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August 1995

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Shoreline and Sediment Volume Changes at the Colorado River Mouth, Texas

by *Guoxiong Liang,*
Scripps Institution of Oceanography

Prepared for Headquarters, U.S. Army Corps of Engineers

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by Guoxiong Liang

Scripps Institution of Oceanography
University of California, San Diego
La Jolla, CA 92093-0222

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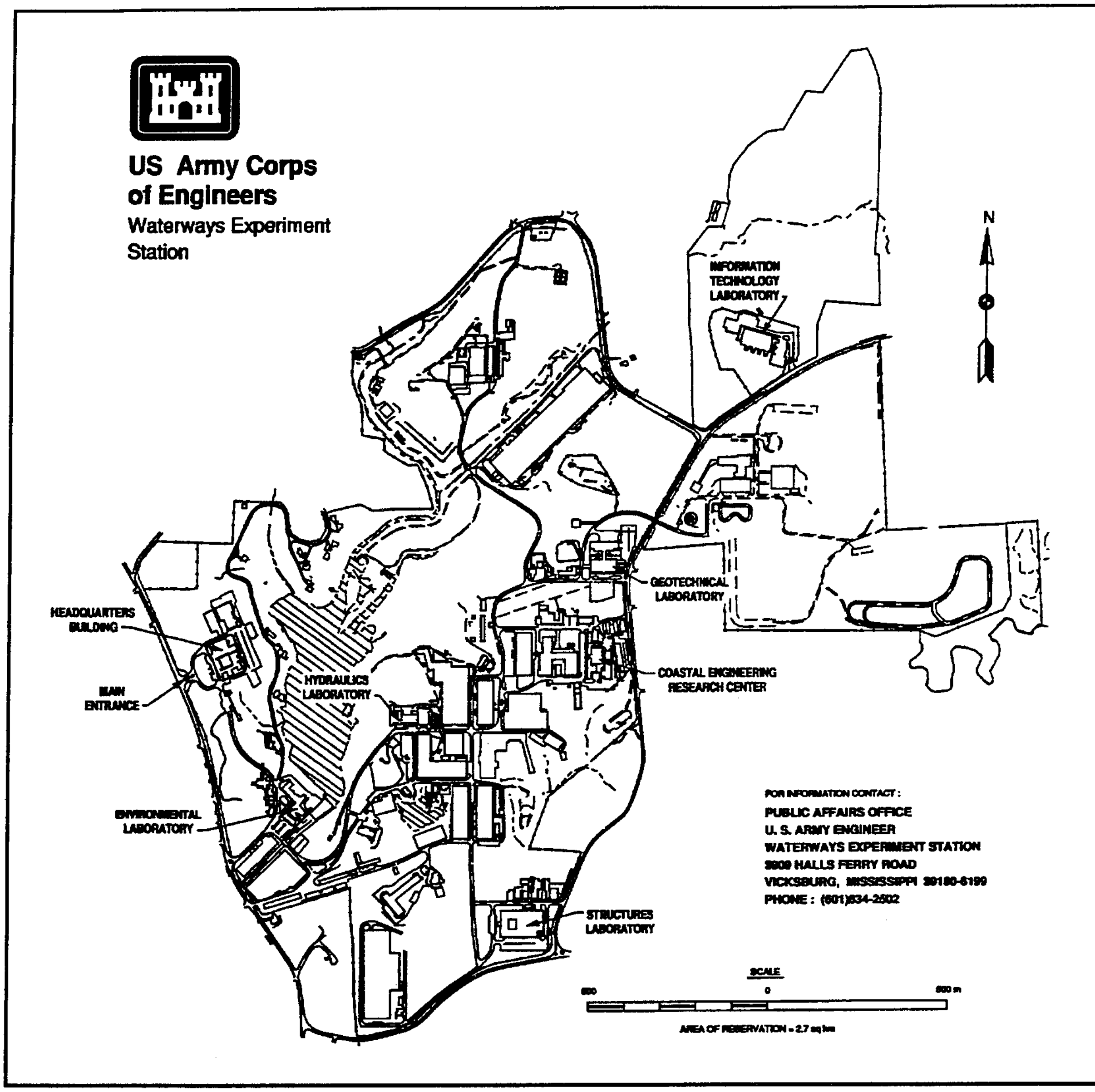

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Preface

This report is a contract final report on the changes in shoreline and sediment transport at the Colorado River mouth, Texas, in partial fulfillment of Contract No. DACW39-90-K-0007 with Waterways Experiment Station's (WES) Coastal Engineering Research Center (CERC).

The data for the report were collected from 1990 to 1992 by CERC's Prototype Measurement and Analysis Branch Personnel with Principal Investigator Dr. Thomas E. White in Work Unit 22113 "Mouth of the Colorado River, Texas" in the Monitoring Completed Coastal projects (MCCP) program at CERC.

This report was prepared by Mr. Guoxiong Liang, Research Assistant, at Scripps Institution of Oceanography (SIO), University of California at San Diego (UCSC), under the direct supervision of Dr. Richard J. Seymour, Research Engineer, SIO, UCSD.

Technical oversight and cooperation were performed by the project Principal Investigator, Dr. Thomas E. White, at CERC.

WES supervisors during this report's preparation were Branch Chief, William L. Preslan; Division Chief, Thomas W. Richardson; Program Manager, Carolyn M. Holmes; Assistant Director of CERC, Charles C. Calhoun, Jr.; Director of CERC, Dr. James R. Houston.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander of WES was COL Bruce K. Howard, EN.

1 Introduction

Background

This report is a part of the final report for the study on the changes in shoreline and sediment transport at the Colorado River mouth, Texas, prepared for the US Army Engineer Waterways Experiment Station's (WES's) Coastal Engineering Research Center (CERC). The data for the report were collected by the Monitoring Completed Coastal Projects (MCCP) program Colorado River work unit.

The purposes of this study are to estimate the efficiency of some coastal projects such as jetties and weir, to test the performance of several longshore sediment transport formulas, and to test surf zone wave-and-current models and shoreline response models.

General Setting of the Study Area

The Colorado river mouth is located at 28°35.5'N latitude and 95°59'W longitude. The Colorado River, cutting across the Matagorda Peninsula, discharges into the Gulf of Mexico (Figure 1).

The Colorado River, Texas, has a length of about 1,550 km and its drainage basin is about 108.2×10^3 km^2. With an annual water discharge of about 2.2×10^9 m^3 (Aronow and Kaczorowski, 1985), the Colorado River contributes about 7.1×10^6 m^3 of suspension load to Matagorda Bay and the Gulf of Mexico (MaGowen and Brewton 1975).

Tides in the northern Gulf of Mexico are chiefly diurnal, with an average range of 0.6 m and a maximum of 0.9 m (Aronow and Kaczorowski 1985).

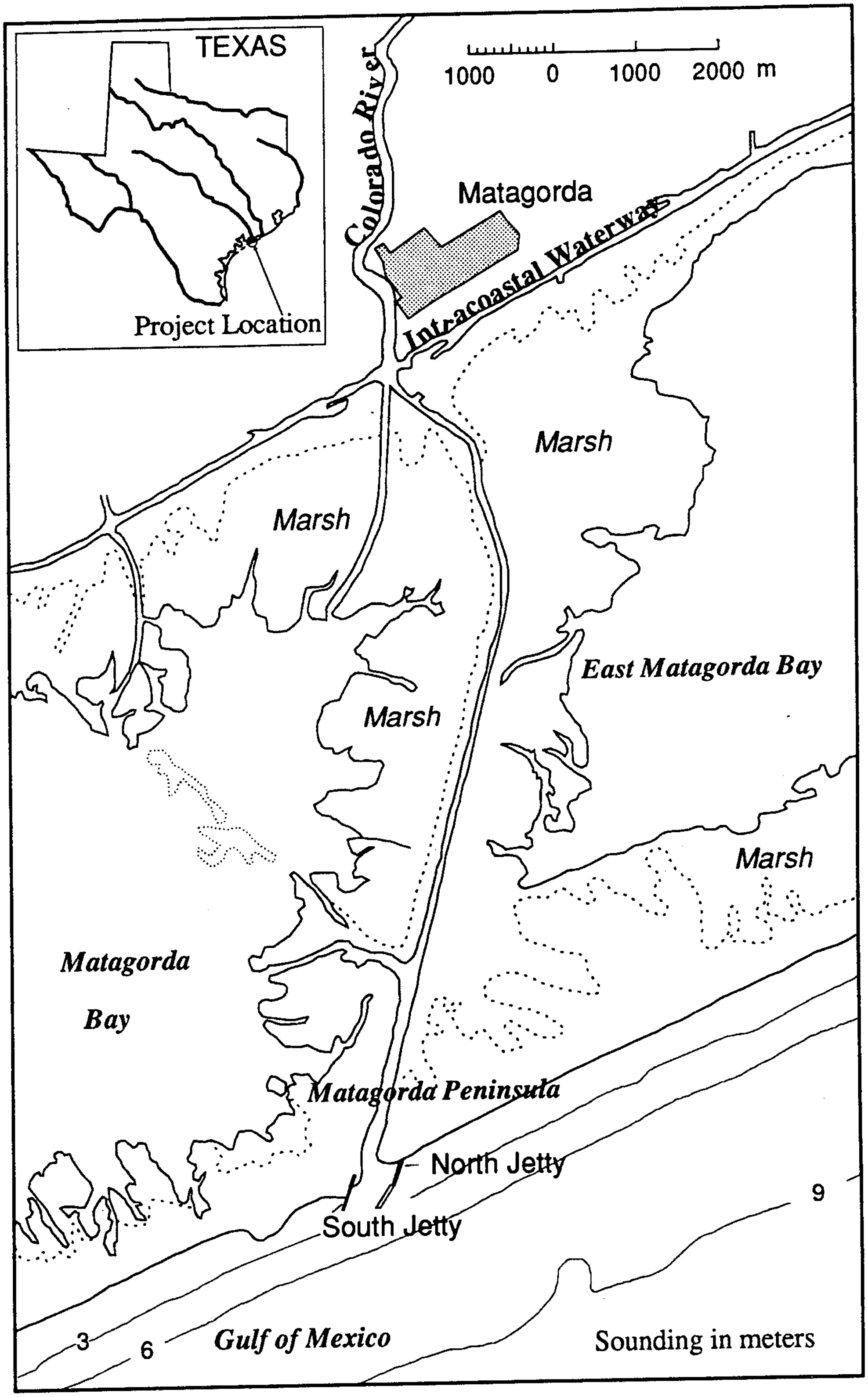

Figure 1. Locality map of Colorado River mouth, Texas

In tidal inlets, tidal currents are an important mechanism for sediment transport.

