SHORELINE RESPONSE TO JETTY EXTENSION AND NATURAL FORCING EVENTS AT SIUSLAW BAY, OREGON 1981-1990

by

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Acknowledgments

To my mother,
for the intellectual integrity that
permeates her life, and the undying
belief that I can do anything

To my father,
Whose friendship uncovers new pleasures
as it grows and develops

To the mystical and beautiful earth, who
reminds with excellent timing that
after all, all time is relevent

A special thanks to Stephen Chesser at the Army Corps of Engineers for providing the following data and priceless encouragement

and to Fred Crooks, a fellow graduate student whose computer skills and knowledge helped me immensely

LIST of FIGURES

"Here is no water but only rocks, rocks and no water
and the sandy road."
T.S. Eliot
The Wasteland

In man's frenzy to apply his
technology to understand any
Chaos that he has wrought
onto the natural world,

he has forgotten to remember,
that the power of change
the earth holds within,
is more powerful than his
puny conceptions can visualize.

Camela Carstarphen
Oct. 30, 1991

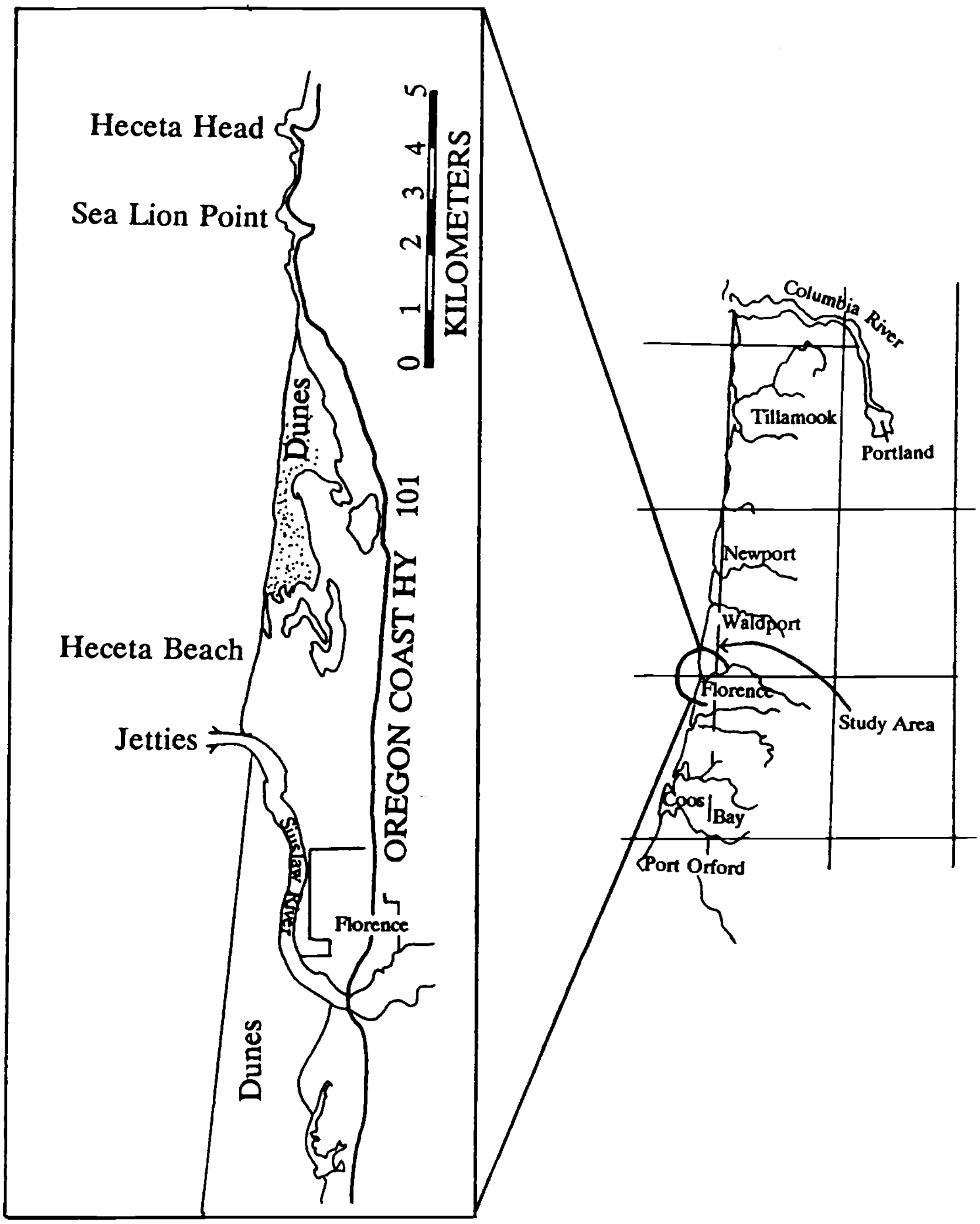
INTRODUCTION

This paper investigated observed morphologic changes in sand accretion and erosion due to sedimentary processes at the jetty entrance to the Siuslaw River near Florence, Oregon. Ten years of data on morphologic change in sand and sediment distribution, collected semiannually between 1981-1990, was used to analyze the nearshore sedimentation processes around the jetty to determine if observed morphologic changes are the result of the extension of the Siuslaw River jetties or to natural climatic forcing processes, such as the 1982-1983 EL Nino. During the ten years of recorded data an El Nino occurred in the winter of 1982-1983 and jetties were extended in 1984-85.

