inlet. The combined effects of this artificial manipulation of the inlet caused increased shoaling. The updrift barrier, Cupsogue Spit, laterally accreted westward and narrowed the inlet throat and length. A highly detailed survey taken in 1949 reveals a developed ebb-tidal delta and a large flood-tidal delta, mostly supratidal. By July 1951, the inlet closed naturally.

Hydrographic measurements taken by current-float observations during the 1949 survey show that peak ebb and flood velocities were nearly equal at 5.2 and 5.3 ft/sec, respectively. The bay high tide followed peak flood flow by 24 minutes, while peak ebb flow trailed low water by 1.5 minutes. The close phase relationship of the vertical tidal curve and current velocities denotes a progressive tidal wave condition at the inlet.

# 1952-1967

In 1952, jetty construction was initiated to reopen and stabilize Moriches Inlet in response to local interests. An eastern jetty was built approximately 800 ft from the western jetty. In 1953, when construction was completed across the barrier island, dredging began to reestablish the inlet. On 6 November 1953, before channel completion, an extratropical storm impacted the area and breached the new opening.

For the remainder of the study period, the geomorphic and hydraulic history of the inlet was dominated by dredge/spoil operations (Table 1). During this time, 2 million  $yd^3$  of sediment were dredged from the inlet and bay, with much of the spoils placed on the flood-tidal delta. As a result of the excavation projects and natural scouring, the hydraulic radius of the inlet increased, accompanied by an increase in the bay tidal range from 0.6 ft in 1955 to 1.5 ft in 1967.

The changes in the inlet delta morphology and tidal current regime indicate that the sedimentation patterns changed. A marked decrease in size of the flood-tidal delta simultaneous with an increase in size of the ebb-tidal delta suggest bay flushing had begun. Current velocity measurements taken in 1955-56 and in 1967 confirm that the inlet was hydraulically ebb-dominant. In November 1955 through May 1956, inlet velocities were measures at 5.2 ft/sec during flood and 6.5 ft/sec during ebb. In 1967, current velocity measurements taken midchannel at an intermediate depth gave peak flood velocities at 2.4 ft/sec while peak ebb velocities were recorded at 4.3 ft/sec.

#### METHODOLOGY

The primary data base for analysis is a time-series of bathymetric surveys of Moriches Inlet and Bay, including coverage of the inlet, adjacent barrier islands, ebb-tidal delta, flood-tidal delta, and the surrounding bay. A spatial analysis was undertaken on each chart in an attempt to distinguish the morphological components of the system and their changes through time. The objective is that this type of analysis should yield time-averaged results of net sediment transport within the surveyed areas.

TABLE 1. Moriches Inlet improvement projects based on published and unpublished records of the New York District (U.S. Army Corps of Engineers) and Suffolk County Department of Public Works.

Date	Project	Agency
1933	Dredge: 600 ft x 35 ft x 6 ft channel = $4.600$ vd <sup>3</sup>	Local Interests
1935	Dredge: 3,360 yd <sup>3</sup>	Suffolk County
1947	Construction: West jetty	,
	Dredge: Northwest Channel	Suffolk County
1952	Construction: Jetties spaced 800 ft East jetty (846 ft long) West jetty (1.461 ft long)	New York State
1953	Dredge: 747,310 inlet cut	Suffolk County
1954	Construction: Jetties extended Spoil: Close Northwest Channel	Suffolk County New York State
1958	Dredge: 365,715 yd <sup>3</sup> - Northwest Channel (200 ft x 10 ft channel)	Suffolk County
1962	Dredge: 1,014,834 yd <sup>3</sup> - dredge inlet Spoil: Close Northwest Channel	Suffolk County
1966	Dredge: 677,850 yd <sup>3</sup> - Northwest Channel (1,300 ft wide x 12 ft deep)	Suffolk County

In addition to documenting the changes of the inlet/bay system, critical parameters were examined in order to develop a process/response relationship for ebb-tidal dominance. One of the more significant factors influencing tidal dominance is the change in bay surface area over a tidal period (Oliviera, 1970; King, 1974; Seelig and Sorensen, 1978; FitzGerald and Nummedal, 1983). None of the surveys available to this study, however, covered the entire bay. As a result, the soundings were confined to the flood-tidal delta in the immediate inlet vicinity.