The Texas coast, with an orientation of SW-NE, is wave-dominated (Hayes 1965). The prevailing wind is from the southeast quadrant. Most waves reach the shoreline at an angle. Accordingly, a longshore current that moves sediment to the southwest is created (MaGowen and Brewton 1975).The Matagorda Peninsula ranges in width from 1,200 to 1,600 m, and has an average elevation of about 2 m. The gulf shoreline, orienting roughly SWW-NEE, is generally linear. The contours are roughly parallel to the shoreline.

History of Shoreline in the Vicinity of the Colorado River Mouth

Because of the existence of barrier islands, the shoreline nearby the Colorado River mouth consists of a mainland shoreline (inner shoreline) and a Gulf shoreline (outer shoreline). The mainland shoreline, facing bays behind the barrier islands, is irregular and devoid of beach; whereas the Gulf shoreline is very regular with well-developed sand beach (LeBlanc and Hodgson 1959).

During the last Pleistocene glaciation, sea level in the Gulf of Mexico was lowered approximately 120 m (Curray 1960). The mainland shoreline, which is believed to have originated in this stage, was probably 80 to 224 km seaward from the present one (LeBlanc and Hodgson 1959). Sea level started to rise about 18,000 years B.P. As the sea level rises, the mainland shoreline gradually migrates landward.

Sea level reached its present position around 3,000 years B.P. A remarkable feature associated with the sea level stillstand was the formation of a series of barrier islands that gave the rising of the Gulf shoreline (LeBlanc and Hodgson 1959).

Prior to the time of sea level stillstand, the Colorado River was discharging into an estuary that was shared with the Brazo River. The estuary had an estimated average depth of 7.6 m, a width of 48 km, and a length of 35 km (MaGowen and Brewton 1975). As the rate of sea level rise decreased, the Colorado and Brazo Rivers completely filled their common estuary (Wilkinson and Basse 1978). According to MaGowen and Brewton, about

1,000 years ago, the Colorado River began discharging into Matagorda Bay in the vicinity of the small town of Matagorda.

The Colorado River built its delta across Matagorda Bay, a distance of about 6.4 km, from 1929 through 1935 (Wadsworth 1966). The delta, which covered 0.2 km^2 (45 Acres) in 1908 and 7.2 km^2 (1780 acres) in 1930, attained an area of 28.7 km^2 (7098 acres) by 1941. The rapid deposition was caused by the removal of a log jam that extended 74 km upstream from the town of Matagorda. A great amount of sediment had accumulated in the river downstream to the jam because of the significantly reduced flow. Upon the release of the jam in 1929, sediment was quickly transported to Matagorda Bay, creating a delta that prograded completely across the bay. In 1936, a channel was dredged through the Matagorda Peninsula, and the Colorado River began discharging into the Gulf of Mexico.

Data Availability

The bathymetry survey for this study was designed on the context of the data of the 1984 survey. In the northeast bank of the river mouth (the north section), eight cross-shore profiles (NJ0 through NJ7) were selected (Figure 2, upper). In the southwest bank (the south section), five profiles, SJ0 through SJ4, were selected (Figure 2, lower). All these 1984 profiles were defined as principal profiles.

In the north section, all the bench marks were located in a straight base line that was set roughly on the top of a series of sand dunes. Profile lines were perpendicular to the base line. The distance between two neighboring principal profiles was 457.2 m while that between NJ0 and NJ1 was 353.6 m. From the north jetty, the north section extended about 3,200 m alongshore. Within each of the two sections that were respectively between NJ0-NJ1 and NJ1-NJ2, two additional profiles were inserted. While one profile was added to the mid-points between NJ2-NJ3 and NJ3-NJ4, respectively.

In the south section, the distance between two neighboring principal profiles was 457.2 m. Between SJ0 and the south jetty, three profiles were added. Another profile was inserted between SJ0 and SJ1. The total longshore length of the south section was about 2,286 m.

The elevations of the nearshore profiles were measured using a system consisting of a laser GEODIMETER and a 6-m-high sled. At the same time as

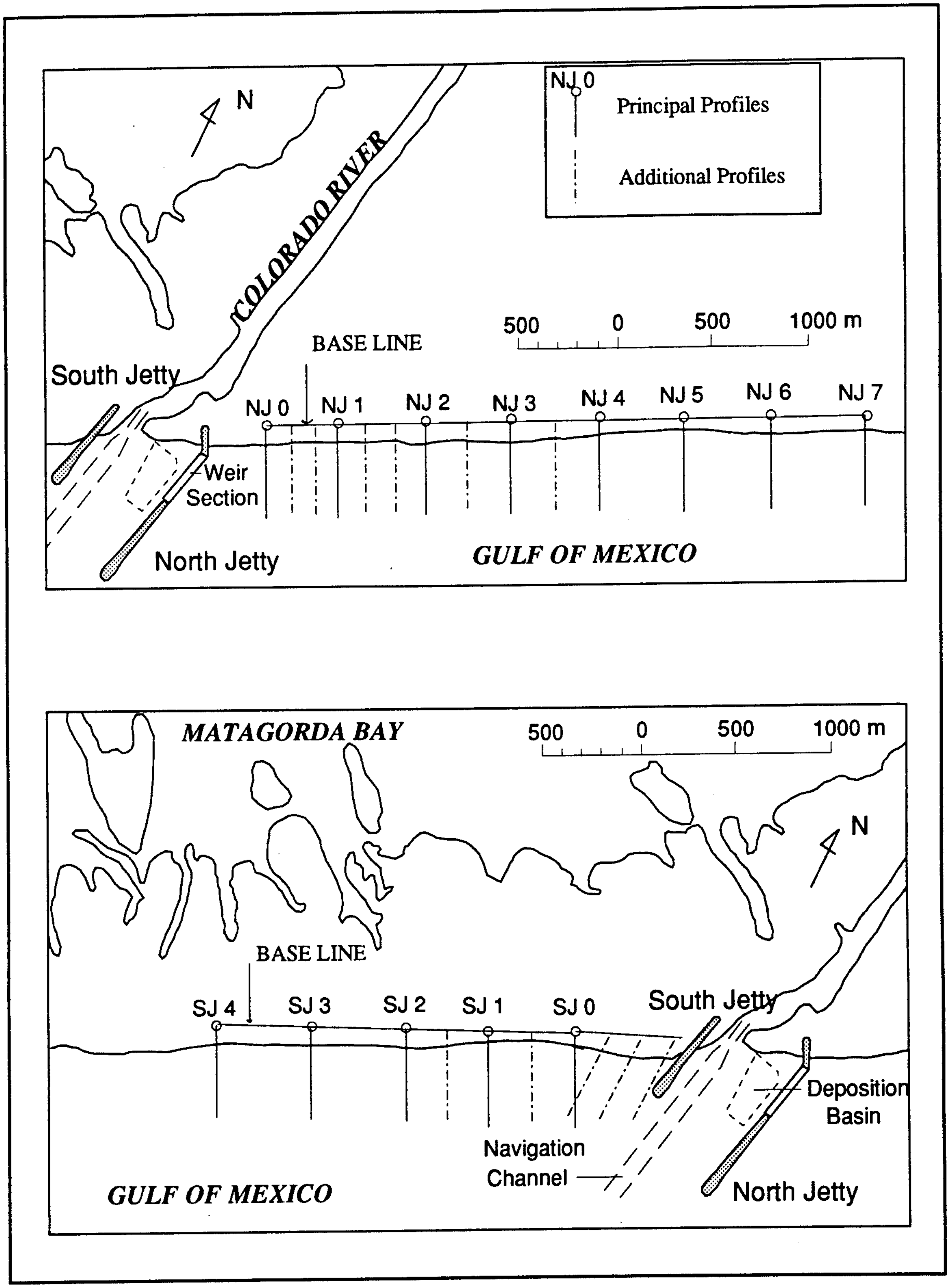

Figure 2. Positions of profiles in the north section(upper) and the south section (lower).

the bathymetric survey, several tripods or sleds that carried pressure sensors, eletromagnectic current meters (ECM) and optical backscatter sensors (OBS) were located in the surf zone along profile NJ0.

The bathymetric data were processed by the Interactive Survey Reduction Program (ISRP), a program for personal computers (Birkemeire 1984a). The data, comprised profiles with uneven-spaced grid points, were converted into profiles with even-spaced grid points by means of biharmonic interpolation.

In the north section, data were collected in December of 1990, July of 1991, and January of 1992. The data available from each profile is listed in Table 1.

In the south section, beach profiles were measured in July of 1991 and January of 1992. The outmost points of the profile reach the shoreline (Table 2).

From January 9 to January 18 of 1992, three profiles (NJ00+2/3, NJ0 and NJ0+1/3) near the north jetty were measured daily using leveling and measuring rod. On January 21, these profiles were measured by the laser GEODIMETER system. During this period, a storm reached the study area and caused significant variation in the beach morphology. This process was well documented in the data.