The study area extends over five miles north and south of the jetties and from the dune crest to an offshore depth of twenty feet. The study methodology uses morphological, graphical and statistical assessment techniques. The objective of this study was to comprehensively analyze all of the survey data collected by the Army Corps of Engineers (COE) to determine if any modification to shoreline morphology has occured over the ten year study and if that change has a causal relationship with the jetty extension. It poses these questions: (1) are these changes large enough to be observable in volume comparisons, graphing comparisons and morpological comparisons? (2) Within the data can the jetty event be separated from the El Nino event? and (3) After separation of these two events what conclusion does the statistical analysis point towards? To answer this last question I posed a Null Hypothesis that 1981=1985=1989=1990 from which to base the analysis. The Alternate Hypothesis is that 1981≠1985≠1989≠1990.

Statistical analysis of these volume changes was based on comparing natural variation within the areas north and south of the jetties; specifically, the natural variation between an inner and an outer cell. This approach allows an analysis of the character of volume variance over time without having to contend with the El Nino affect. This specific approach is termed an Analysis of Variance (ANOVA). Within this approach are several techniques. Because I have no expectations for any volume variances, the Tukey-Kramer test for difference was applied. This is a valid test given that my sample sizes are the same for all years analyzed, and that the means for the years do not vary significantly from one another. The years 1981, 1985, 1989, and 1990 were used in this analysis.

Figure 1. Location map of study area.



BACKGROUND

The Project

Beginning in 1981 the U.S. Army Corps of Engineers (COE) initiated a shoreline surveillance program to monitor the effects of jetty extension on the beach morphology in and adjacent to Siuslaw Bay, centrally located on the Oregon Coast. Jetties that were constructed by 1917 at the mouth of Siuslaw river were extended an additional 2500 feet in 1984-1985 (Fig. 1). The objective for extending the jetties was to minimize shoaling of sand into the river mouth and thus reduce the need for dredging the entrance to the channel.

The COE monitoring program for this construction has two purposes: (1) to discern if there is any disturbance of beach morphology associated with the jetty extension and (2) to discern if the extension was successful in curbing infilling of the channel. This second purpose is part of the Monitoring of Completed Coastal Projects Study(MCCP), now under way (Burke 1991).

To conduct the study, the COE took semi-annual surveys, conducted dye tracer studies of surface circulation around the jetties (on video tape) and on four different occasions studied the bottom circulation with seabed drifters (Chesser,1987).

Analytical work using the entire COE data set has not been completed although a COE in-house report was completed for the data through 1987 (Chesser,1987).

The monitoring study has consisted of approximately 70 measured profiles located symmetrically north and south, on either side of the jetties. The profiles were surveyed from the crest of the foredune out to a water depth of approximately 20 feet.

From these surveys, changes in sand volume and distribution are observable and can be used in discerning if disturbance of the nearshore processes have occurred. Any significant change would require an establishment of a new equilibrium between the shoreline and the nearshore energy regime. Komar has suggested that such adjustment involves the change in a point location, the **nodal point,** which separates the zone of erosion from the zone of accretion (Komar,1976b).

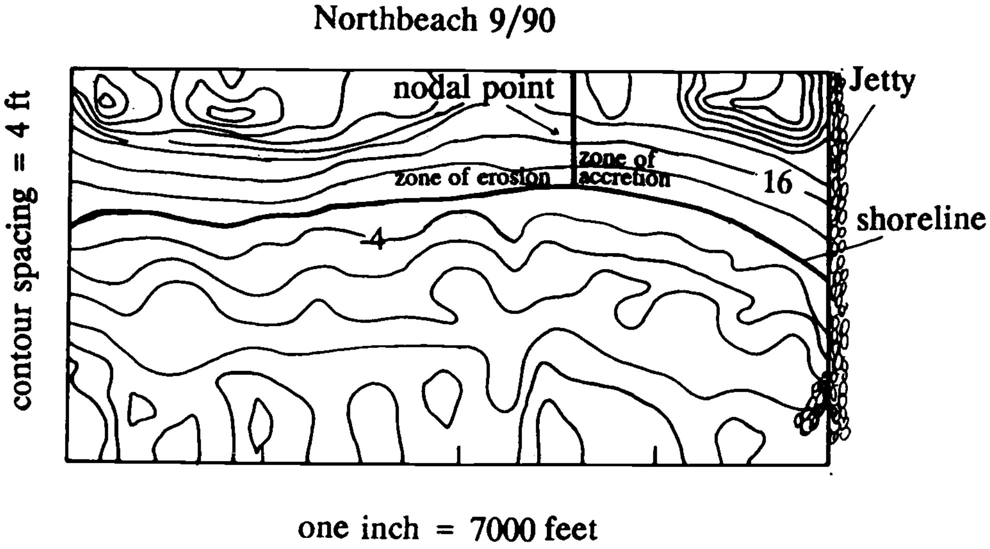


Figure 2. Illustration of nodal point as it divides the zone of accretion from the zone of erosion using the fall 1990 survey for the North data cell.

This nodal point would also affect sediment distribution laterally and would be evident in volume calculations.

Previous studies have defined shoreline changes due to the initial construction of the Siuslaw jetties (Komar et el., 1976a). Using air photos, Komar compared observed changes in shoreline location since 1889, through initial jetty construction and up to 1974 to calculated changes using a computer modeling system (Komar,1983). The beach responses from modeling predictions are similiar to those shown in actual air photos. Komar noted a rapid readjustment after initial construction, with little overall change in the shoreline for over 50 years.

Komar did a specific analysis of the Siuslaw Jetties attempting to predict changes following the jetty extension (1975). His historical analysis was conducted to understand the "equilibrium shoreline configuration adjacent to the jetties". From this, Komar devised the energy regime for the Siuslaw jetties quantitatively, so that consideration of future alterations due to extension could be made. Specifically, he looked at wave patterns (refraction and diffraction), longshore currents and sand transport.

His logistical approach to this problem includes: (1) defining an initial shoreline configuration, (2) establishing sources of sand to the beach (rivers) and possible loses, (3) giving offshore wave parameters (height, period, approach angle of waves), (4) indicating how the littoral transport of sand along beach is to be governed by wave parameters, (5) determining how the shoreline is altered from its initial configuration under these conditions at increments of time for some total span of time.