The selection of surveys with adequate coverage of the features aforementioned produced five working maps--a composite of 1932 and 1933 surveys, 1940, 1949, 1955, and 1967. A control grid of the study area was also constructed. The size of the grid was dictated by the survey of minimum areal coverage (Fig. 2). The establishment and utilization of this grid allow quantitative comparisons of the inlet/bay system to be made.

A survey of Moriches Bay and Fire Island from 1891, when no inlet existed, provided a baseline for comparison of the development of the flood-tidal delta. At that time, maximum depths in the bay were 8 ft. However, no available bathymetry of the nearshore zone exists which could serve as a baseline for ebb-delta growth. Soundings were



FIGURE 2. Control grid dimensions and compartment locations. MSL shoreline shown based on USACE 1955 survey.

taken, though, in 1951 when the inlet had naturally closed. Using the technique developed by Dean and Walton (1975), a hypothetical shoreline was created based on these soundings in which contour lines parallel the coast. The idealized bathymetry was then used in conjunction with the 1891 bay for analysis. For reference, the control grid was superimposed on the site of the stabilized inlet.

For the purposes of this study, the Moriches Inlet and Bay system was divided into three compartments within the control grid:

- 1) The bay, which represents the area landward of the bay shoreline.
- 2) The inlet proper.
- The ocean or nearshore zone--that area oceanward of the inlet including subtidal segments of the barrier islands.

These subdivisions allow independent analysis of the inlet and the ebband flood-tidal deltas (Fig. 2).

The areal distribution of the geomorphic features on the individual charts was measured using a digital compensating polar planimeter. Areas enclosed between isobaths within the control grid were obtained to the nearest 1,000 ft<sup>2</sup>. The area measured for each interval supplied the data for volumetric analysis.

The areas measured at each isobath by planimetry were multiplied by the contour interval to produce a volumetric "slice" of water. The sum of all slices is a close measure of the total amount of water in that compartment. In this way, the amount of sediment deposited in the ebb and flood deltas of each survey can be directly compared.

# HARMONIC ANALYSIS

In the absence of complete velocity measurements, vertical tide records taken at the U.S. Coast Guard Station in Moriches Bay were obtained. Four 29-day continuous records were selected which roughly corresponded with the bathymetric surveys or significant events from 1944, 1955, 1966, and 1967. Based on the equation of continuity (2) and following the work of Boon and Byrne (1981), the tidal signatures of the bay can be related to the dynamics of the tidal flow through the system.

Harmonic analysis used on filtered, digitized bay-tidal curves supplied the amplitude and phase relationships of the principal tidal constituents. In a semidiurnal system, the constituents which can sufficiently represent the bay tidal curves are the  $M_2$  [the principal lunar semidiurnal constituent with a period of 12.42 hours (hr)],  $M_4$  (6.21-hr period), and  $M_6$  (4.14-hr period) harmonics (Shureman, 1958). These overtides have speeds (frequencies) which are exact multiples of the elementary constituent. Therefore, the combination of the overtides can represent the distortion of the mean bay tidal curve, and rise/fall durations can be observed.

### RESULTS

# VOLUMETRIC RESULTS

The results of the volume calculations are presented in Table 2. These are calculations of the water volume for each compartment referenced to MSL. This datum plane is considered constant through the study period.

TABLE 2. Compartment and total water volumes. Reference datum is mean sea level. Unit of measure is  $x \ 10^3 \ ft^3$ .

volume	Volume	Volume	Volume
0	146,168	198,106	344,274
4,782	127,900	186,334	319,016
22,784	27,546	131,116	181,446
1,710	56,136	202,462	260,308
14,590	61,964	195,466	272,020
17,134	128,568	124,640	270,342
	0 4,782 22,784 1,710 14,590 17,134	Volume      Volume        0      146,168        4,782      127,900        22,784      27,546        1,710      56,136        14,590      61,964        17,134      128,568	Volume      Volume      Volume        0      146,168      198,106        4,782      127,900      186,334        22,784      27,546      131,116        1,710      56,136      202,462        14,590      61,964      195,466        17,134      128,568      124,640

The raw volumes are not adjusted for any dredge and spoil quantities listed in Table 1. While these quantities alter the results to some degree, the exact location of the dredging projects and the distribution of spoils are not known. Therefore, it is difficult to calculate the amount of sediment which has truly been removed from the control area.