Table 1
Availability of Bathymetric Data in the North Section[1]

Profile Number (1)	Location (m)	December of. 1990		July of 1991		January of 1992		Profile Number(2)
		D1	D2	D1	D2	D1	D2	
NJ 0	0	35	770	0	425	0	160	100
NJ 0+1/3	117.9	90	780	10	390	10	150	103
NJ 0+2/3	235.7	90	765	40	450	10	150	107
NJ 1	353.6	90	760	15	400	0	840	110
NJ 1+1/3	506.0	5	700	15	90	5	850	113
NJ 1+2/3	658.4	0	665	10	85	10	840	117
NJ 2	810.8	0	665	0	85	10	870	120
NJ 2+1/2	1139.9	20	650	25	75	0	840	125
NJ 3	1268.0	0	730	0	90	0	865	130
NJ 3+1/2	1497.1	75	710	15	85	40	820	135
NJ 4	1725.2	0	690	0	75	10	895	140
NJ 5	2182.4	70	740	0	70	0	795	150
NJ 6	2639.6	–	–	25	75	30	840	160
NJ 7	3096.8	15	775	0	90	0	795	170

[1] 'Profile numbers(1)' were survey number; 'Profile numbers(2)' were numbered by ISRP; 'Location' is the longshore distance (northwards) from the NJ0 profile line; 'D1' indicates the distance from the base line to the inland end of a profile while 'D2' indicates that to the offshore end.

Table 2
Availability of Bathymetric Data in the South Section[1]

Profile Number (1)	Location (m)	December of. 1990		July of 1991		January of 1992		Profile Number(2)
		D1	D2	D1	D2	D1	D2	
SJ 00	-457.2	–	–	175	240	0	260	290
SJ 00+1/3	-304.8	–	–	50	230	45	250	293
SJ 00+2/3	-152.4	–	–	80	225	80	225	297
SJ 0	0	–	–	75	200	0	160	200
SJ 0+1/2	+228.6	–	–	75	220	0	160	205
SJ 1	+457.2	–	–	40	210	0	160	210
SJ 2	+914.4	–	–	50	200	–	–	220
SJ 3	+1371.6	–	–	0	180	–	–	230
SJ 4	+1828.8	–	–	40	160	–	–	240

[1] Location is the longshore distance from SJ0 profile line; '-' indicates northwards while '+' indicates southwards; For the other representations, refer to Table 1.

2 Shoreline and Sediment Volume Changes in the North Section

Changes in Shoreline

By comparing the data of 1984 and 1990, it is obvious that the shoreline in the north section had undergone an accretion process. At each principal profile (except NJO that remained unchanged), the shoreline migrated seawards (Figure 3).

The data in January of 1992 indicated that the shoreline retreated from the position of 1990. This erosion is believed to have resulted from the strong waves caused by the storm. However, the 1984 shoreline had been eroded in only two positions, .

From Figure 4a, it can be found that the most intensive accretion from 1984 to 1990 happened at profile NJ1 and the average accretion distance was 19.2 m. In addition to that at NJO, accretions at NJ5 and NJ7 were below the average value. From 1984 to 1990, an area of 63,000 m^2 was gained within the north section.

In comparison with the 1984 shoreline, the accretion in January of 1992 at NJ1 was still the maximum in the north section (Figure 4b). The average accretion over the 1984 shoreline was 8.8 m. Despite the erosion event (that probably was a short-term phenomenon), the area above sea level was 30,000 m^2 larger than that in 1984.

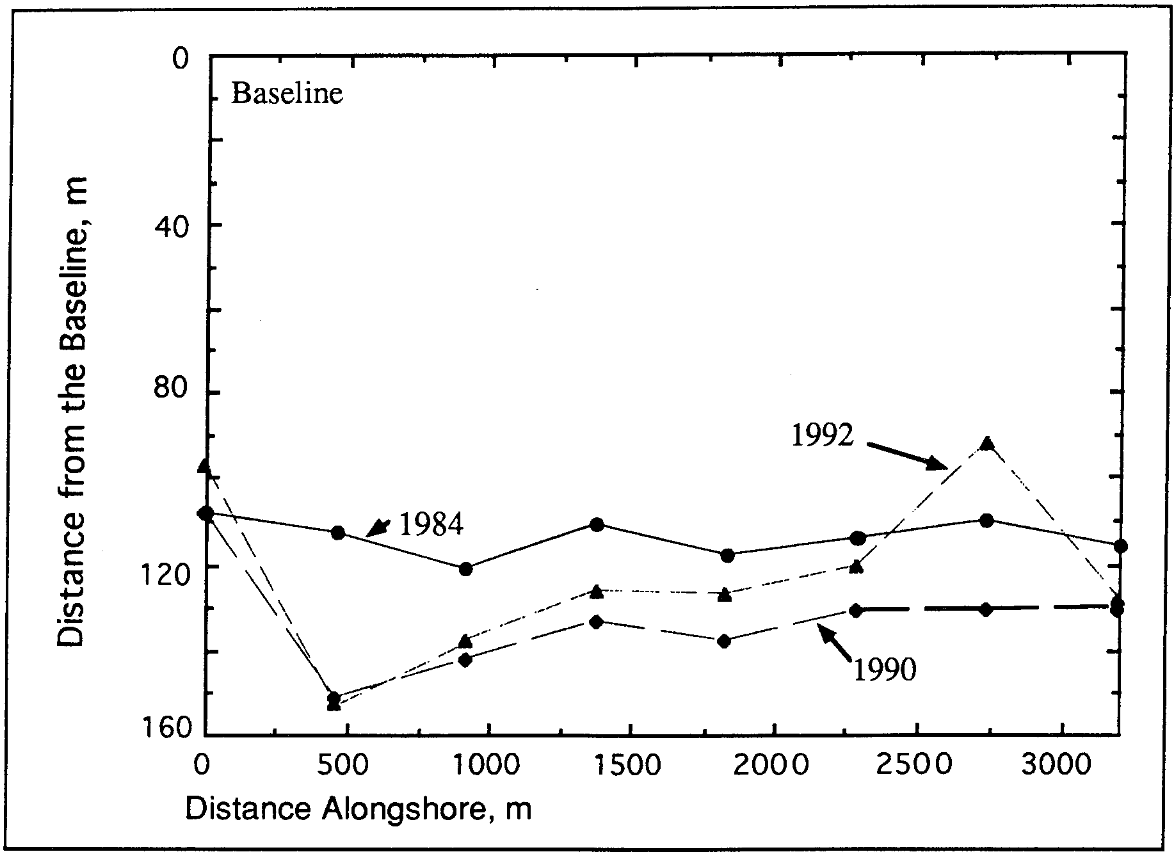

Figure 3. Shoreline changes at the north section, from 1984 to 1992

Changes in Sediment Volumes

Following the procedures explained in the Appendix, the volume change per unit longshore length (m^3 per m) can be estimated.

Each 1984 profile extended 125 m offshore from the base line. The offshore ends of the profiles were roughly located on a longshore sand bar. The volume changes in this section are listed in Table 3. At NJ0, the erosion was significant. However, all the other profiles, either in 1990 or in 1992, showed accretion over 1984. In 1990, the accretion rate ranged from 24.56 to 74.09 m^3 per m while in 1992 that ranged 30.09 to 66.02 m^3 per m.

The volume change in the entire section can be calculated using (A4) and (A5). From 1984 to 1990, the volume increased by about 135,000 m^3.