Based on this information Komar predicts that jetty extension may bring about some accretion of the shoreline in the immediate vicinity due to either the small increase in sheltering or the affects of incoming waves, reducing thier energy closest to the jetty. This energy reduction is accomplished through the longshore variation in wave height (lowest waves closet to the jetties increasing in energy away from the jetty). The generated longshore current flowing toward the jetty will predictibly turn seaward as a rip current.

Komar's analysis includes an additional hypothesis. As the shoreline moves out during accretion, an oblique wave approach will be generated. The energy from this setup offsets longshore movement in the opposite direction, away from the zone closest to the jetty(1975). The significance of this scenario is that this offset of energy to a zero line, is the new established equilibrium shoreline configuration which is different from the previous configuration with a straightened shoreface. This new configuartion would be stable because net energy is zero. In turn this new energy regime would call for a modification of the nodal point and a shift in the zone of erosion. This is not the case in Komar's previous hypothesis.

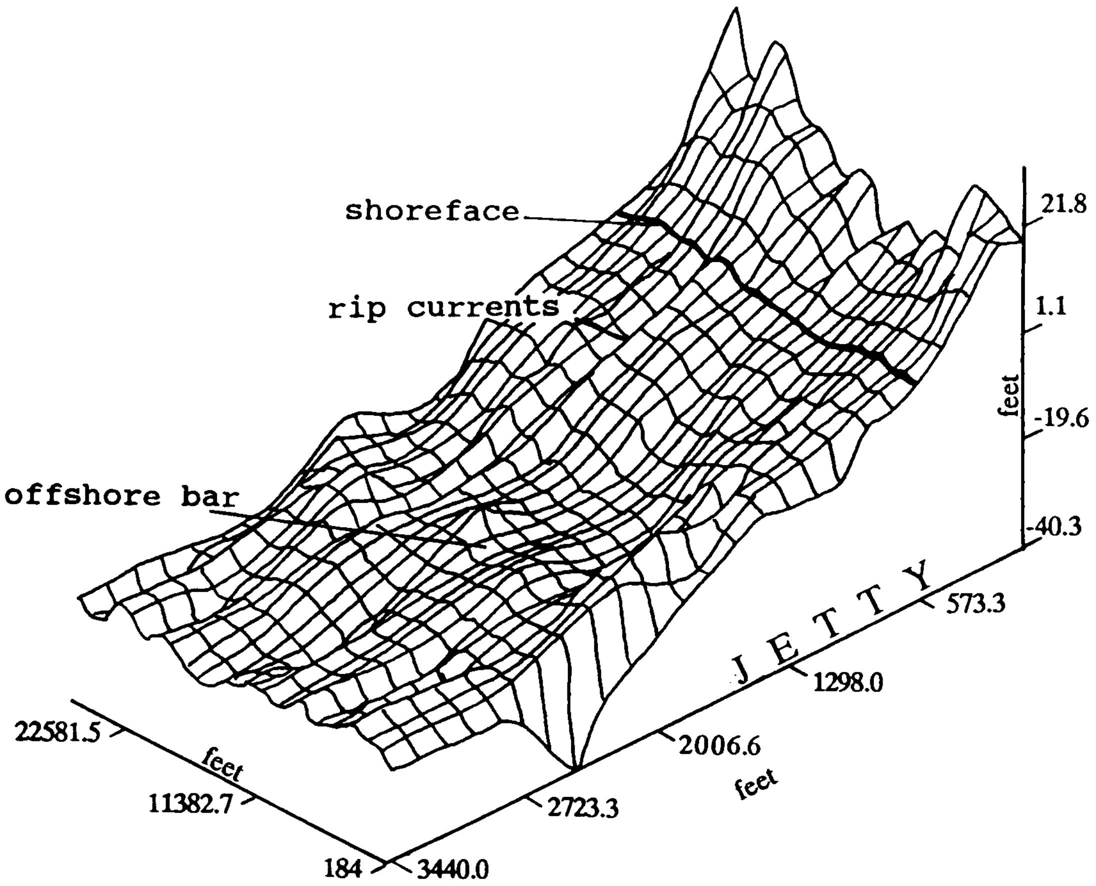
Coastal Processes and Geology

Fox and Davis attempted to quantify the seasonal variation and dispersal of sand on Oregon's coasts(1978). In general the processes of erosion and deposition are recognized as annually cyclic with no net movement of sand along the coast (Komar,1975). The winter wave regime is high-energy, with waves approaching from the Southwest. Average significant wave height varies from three to five meters. During this period sand is removed from the beach face offshore to a bar. The location of this bar varies in its distance from shore depending on the severity of the winter season.

Following this storm-intense period is the spring and summer regime with a change of wave approach to the northwest and a decrease in significant wave height to one to three meters occurs. This change in wave climate results in onshore migration of the offshore bars and replenishment of the beach.