The water volumes for the bay and ocean compartment both show an increase in sedimentation from the time of the breach until 1949, or approximately the time of the inlet closure. The 1940 survey results show that period as the 'richest' in sediment. From 1955 to 1967 (or extrapolating back to the reopening in 1953), the bay and ocean compartments show a complementary trend. As the bay compartment exported sediment as indicated by the increase in water volume, the sedimentation in the ocean compartment increased. These results are clear evidence that Moriches Inlet became ebb-dominated after reopening.

The totals shown in Table 2 also signify that the inlet system was stable after jetty construction, measured by the total sediment flux. The total water volume varied by only  $10 \times 10^6$  ft<sup>3</sup> from 1949 to 1967. As expected, sediment volume was lowest in the pre-breach and 1932-1933 composites due to the relative immaturity of the inlet/bay system.

### INLET MEASUREMENTS

Inlet dimensions, parameters in the governing equations of the dynamics of tidal flow (Equations 1 and 2), were measured from the base maps. With a known inlet volume previously identified, the mean cross-sectional area can be calculated using the inlet length. Table 3 lists inlet lengths, widths, and cross-sectional areas at MSL.

Date	Inlet Length (ft)	Width (ft)	Mean Cross-sectional Area (ft²) (MSL datum)
1932-1933	520	1,420	9,196
1940	3,108	2,442	7,331
1949	652	337	2,623
1955	2,100	800	6,948
1967	1,384	800	12,380

TABLE 3. Moriches Inlet dimensions.

Moriches Inlet reached its greatest cross-sectional area of 12,380 ft<sup>2</sup> in 1967 from scouring and dredging. In the 1932-1933 composite, the inlet had a large hydraulic radius, producing a relatively high mean cross-sectional area of 9,196 ft<sup>2</sup>. The inlet was most constricted in 1949 with a mean area of 2,623 ft<sup>2</sup>. After construction of the jetties (1952), inlet size increased again to 6,948 ft<sup>2</sup> by 1955.

# INTERTIDAL AREA

The change in bay area over a tidal cycle is an important quantity affecting net sediment transport (Equation 2). According to King (1974), a large area change produces net offshore transport. In Moriches Inlet, the amount of intertidal area change within the control grid is a function of a combination of factors. These factors include the size of the flood-tidal delta, the slopes of the flood-tidal delta margins, and perhaps most significant, the varying tidal range in the bay.

Table 4 lists the intertidal area changes in both the bay and inlet compartments as determined by measurement and hypsometric analysis. The inlet compartment, which was included to account for the water storage of the 1940 survey, had a significant amount of intertidal area within the long waterway. The tabulated totals for each survey show a correlation with the magnitude of the tide range at that time. In 1967, when the bay tidal range was 1.5 ft, the corresponding intertidal area was 9,638  $\times$  10<sup>3</sup> ft<sup>2</sup>, while in 1932-1933 when the tidal range was only 0.4 ft, the intertidal area was also the lowest at 1,132  $\times$  10<sup>3</sup> ft<sup>2</sup>. The data from 1940, 1949, and 1955 (when the tidal range was

nearly constant) show that the smaller-scale variations in intertidal area were the result of the flood-tidal delta morphology.

TABLE 4. Intertidal areas of the bay and inlet compartments. Unit of measure =  $x \ 10^3 \ ft^2$ . (1) MHW to MSL area from measured results. (2) MSL to MLW area from hypsometric function.

Date	Inlet <sup>1</sup>	Inlet <sup>2</sup>	Bay <sup>1</sup>	Bay <sup>2</sup>	Total
1932-1933	34	46	648	404	1,132
1940	440	701	2,055	1,347	4,543
1949	12	14	2,865	1,992	4,883
1955	14	16	3,812	1,986	5,828
1967	0	4	6,260	3,374	9,638

### HARMONIC ANALYSIS

In contrast to the work of Boon and Byrne (1981), the results from the harmonic analysis of the bay tidal records show no mean rise/fall duration differences. Mean sinusoidal curves produced from the amplitudes and phase angles of the  $M_2$ ,  $M_4$ , and  $M_6$  constituents for each digitized record were constructed. In the resultant curve of each tide record, the rise duration equals the fall duration within the resolution of the five-minute increment used in calculation.