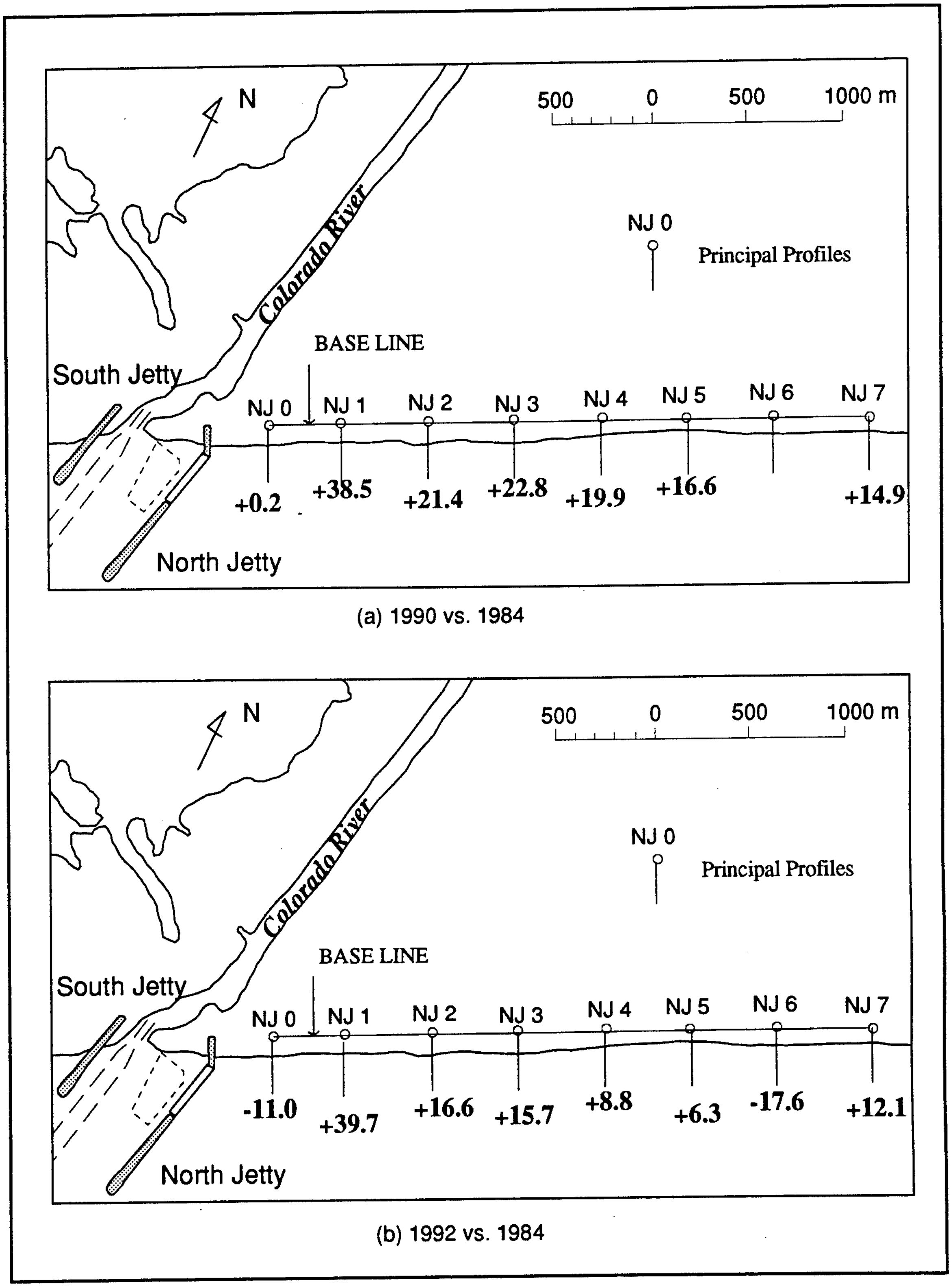

Figure 4. Accretion and erosion at each profile in the north section

Referring to Table 3, it is suggested that the erosion event of 1992 also affected the sediment volume. The principal profiles near the jetty underwent erosion in comparison with the data of 1990. The total volume eroded was estimated as 19,000 m^3.

Table 3
Changes in Volume in the North Section[1]
(0-125 m from Base Line)

Profile	NJ 0	NJ 1	NJ 2	NJ 3	NJ 4	NJ 5	NJ 6[2]	NJ 7
'90 vs. '84	-88.09	+65.75	+74.09	+61.82	+41.08	+46.18	–	+24.56
'92 vs. '84	-97.04	+63.64	+66.02	+42.22	+31.99	+47.64	+30.09	+34.69
'92 vs. '90	-8.95	-2.11	-8.07	-19.6	-9.09	+1.46	–	+10.13

[1] '+' indicates accretion while '-' indicates erosion.
[2] Data from 1990 survey were unavailable at this profile.

Generally, the accretion in the north section was obvious. Located at the updrift part of the jetty, this section was trapping the sediment carried by the longshore current and blocked by the north jetty. The tendency agreed with the analysis of MaGowen and Brewton (1975).

The surveys in 1990 and 1992 extended to about 700 m offshore. At the same time, six additional profiles were inserted into several principal profiles. The volume changes in these longer profiles differed from that listed in Table 3. For example, principal profile NJ5 showed slight accretion in the upper 125 m, while the whole profile underwent erosion (Figure 5). The erosion values also implied that there was severe erosion happening in the underwater parts of most profiles. The total sand eroded was about 84,600 m^3, which was as much as four times of that in the upper 125-m section.

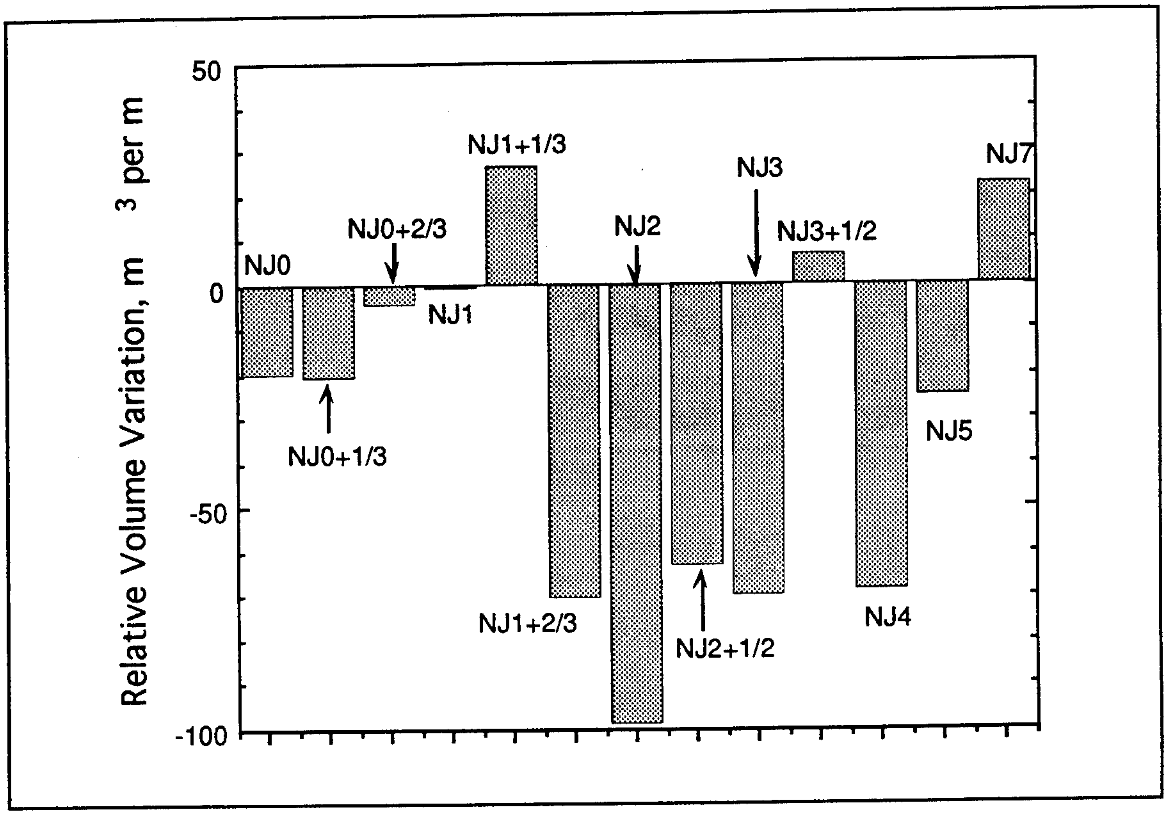

Figure 5. Volume changes in the north section from December of 1990 to January of 1992 (from the baseline to 700 m offshore)

3 Shoreline and Sediment Volume Changes in the South Section

Restricted by weather, transportation and other technical difficulties, the survey in the south section was not as successful as that in the north section. The survey in July of 1991 covered only the area from the shoreline up to the base line while the survey in January of 1992 measured only several profiles near the south jetty.

Due to the inability to recover the bench marks of some principal profiles, some data collected in this study did not match the data of 1984 either in locations or in reference elevations. Figure 6 shows one of the examples of them. The profile SJ1 of 1984 indicated that near the base line there was a 2-m-high terrace that was not supposed to change dramatically. In contrast, in the same profile of 1992, no terrace appeared. Furthermore, none of the elevations seemed to match. Similar situations made a considerable amount of data unuseable.

Based on the analysis of the data at SJ0, the shoreline migrated seawards from 1984 to 1992. However, the profile line in this study was too short to determine the length of extending.

There were six profiles (SJ00, SJ00+1/3, SJ00+2/3, SJ0, SJ0+1/2, and SJ1) that could be used for estimating volume changes from 1991 to 1992. The results showed that all the profiles, which extended from the foot of a bluff to the shoreline, were being eroded (Figure 7). The maximum erosion was at profile SJ0+1/2. The total volume eroded in this 900-meter longshore section was about 22,100 m^3.