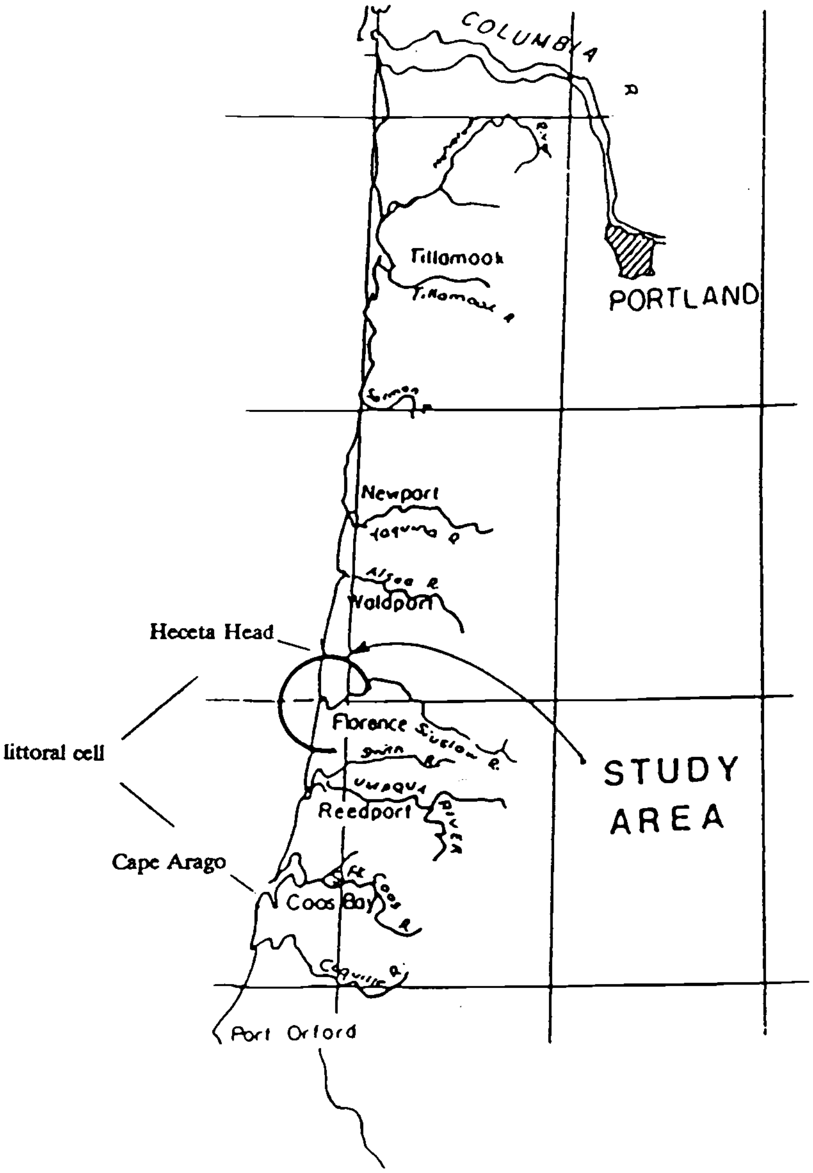
The development of longshore and rip currents (Fig. 3) along the Oregon Coast can modify incoming wave energy in summer and winter. This factor and the pre-existing beach profiles determine the magnitude that the incoming waves will affect the beach face. However, in general, the documented seasonal variation of Fox and Davis (1978) is consistent with present studies along the coast.

Figure 3. Illustration of rip currents, shoreface position, and the offshore bar developed in the winter using a three dimensional Surfer Plot of the North data cell, Spring 1985.



Northbeach 3 /85

Figure 4. The Oregon Coast divided into "littoral cells"



Protruding coastal headlands form barriers to littoral energy preventing movement of sediment around them. These headlands form fairly self contained "cells"(Fig. 4). These littoral cells have been the topic of recent studies to determine if headlands form true barriers to sand dispersal and if large interannual events cause the loss of sand (Peterson, Jackson, et. al.,1990)? The Peterson, Jackson (et.al., 1990) paper also focuses on the importance of the migration of the Aleutian Low versus the effect of El Nino in the movement of large volumes of sand around headlands creating "communication" between the littoral cells (1990). The study area is near the north end of a large littoral cell bounded by Cape Arago 80/50 KM/mi to the south and Heceta Head 13/8 km/mi north.

From precipitation records, the Siuslaw River flow is estimated to be 3150ft3/sec. The diurnal range of tide is 6.9 feet and estimated extreme high water is 11 feet above mean lower low water (Komar, 1975). The tidal prism is approximately 8400 acre feet for the diurnal range (Komar, 1975). Within the study areas littoral cell are two other major drainages, the Umpqua, 21 nautical miles south, and Coos Bay, 40 nautical miles south. Both of these have jetty construction at the entrance. The Umpqua River is the major contributer of sediments to the littoral cell, other than the erosion of headlands, beaches, and dunes. Coos Bay is probably a sink rather than a source of coastal sediment. The Siuslaw River contributes very little sediment, but this contribution is mineralogically distinct from the Umpqua sediments (Chesser and Peterson, 1987). Deglaciation and recent sea level overcompensates for the uplift of the coast, so these drainages are entrenched valleys (Niem, 1976).

METHODOLOGY

Beginning in 1981, the U.S. Army Corps. of Engineers (COE) began beach profile surveys of the area immediately adjacent to the jetties. These surveys were conducted using standard stadia rod and transit. Profile lines were established symmetrically about the jetties. For the first 3000 feet away from the jetties the profile lines are closely spaced, and then set at about 1000 foot intervals afterwards. The surveys measured the elevation from a permanent baseline behind the foredune to a minus 20 foot water depth (Chesser, 87).

Standard land survey techniques were used for the beach and dune portion. Offshore measurements were conducted using a helicopter, with a measured cable suspended with a ball on the end. Contact of the ball to the ocean floor caused a break in the measured cable, which was sighted from shore by the transit. Each profile line has approxiamately 120 points, each with an x,y, and z coordinate (X represents its distance fron the jetty, Y is the distance form shore, and Z is the elevation).

These profiles surveys were conducted twice a year. Once in the spring, after the end of the winter season, and then again in the fall, after the summer season, but before the fall/winter storms begin.