The type and degree of distortion in the combined tidal signature are primarily a function of the phase angle relationship among the overtides. The distortion, however, only appears significant when the ratio of the  $M_4$  and  $M_2$  amplitudes are greater than 0.1. Table 5 illustrates that while the phase angles of the overtides do change, the  $M_4/M_2$  amplitude ratios never exceed 0.04. The effect, then, of the  $M_4$  and  $M_6$  overtides on the principal semidiurnal component are so small that any distortion created is minimal.

The hydrographic data from Moriches Inlet show a small phase lag between bay tidal elevations and channel velocities, indicating a progressive tidal wave condition in the inlet/bay system. Under these circumstances, it appears that, without distortion of the bay tidal elevations, there are still ebb- and flood-velocity differences evidenced by the hydrographic measurements as well as changes in the sizes of the ebb- and flood-tidal deltas. Therefore, other morphodynamic factors such as the frictional effects of a change in bay surface area or channel dimensions must be influencing the direction of net sediment transport.

	M <sub>2</sub>	M <sub>4</sub>	M <sub>6</sub>	M <sub>4</sub> /M <sub>2</sub> Ratio
1944 Amplitude Phase	0.1215 215.07	0.0046 269.54	0.0040 203.06	0.03786
1955 Amplitude Phase	0.0896 124.64	0.0014 214.49	0.0015 146.91	0.01563
1966 Amplitude Phase	0.3992 147.99	0.0095 147.92	0.0155 75.14	0.0238
1967 Amplitude Phase	0.4603 61.66	0.0070 12.39	0.0044 254.71	0.01521

TABLE 5. Moriches Bay overtide constituents phase angle (degrees) and amplitude (ft).

# DISCUSSION

The morphodynamics of an estuarine environment are fundamentally dependent upon wave and tidal energy, and sediment input. In Moriches Inlet and Bay, modulations in tidal range and available sediment appear to be closely related to the variation in morphology and tidal dominance. These changes are primarily the result of man-made modifications through stabilization and dredging of the inlet/bay system.

Relating these factors to the study, it has been demonstrated that the tidal energy in Moriches Inlet has changed over the course of this study. No available data covering the entire study period exist, but it is assumed that wave energy has been relatively constant. Longshore transport rates, storm deposition, jetty trapping, and inlet bypassing--all affect the sediment flux to the inlet/bay system which has been further altered by dredge and spoil operations.

To account for changes in sediment input, the measured volumes were normalized by creating percentiles of the sum of total water volume in the control grid and (1) the inlet and bay total and (2) the ocean compartment. In this way, any decrease or increase of sediment that would affect the system as a whole is taken into consideration.

Figure 3 is a graph showing the distribution of water volume in the control grid for each survey. Incorporated in this figure are pertinent dredge volumes which alter the relative percentage. This correction is based on an assumption that dredged sediment within the control grid is removed from the subtidal system. A decrease in the percent of water in a compartment indicates an increase in sedimentation. Comparing the proportions of volume with a semihypothetical pre-inlet condition, the volume of sediment in the bay and inlet compartments increased to 1949. This trend reversed between 1949 and







1967 when the majority of sedimentation took place in the ocean compartment or ebb-tidal delta. Figure 3 can be interpreted by describing the inlet/bay system as flood-dominant from breach to closure in 1951 and as ebb-dominant from the reopening of the inlet in 1953 to 1967.

The net sedimentation in the bay during flood dominance is due to a combination of factors. Modelers (Oliviera, 1970; King, 1974; Seelig and Sorensen, 1978) have shown that net bayward transport is possible when there is negligible change in the bay-surface area over a tidal period. Flood currents carrying a bedload of sand can lose competence upon entering the static, deeper bay from the confined flow of the inlet, analogous to the formation of a river delta. Other possibilities for bay sedimentation processes include storm and washover deposits, or increase in the flood-tidal delta volumes attributable to spoil operations.

In order to determine the extent of tidal influence on net sedimentation patterns, the principal factors relating to tidal dominance were examined in relation to the volumetric distributions of Figure 3. As mentioned, the variation in intertidal area is considered a dominant factor for bay flushing. Figure 4 shows the relationship of the change in area between MHW and MLW within the control grid plotted against the volumetric percentage of the ocean compartment.