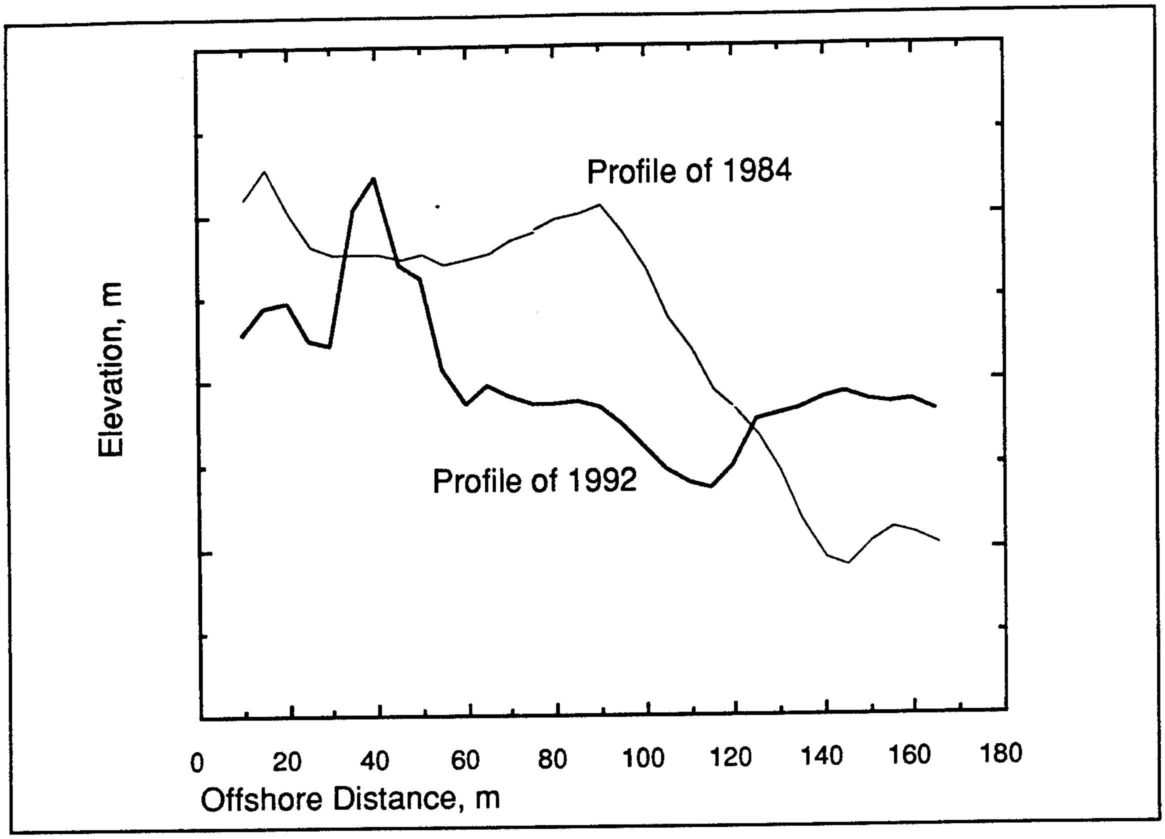

Figure 6. Comparison between elevations of 1984 and 1992 along profile SJ1

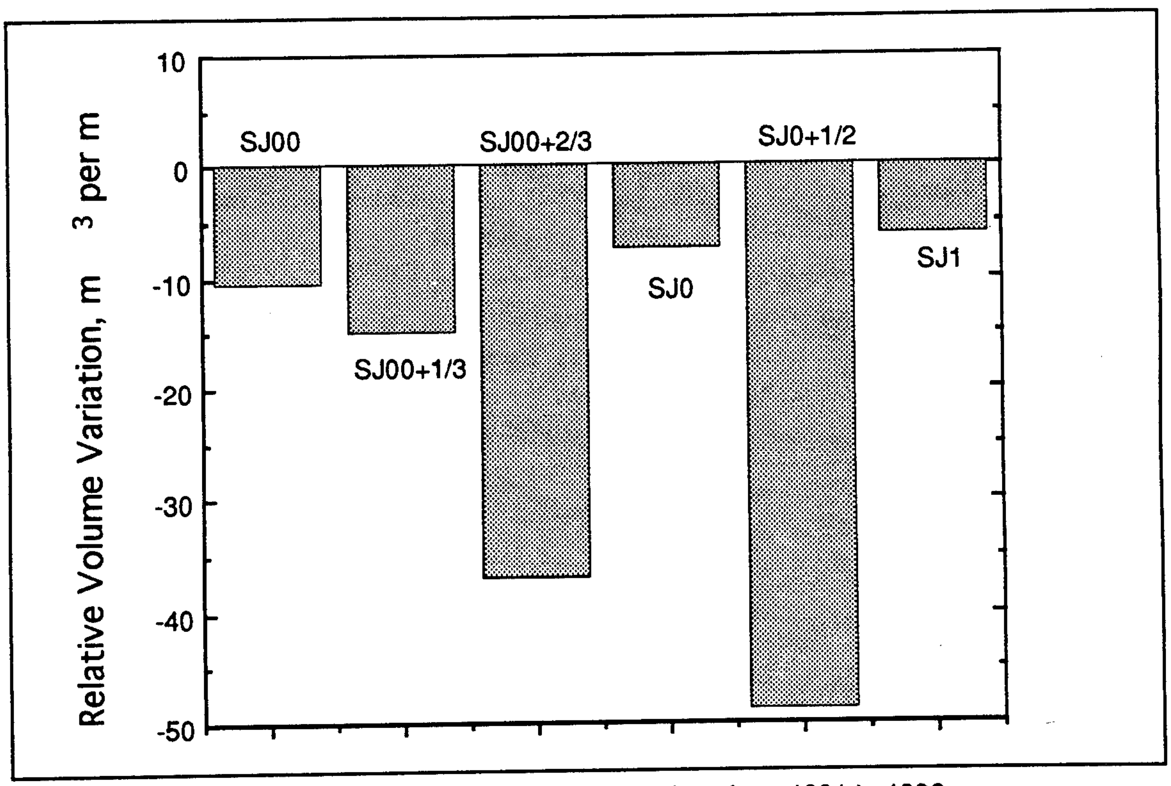

Figure 7. Volume changes in six profiles near the south jetty from 1991 to 1992

4 Complex Principal Component Analysis of Bathymetric Data

Background

Principal component analysis (PCA), also known as the Empirical Orthogonal Function (EOF) technique, has been widely applied to the analysis of the variations in beach morphology (e.g., Winant *et al.* 1975; Aubrey *et al.* 1980; Birkemeier 1984b; Seymour 1989). The primary advantage of the PCA is its ability to compress the complicated variability of the observed data set into the fewest possible modes. It provides an efficient and objective means for describing the variation of a beach profile with time. However, it must be recognized that there is a major disadvantage of conventional PCA. Although capable of describing standing waves in data, it can not detect propagating waves (Horel 1984). Therefore, PCA cannot identify a coherent form that moves through the data, such as a rapidly moving bar.

Complex principal component analysis (CPCA), developed for meteorological application (e.g., Wallace and Dickson 1972; Barnett 1983), has been successfully used to describe an event of a fast-moving sandbar (Liang and Seymour 1991). In comparison with the conventional PCA, CPCA offers significant advantages. Besides being able to give a more compact description for the variation of the data set (fewer functions required), it can also detect propagating waves.

During mid-January of 1992, a storm struck the study area. The morphology variation during pre- and post-storm period was well reflected by three daily wading profiles which were NJ00+2/3, NJ0 and NJ0+1/3. In the profile NJ00+2/3, the strong waves caused a sand bar migrating more than 20

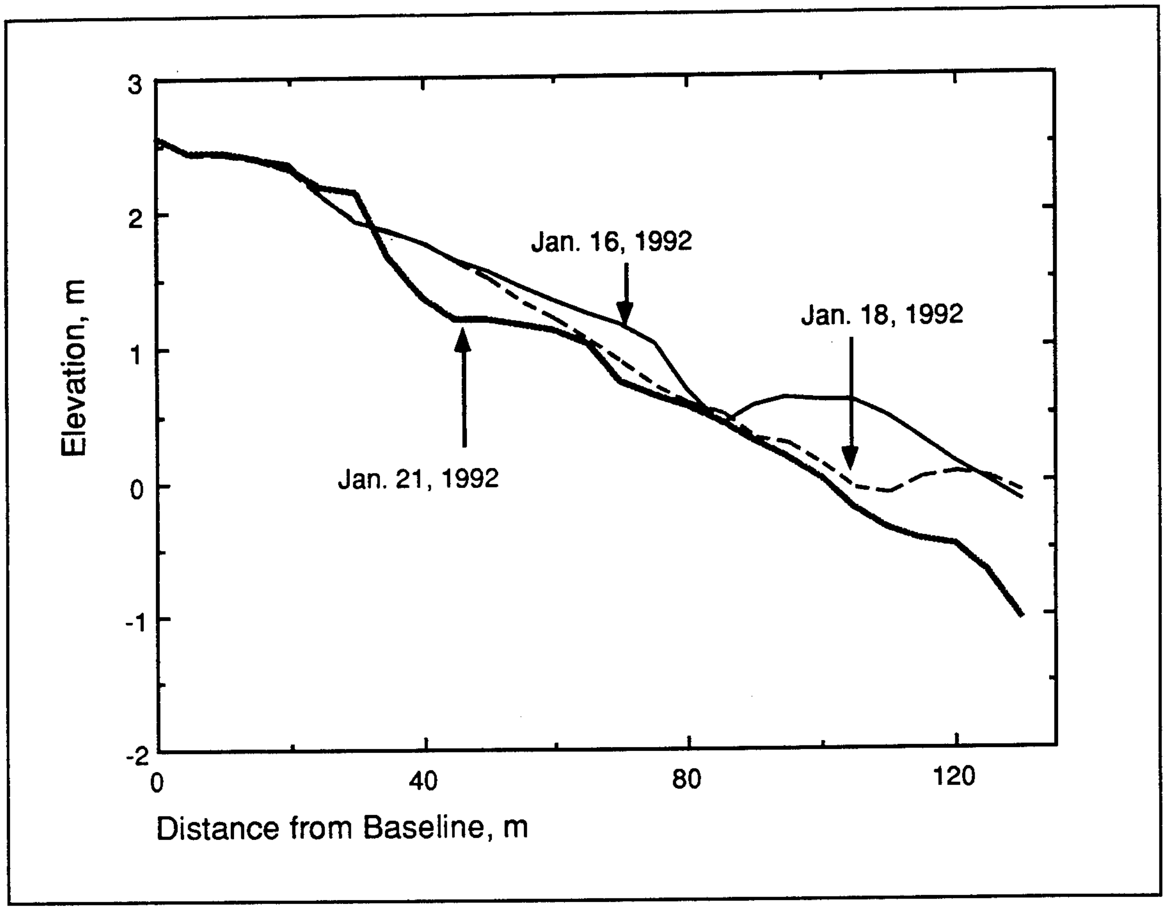

Figure 8. Variation of profile NJ00+2/3 during a storm

m in two days (Figure 8). These data provided a good basis for testing the efficiency of PCA and CPCA.

Analysis Method of CPCA

Following Barnett (1983) and Horel (1984), the CPCA routine is briefly stated as follows.

In terms of the complex representation of a variable, propagating features are commonly described as

$$U_j(t) = u_j(t) + i\hat{u}_j(t) \qquad (4\text{-}1)$$

The real part of (4-1), $U_j(t)$, is simply the original scale field where j denotes spatial position and t is time. The imaginary part, $i\hat{u}_j(t)$ where $i=\sqrt{-1}$ called the Hilbert transform, represents a filtering operation upon $u_j(t)$ in which the amplitude of each spectral component is unchanged but its phase is advanced by $\pi/2$.

After a complex data matrix is generated, the eigenvalues and eigenvectors of the complex cross-correlation matrix can be determined. If the complex data are converted into normalized anomalies by subtracting the mean and dividing by the standard deviation at each spatial position, then the correlation between the jth and kth position is:

$$r_{jk} = \langle U_j(t)*U_k(t) \rangle_t \tag{4-2}$$

where the asterisk * denotes complex conjugation and $\langle \cdots \rangle_t$ indicates a time average. The CPC approach compresses the information contained in the correlation matrix into relatively few complex eigenvectors with elements e_{jn} and complex principal components $P_n(t)$. Since the correlation matrix is Hermitian, it possesses real eigenvalues λ_n.