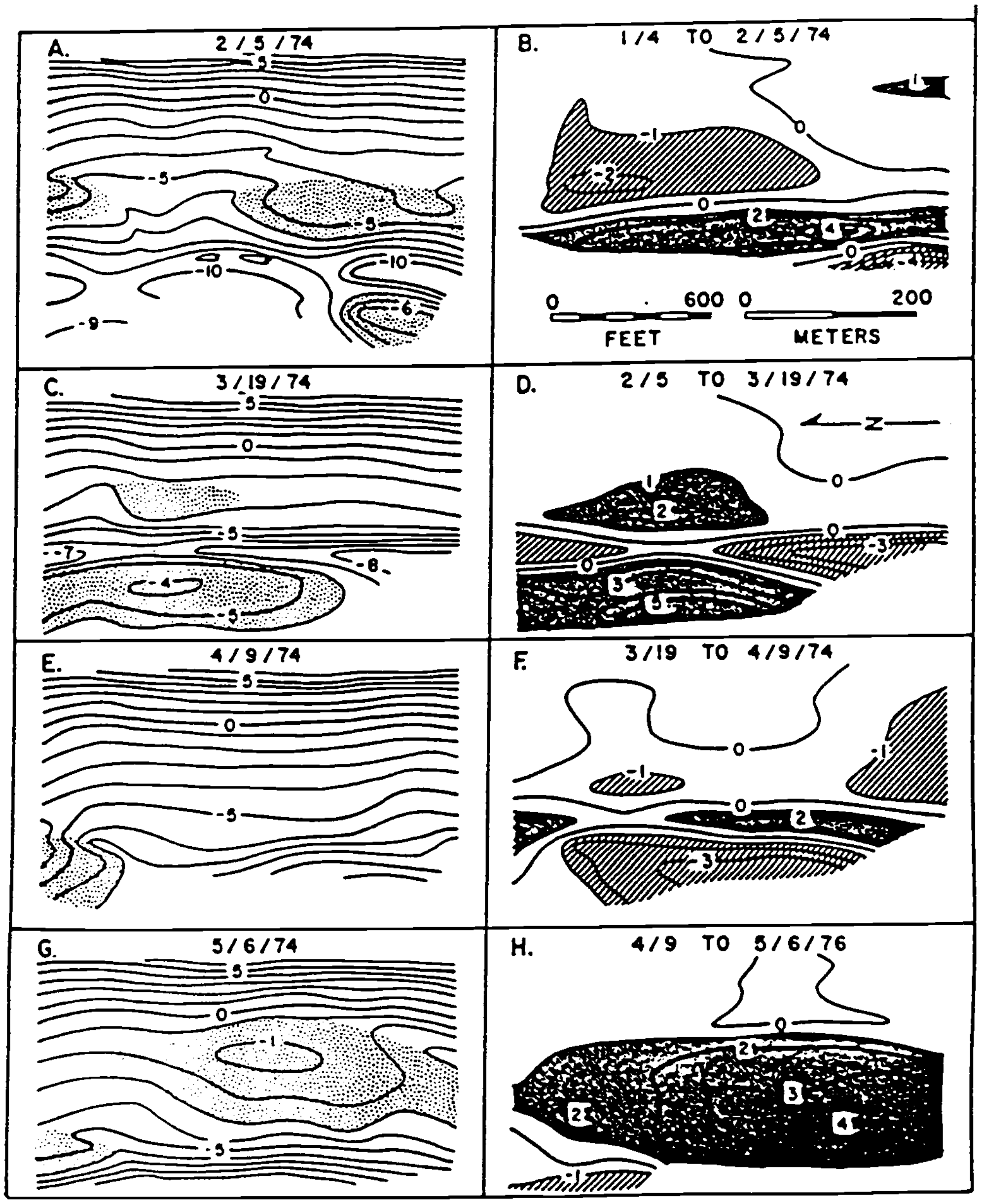
The COE's data processing for the area computes exact volumes of sand eroded or accreted along any given line of profile. But if analyzed only longitudinally, profile line by profile line, an intergrated analysis of the entire area is difficult. The must useful method for analysis is to create topographic maps and three dimensional plots of the area (Fox and Davis, 1978). Fox and Davis employed these methods in their analysis of seasonal variation around Yaquina Bay (Fig. 5).

In an effort to efficiently analyze this data, key years were selected for the morphological, graphical, and statistical analysis. 1981, because it is the first year. 1985 because it clearly after the El Nino winters, and the first after jetty construction completion, 1989 and 1990 because they are the farthest surveys form the end of the jetty construction.

The COE filed this data in files within an Interactive Survey Reduction Program (ISRP) Data Program. This program allows analysis of individual profiles from which volume change can be calculated. Profiles of each line over time can be plotted as well.

This analysis was based on the IBM program; SURFER, which uses the x,y,z coordinate data to create a grid for two and three dimensional representations. In the case of the Siuslaw data a 25 by 25 grid was used. A volume comparison was conducted for 1989 data using a 100 by 100 grid with no significant difference between the two grids. The data was entered in separate files for the areas North and South Cell of the jetties. These two

Figure 5. Example of topography and isopach maps developed by Fox and Davis to quantify seasonal sand distribution (1978).