Of the five survey dates, there is a favorable correlation in 1949, 1955, and 1967. The lack of association between the variables of the earlier surveys is due possibly to (1) the lower precision of the 1940 survey and, therefore, more significant error and (2) a lack of equilibration of the immature system in 1932-1933. However, both these surveys were taken within two years after the impact of major storms on the area. This suggests that the morphology in 1932-1933 and 1940 was shaped more by the occurrence of storms than by tidal flow.

In Figure 5, the intertidal water volumes in the bay and inlet are presented with the same volumetric distributions. The volume of water was obtained by multiplying the intertidal areas by the tidal range. This calculation emphasizes the change in area due to increased tidal range rather than the size and shape of the ebb-tidal delta. The correlation in this graph implies that the water-storage capacity of the flood-tidal delta or the degree of flow through the intertidal areas is also closely related to tidal dominance and not just to the change in area over a tidal period. The greater flow would have higher frictional distortions which indirectly determine the magnitude and direction of tidal dominance.

The tidal range for a given bay-surface area, or more directly the tidal prism, is related to the cross-sectional area of the inlet, according to the work of O'Brien (1931, 1969) and Jarrett (1976). The cross-sectional area and its variation is also an indication of inlet stability (O'Brien and Dean, 1972) and the degree of inlet channelization. Since net transport is sensitive to inlet depth and channel dimensions (King, 1974), the mean cross-sectional areas from Table 3 were plotted against the volumetric distribution as in Figures 4 and 5. From the graph in Figure 6, the cross-sectional area correlated well with the





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percentage of water volume in the bay and inlet compartments. Both variables decreased to a minimum in 1949 and subsequently increased to 1967.

It is worth noting that the changes in mean cross-sectional area qualitatively correspond with the amount of channelization in the floodtidal delta, as indicated by the hypsometric analysis and bathymetric charts. One can conclude from Figure 6 that as the degree of flow through the inlet increased with the tidal prism, this flow became more confined by the flood-tidal delta complex. The system response was an increase in effective channelization (i.e., more efficient flow) and ebb-dominant, net-sediment transport.

By examining the process/response relationships of the inlet/bay system, one can construct an interpretational history of the evolution of Moriches Inlet and Bay. The natural setting of Fire Island is a typically long, low-lying, microtidal barrier island backed by a broad open bay. Through the impact of storms, the barrier has been breached frequently, creating temporary inlets with deltas forming from the excess available sediment. With minimum tidal flow and perpetual longshore transport of sediment, Moriches Inlet migrated westerly with gradual inlet shoaling. As the inlet laterally migrated, it successfully receded from the flood-tidal delta complex, leaving the easternmost portions inactive. With the migration, the inlet faced a portion of the open bay, which enabled further sedimentation through bay trapping.

This natural process was interrupted initially by the construction of the western downdrift jetty. By preventing continued migration, sediment from longshore transport accelerated the rate of shoaling in the inlet throat, resulting finally in inlet closure.

When Moriches Inlet was reopened, the twin jetties were emplaced at an 800-ft spacing, much narrower than any inlet width that had been maintained naturally. The jetties also prevented the inlet from migrating away from the flood-tidal delta in addition to trapping sand from longshore transport. The effect was to initiate scouring through the inlet and contiguous flood-tidal delta. The system responded with an increase in channelized flow, increase in the tidal range, and the initiation of bay flushing and net oceanward sediment transport.

The subsequent dredging and spoil operations in the inlet and bay enhanced this response by increasing the scale of channelized flow through the inlet and bay, the inlet cross-sectional area, the bay-tidal range, and the change in bay surface area. By 1967, Moriches Inlet had become ebb-dominant as a result of these man-made alterations to the system.

# CONCLUSIONS

An historical spatial analysis of the Moriches Inlet and Bay system revealed that:

- 1) Moriches Inlet experienced a reversal in net sedimentation from flood-dominant during 1931-1951 to ebb-dominant during 1953-1967.
- 2) This reversal was initiated by modifications of the system by dredging and inlet stabilization. The modifications enhanced system-wide variations indicated by changes in:
  - a) Intertidal bay surface area.
  - b) Inlet cross-sectional area.
  - Tidal range. c)
  - c) Tidal range.d) Channelized tidal flow.

These factors control the direction and magnitude of tidal dominance.

3) Harmonic analysis of Moriches Bay tidal records for 29-day periods in 1944, 1955, 1966, and 1967 indicate that no rise/fall duration differences exist in the mean tidal curve to account for dominant tidal flow.

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