The observation $U_j(t)$ can be represented as a sum of the contributions from the N principal components:

$$U_j(t) = \sum_{n=1}^{N} e_{jn} * P_n(t) \tag{4-3}$$

The complex principal components are normalized too, *i.e.* $\langle P_n(t)*P_m(t) \rangle_t = \delta_{mn}$, and the complex eigenvectors are orthogonal, *i.e.* $\langle e_{jn}*e_{jm} \rangle_j = \lambda_n \delta_{nm}$. An element, e_{jn}, of the nth complex eigenvector can be interpreted as:

$$e_{jn} = \langle U_j(t)*P_n(t) \rangle_t = s_{jn} e^{i\theta_{jn}} \tag{4-4}$$

Hence e_{jn} is the complex relation between jth time series and nth principal component where s_{jn} is the magnitude of the correlation and θ_{jn} is the phase.

It is possible to reconstruct the portion of each complex time series which is explained by the nth component:

$$U_j'(t) = e_{jn} * P_n(t) \tag{4-5}$$

Since the real and imaginary parts of (4-1) are a Hilbert transform of one another, in theory, the real part can be considered alone. For further discussion, refer to Horel (1984).

Analysis Results

Of each profile, a section from the sand dune to the sand bar was chosen. Each profile was analyzed by both PCA and CPCA. Some results are listed in Table 4.

Table 4
Percentage of Variation Explained by Principal Components

Profile Number	Variation Explained by Principal Components (%)					
	1st PC	2nd PC	3rd PC	1st CPC	2nd CPC	3rd CPC
NJ00+2/3(097)	61.41	16.22	9.98	68.71	18.61	7.92
Cumulate	61.41	77.63	87.61	68.71	87.32	95.24
NJ0 (100)	32.25	25.52	3.48	51.52	15.16	13.38
Cumulate	32.25	57.67	61.15	51.52	76.68	90.06
NJ0+1/3 (103)	32.22	21.96	20.20	46.28	30.11	13.32
Cumulate	32.22	54.18	74.38	46.28	76.39	89.51

Apparently, the principal components derived from CPCA have better abilities to describe the variation. For each profile, the first two complex components can explain as much as the first three conventional components. The first three complex components can explain as much as 90% of the variation.

Using (4-3) and (4-5), the variation in profile can be reconstructed by principal components. Figure 9a, 9b and 9c show that the reconstructed results are well fitted to the observed data.

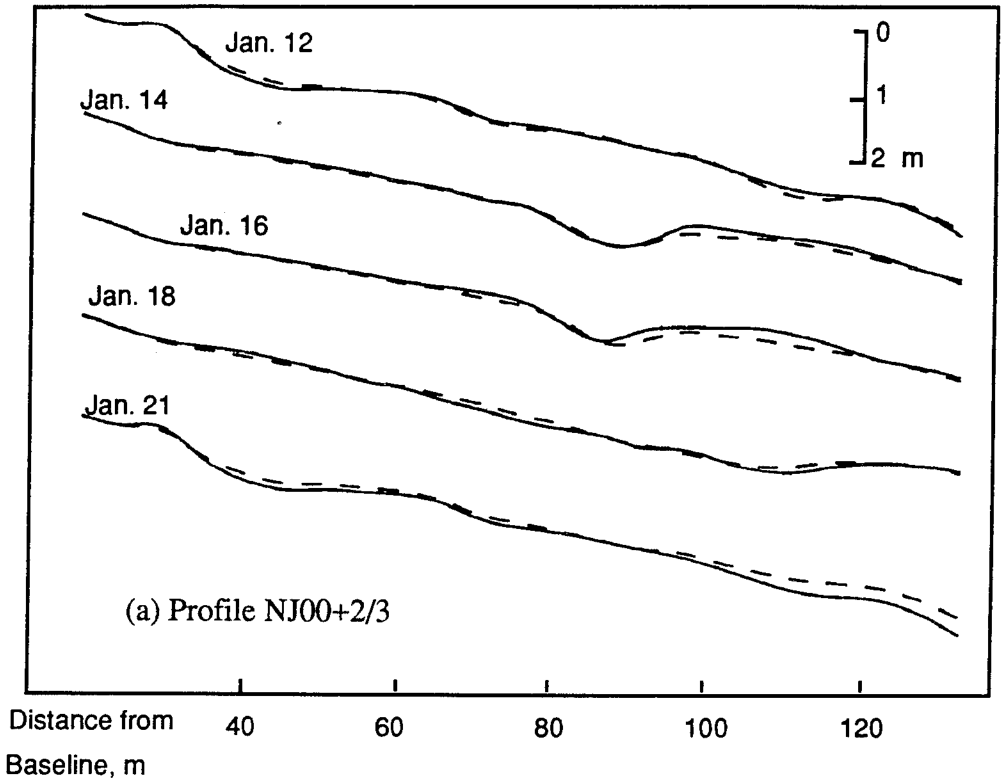

Figure 9. The observed data (solid lines) versus the reconstructed results (dash lines) derived from the first and second complex principal components (Sheet 1 of 3)

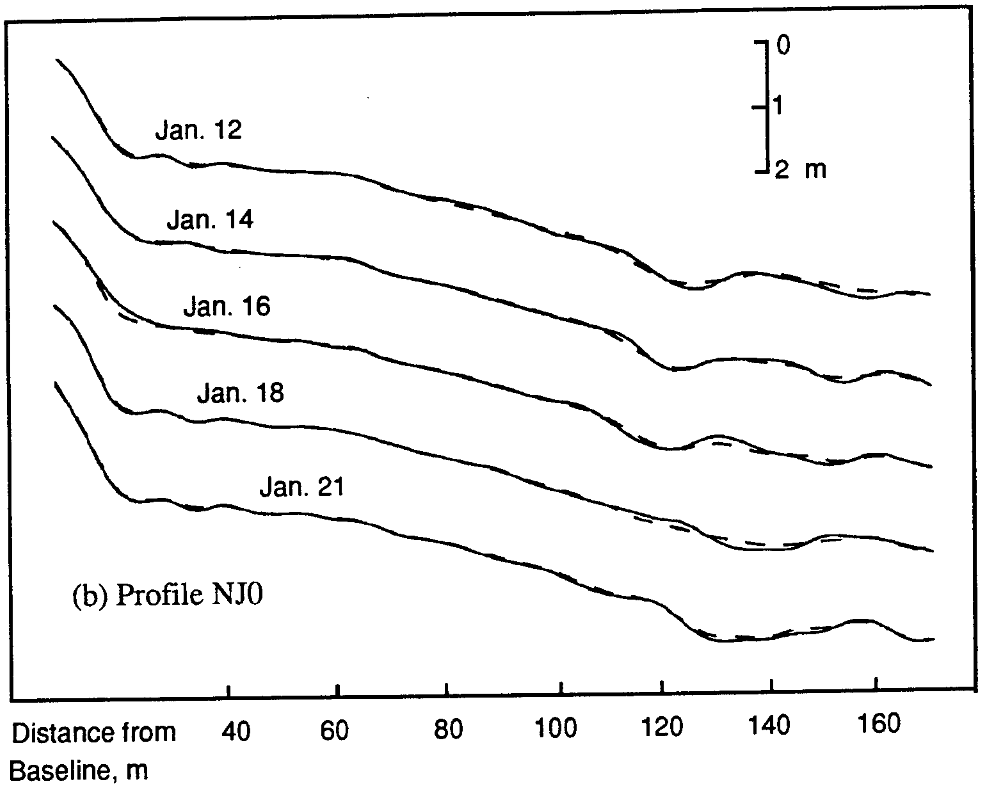

Figure 9. (Sheet 2 0f 3)