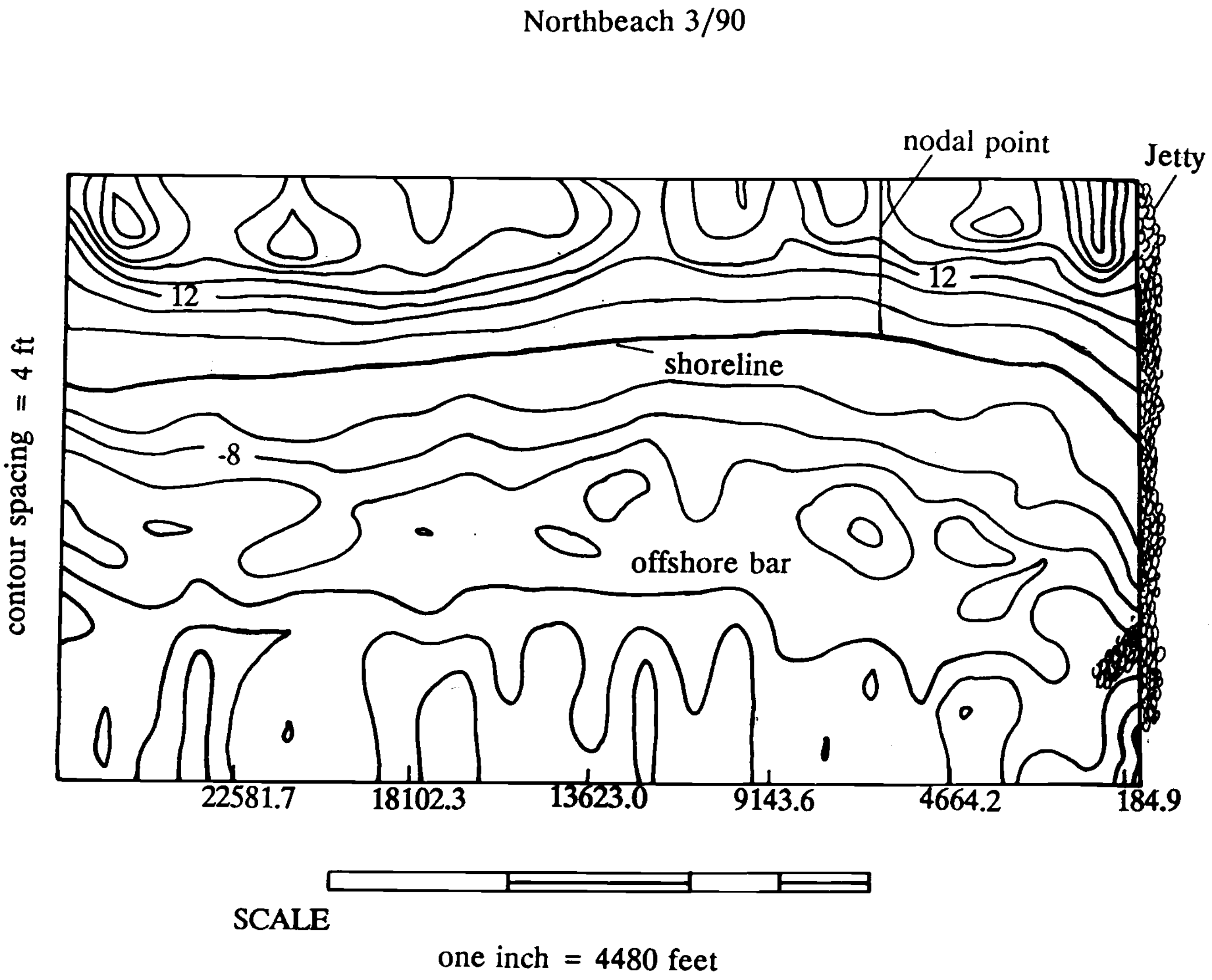
files representing the north cell and the south cell have been modeled separately. Because the profile data set to the southbeach is a little longer than Northbeach, the scales for these two are different. The scales were set for convenience and to minimize distortion. All the plots have some horizontal exagerration. This value hovers around 25%.

SURFER calculated volumes changes, plotted topography maps, and created three dimensional plots of the two cells. From the maps generated, shoreline positions were analyzed, the nodal point was identified, and the position of the offshore bar located (Fig. 6).

The occurence of El Nino was both a blessing and a hazard. Ten years of semi-annual data that also spans an El Nino event is a rare occurrence on the Oregon Coast. The Study area is the northern section of the largest littoral cell on the Oregon Coast (Komar,1975). The entire littoral cell, extending from Heceta Head to the north to Cape Arago to the south, is sixty miles long. The Siuslaw jetties are six miles south of Heceta Head.

The Study area is a small unit, **the data cell**, within the larger littoral cell. This data cell extends five miles north and south of the jetties. To first tackle this analysis I divided the Data Cell into subcells. These are termed the North Cell and the South Cell with respect to the jetty. On the basis

Figure 6. North data cell topo map with offshore bar, shoreline position (bold) and the nodal point illustrated. The spring survey of 1990 was selected for further illustration of the topographic variation between spring and fall.



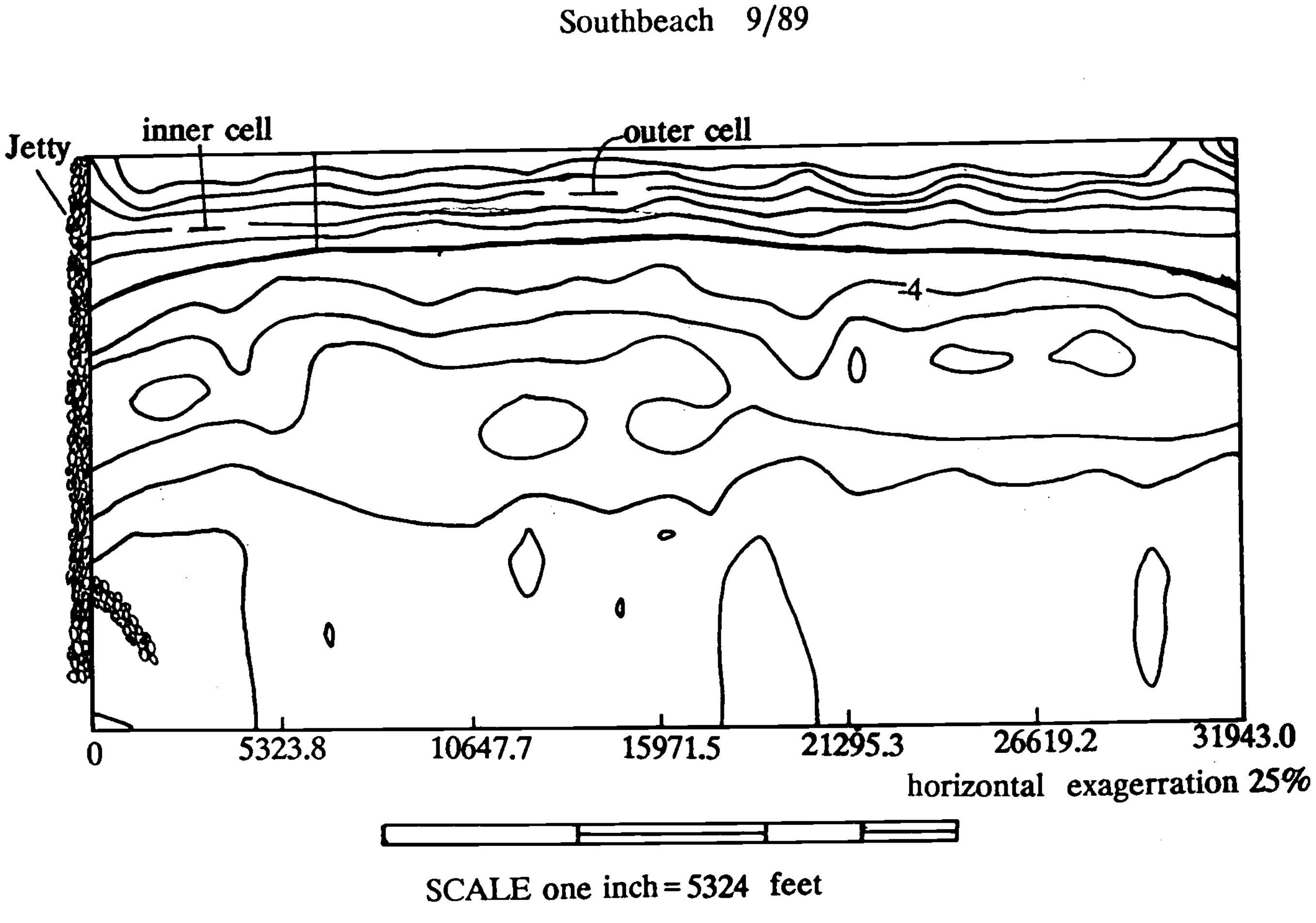
of the nodal point location each cell was divided into an inner and an outer cell. The inner cell being closest to the jetty (Fig 7).

The first problem that arose was the positioning of the offshore bars that form as a receptacle of sand being eroded off of the beach face during the winter. The topographic maps generated by SURFER and the profiles generated by ISRP (Chesser,1987) illustrate that the data cell did not always include the offshore bar. Because of this, winter volume comparisons are not valid. All volume comparisons are based on the fall readings after summer seas have returned the offshore sand to the beach, or at least within our "data window".

The second problem was to separate the El Nino storm effect on sand distribution from any caused by the jetty extension. Is it possible to separate the jetty effect from the climatic forcing event? There is really no way to know how far offshore El Nino carried out the sand in the winter of 1982-1983. Conceivably, that sand was lost completely from the littoral cell altogether. By dividing the North and South cell into an inner and outer cell, statistical analysis was able to focus on the changes in the way these two subcells varied fron one another. This eliminated the affect of El Nino from the statistical analysis by focusing on alongshore response and not on volume change alone.

This division of inner and outer cells was an attempt to bracket the area most sensitive to jetty construction. I based

Figure 7. Example of the division of inner and outer sub-cells using Southbeach Cell 1989. The nodal point is drawn as a division between the inner and the outer cell.



the delineation of the inner and outer cell on profile spacing, and morphological change in the shoreline. These two factors coincided well.

The location of the nodal point matches the change in profile spacing from a tight cluster to wider spacings. Because I wanted to substantiate this nodal point location with volume characterization, I divided the north and south cell into 25 unit cells, and computed volume changes for all years, unit cell by unit cell, with 1981 as a normal base. Figures 8a and 8c graph these unit to unit volume changes for the individual years for the Northbeach cell and the Southbeach cell respectively. Figures 8b and 8d combine all years for the Northbeach and Southbeach cell to illustrate this volume characterization point. This data break coincides geographically with the nodal zone. The upper unit cells (the inner sub-cell) are the most sensitive, while the rest (the outer sub-cell) are less sensitive. The volume change characterization, morphological change of the shoreline, and spacing of profile lines are the basis of the inner and outer cell differentiation.

1981 was set as the standard for volume variance between the inner and the outer cell for both the North and South cells. The data for the other three years was compared to 1981 to assertain if that standard variance was altered post-jetty extension. Although El Nino causes a net loss of sand, it does not change processes that affect the littoral zone, so that the normal

Figure 8a. Northbeach cell volume comparison unit cell by unit cell. There are 24 unit cells with the unit cell adjacent to the jetty on the left, and distance increasing away from the jetty to the right along the x-axis. Volume change is in millions along the y-axis with plots for each unit cell extending either above or below a 0 datum line.