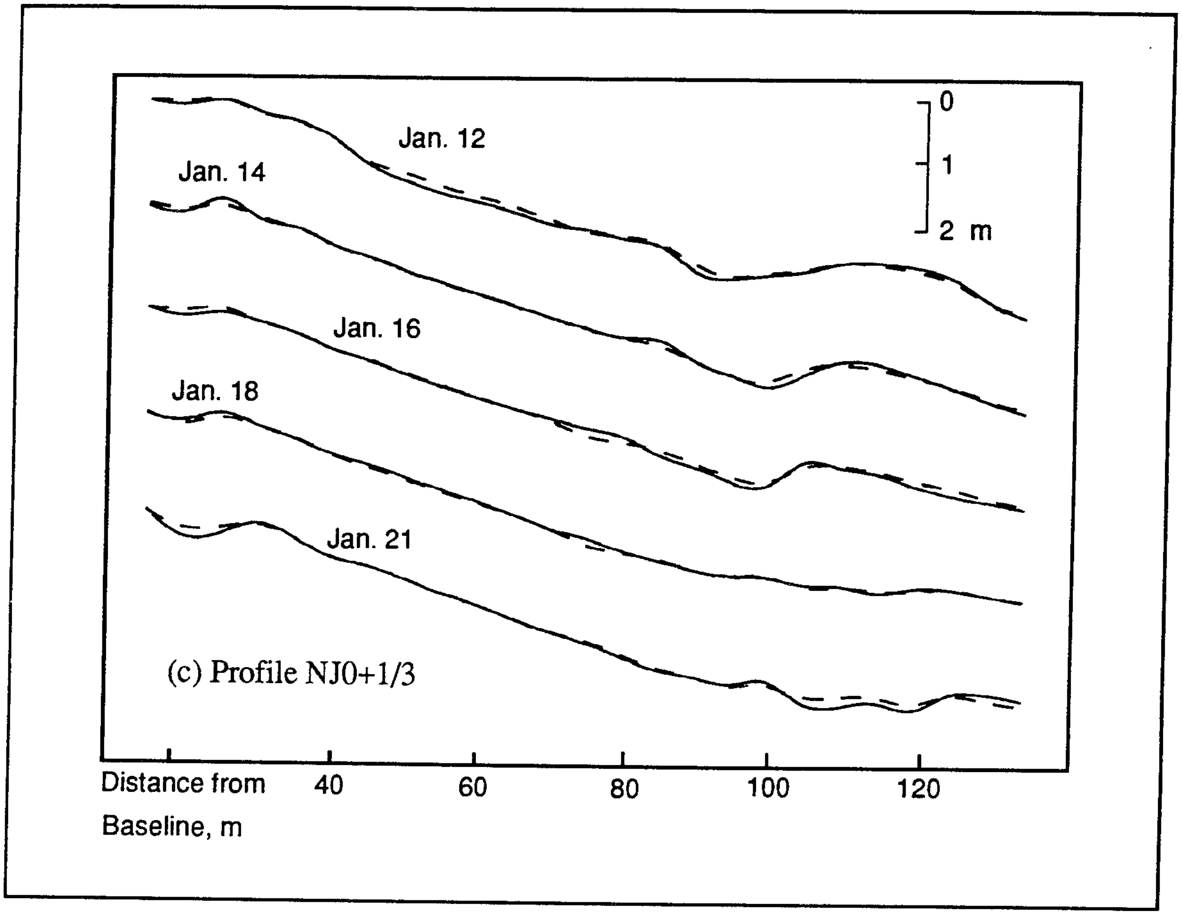

Figure 9. (Sheet 3 Of 3)

5 Principal Component Analysis of Volume Changes

Choosing Volume Variations as Variables

As discussed in the last part, the application of PCA in coastal study is focused on the morphology variations. By analyzing the changes of elevations at certain grid points, PCA can describe the variation of a beach profile with time.

In order to detect the spatial variation in the alongshore direction, many attempts have been made by means of dealing with the intertidal slopes (Losana *et al.* 1991), using CPCA to analyze longshore profile (Liang and Seymour 1991), or introducing a three-mode PCA (Medina *et al.* 1992). In many cases, the results of these techniques are not easy to explain.

In this study, a new variable, the volume change, is selected to be analyzed by PCA. The variation in each profile is compressed to only one variable instead of the changes in elevation at many grid points. Therefore, the variation alongshore will be indicated.

In practice, changes of volume in certain areas or profiles are more meaningful for engineering projects. With the ability to describe and to predict the volume changes, PCA is expected to have wider use in coastal studies.

Results and Discussion

The data set used in this analysis consists of three variables. Each variable, the volume change in a certain profile, is a time series (Figure 10). Because the size of the data set is small, the conventional PCA attained satisfactory results (Table 5).

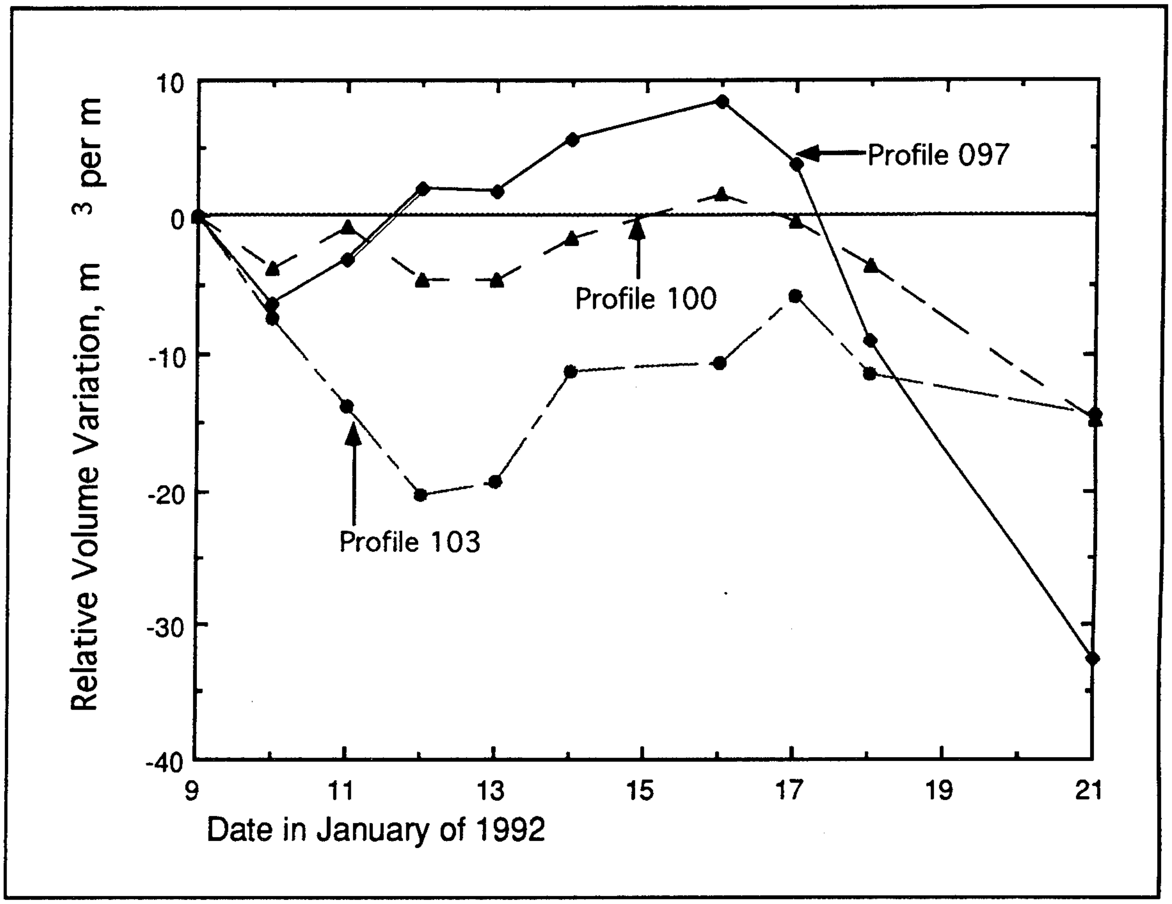

Figure 10. Volume changes in three profiles near the north jetty, January 9 to January 21, 1992

Table 5
Variation in Volumes Explained by Principal Components

Principal Component	1st PC	2nd PC	3rd PC
Variation Explained (%)	69.58	29.22	1.20
Cumulate (%)	69.58	98.80	100.00

The first two components can explain almost 100% of the variation. It proved that, even for a data set of small size, PCA is still capable of compressing the variability of the data set into fewer modes.

To detect the spatial variation in the longshore direction, the correlations between every component and every variable were calculated. Results showed that the first component, which explained about 70% of the total variation, was well fitted to the volume changes in profile NJ0 (Figure 11a); and the second component, explaining about 30% of the variation, was well fitted the volume changes in profile NJ0+1/3 (Figure 11b). It implied that the variation in these two profiles can represent the total variation over this section.

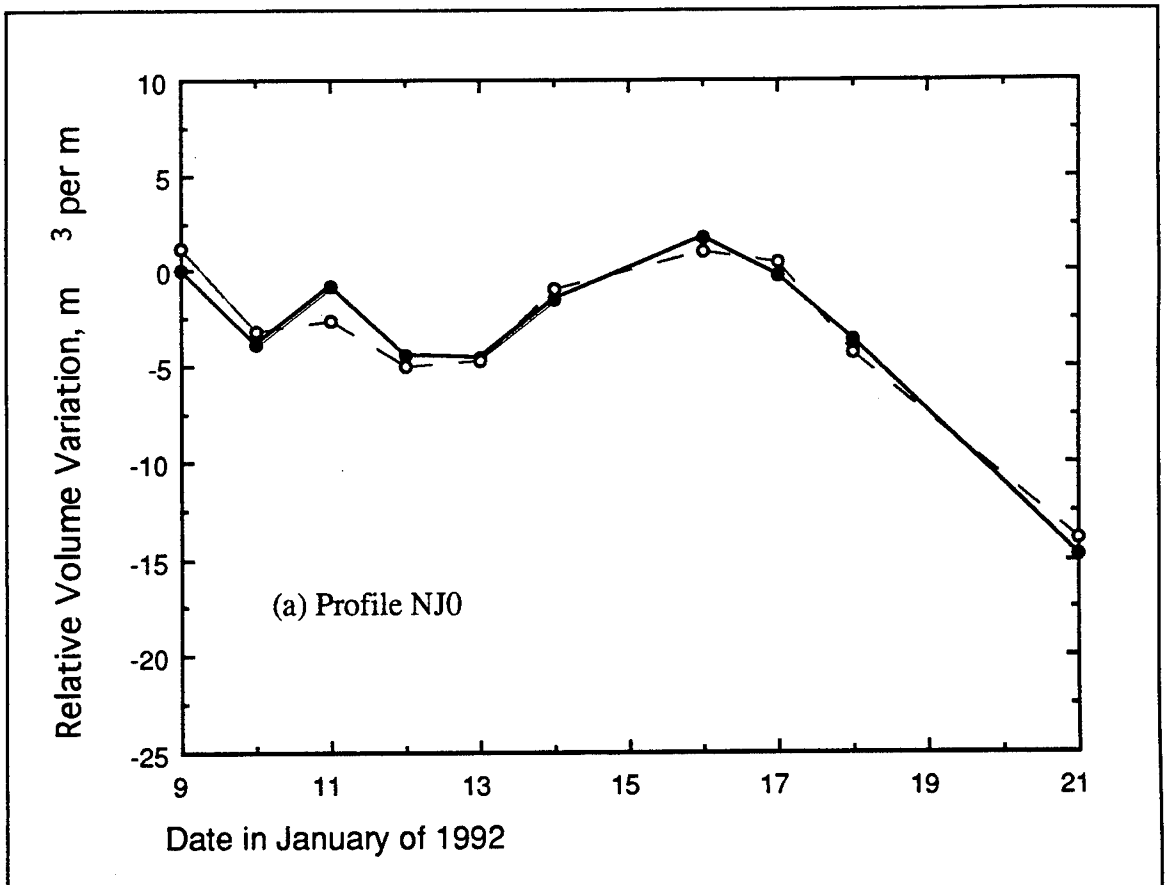

Figure 11. Volume changes (solid line) in two profiles versus the first or second principal component (dash line) (Continued)

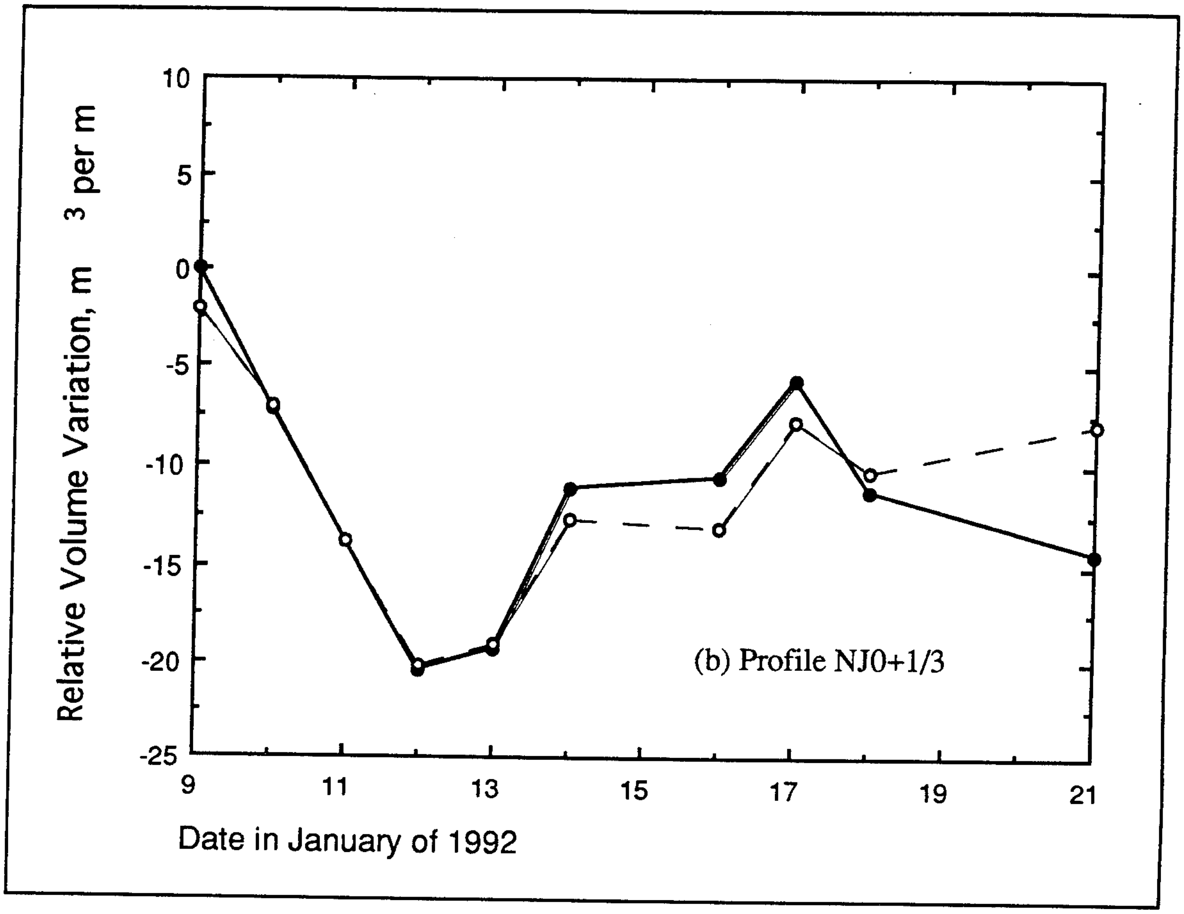

Figure 11. (Concluded)

6 Conclusions

In terms of the long-term variation, the shoreline in the north section is accretional. From 1984 to 1990, an area of 63,000 m^2 was gained within the north section.

Some severe erosion can be caused by storm. In a 270-m by 140 m area between NJ00+2/3 and NJ0+1/3, the sediment volume decreased more than 5,000 m^3 in 12 days.

Complex PCA was applied to analyze a fast-moving bar event. It showed significant advantages over the conventional PCA. Using fewer components. CPCA can explain more variations. The results of reconstruction by CPCA well reflected the variation in the observed data set.

One new type of variable, the volume changes in profiles, was selected for principal component analysis. Using the results, the variation alongshore was detected. Further use of this method is expected to be fruitful.

The principal components derived either by PCA or by CPCA are meaningful predictors while combined with some selected dynamics parameters. Since a great amount of data about waves, currents and sediments was collected by this project, further study should include the prediction to the long-term or short-term variation in nearshore morphology and sediment volume by means of principal component analysis.

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Appendix A

Calculation Procedures for Sediment Volume Changes

In order to calculate the change for a profile from time t to t+1, the envelope of them is divided into n small trapezoids (Figure A1), the heights of the trapezoids are $l_1, l_2, ..., l_n$, respectively. The area of ith trapezoid, ΔA_i, is estimated as:

$$\Delta A_i = \tfrac{1}{2}(\Delta H_{i-1} + \Delta H_i) l_i \qquad \text{(A1)}$$

where ΔH_{i-1} and ΔH_i are the two sides of the ith trapezoid.

The area change between t and t+1 is

$$\Delta A = \sum_{i=1}^{n} \Delta A_i \qquad \text{(A2)}$$

If all the l_i's is uniform and equal to l, then

$$\Delta A = (\tfrac{1}{2}\Delta H_0 + \Delta H_1 + \Delta H_2 + \cdots + \Delta H_{n-1} + \tfrac{1}{2}\Delta H_n) l \qquad \text{(A2a)}$$

Hence, Δv, the volume change in a unit length alongshore is simply calculated as

$$\Delta v = \Delta A \times 1 \qquad \text{(A3)}$$

If the longshore distance controlled by this profile is L_i, then ΔV_i, the volume change over this distance should be

$$\Delta V_i = \Delta v_i \times L_i \qquad \text{(A4)}$$

The total volume changes over m profile is estimated as

$$V = \sum_{i=1}^{m} \Delta V_i \qquad \text{(A5)}$$

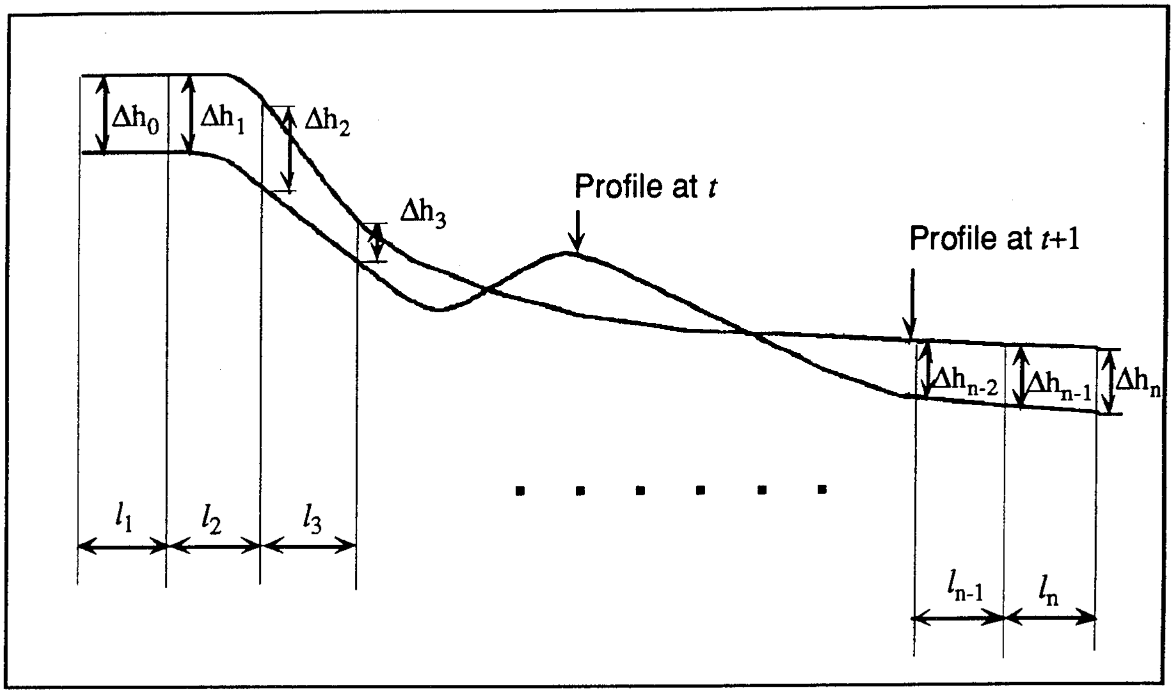

Figure A1. Schematic of calculating volume changes in a profile

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13. ABSTRACT *(Maximum 200 words)*

Shoreline change at the Colorado River mouth, Texas, was estimated based on survey results from 1990 to 1992 and some historic data. In terms of the long-term variation, the shoreline in the north section is accretional. From 1984 to 1990, an area of 63,000 m^2 was gained within the north section. On the other hand, some severe erosion can be caused by storms.

Complex PCA was applied to analyze a fast-moving bar event. It showed significant advantages over the conventional PCA. Using fewer components, CPCA can explain more variations. The results of reconstruction by CPCA reflected the variation in the observed data set well.

Volume changes in profiles were selected as variables for principal component analysis. Using the results, variation alongshore was detected. Further use of this method is expected to be fruitful.

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