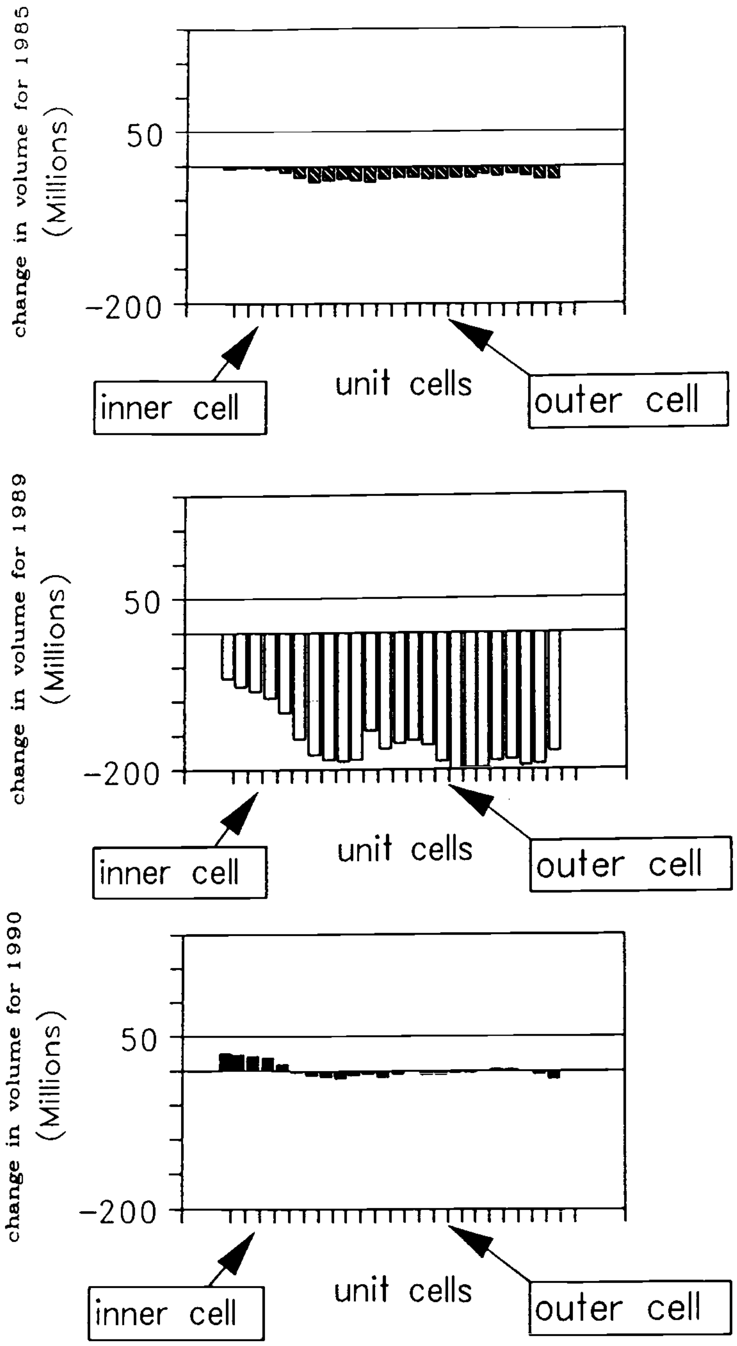


Figure 8b. Combined bar graph of all years for the Northbeach data cell. The arrow indicates the characterization point where volume change increases in magnitude. This point correlates with the topographic expression of the nodal point.

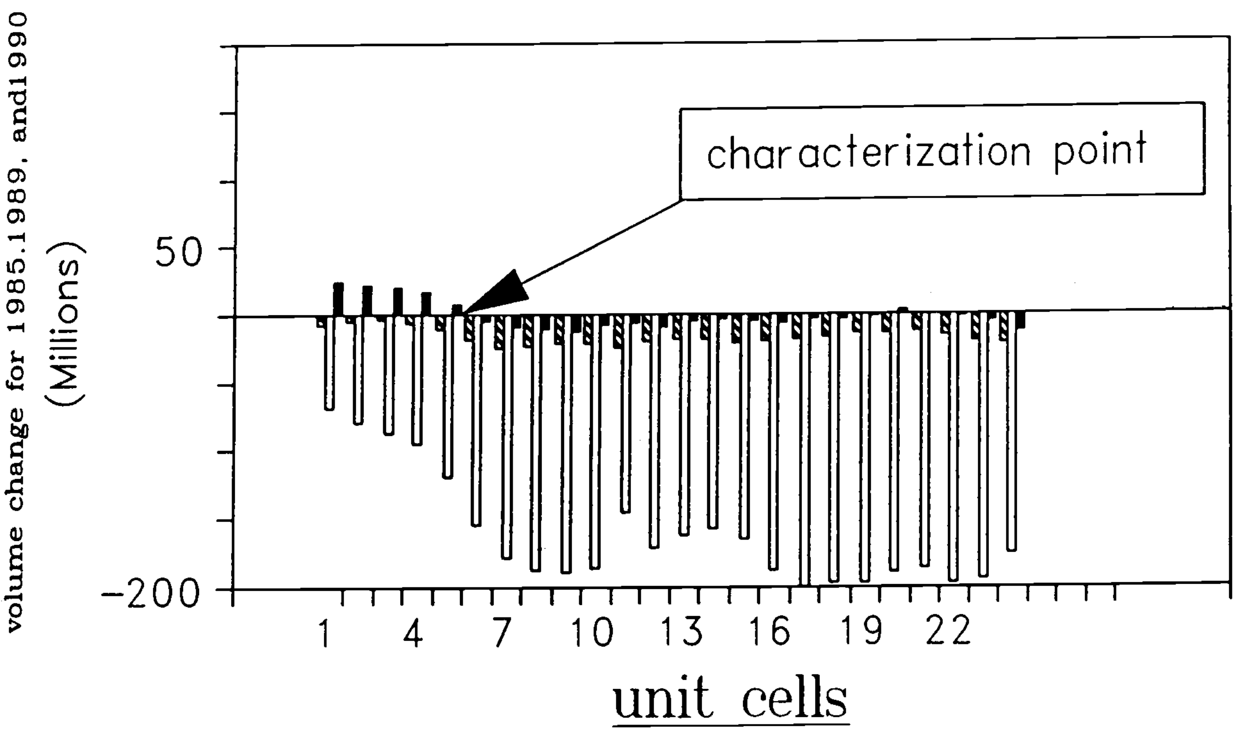


Figure 8c. Southbeach cell volume comparison unit cell by unit cell. There are 24 unit cells with distance away from the jetties increases to the left along the x-axis. Volume change is expressed in millions along the y-axis with the plots for each unit cell extending either above or below a 0 datum line.

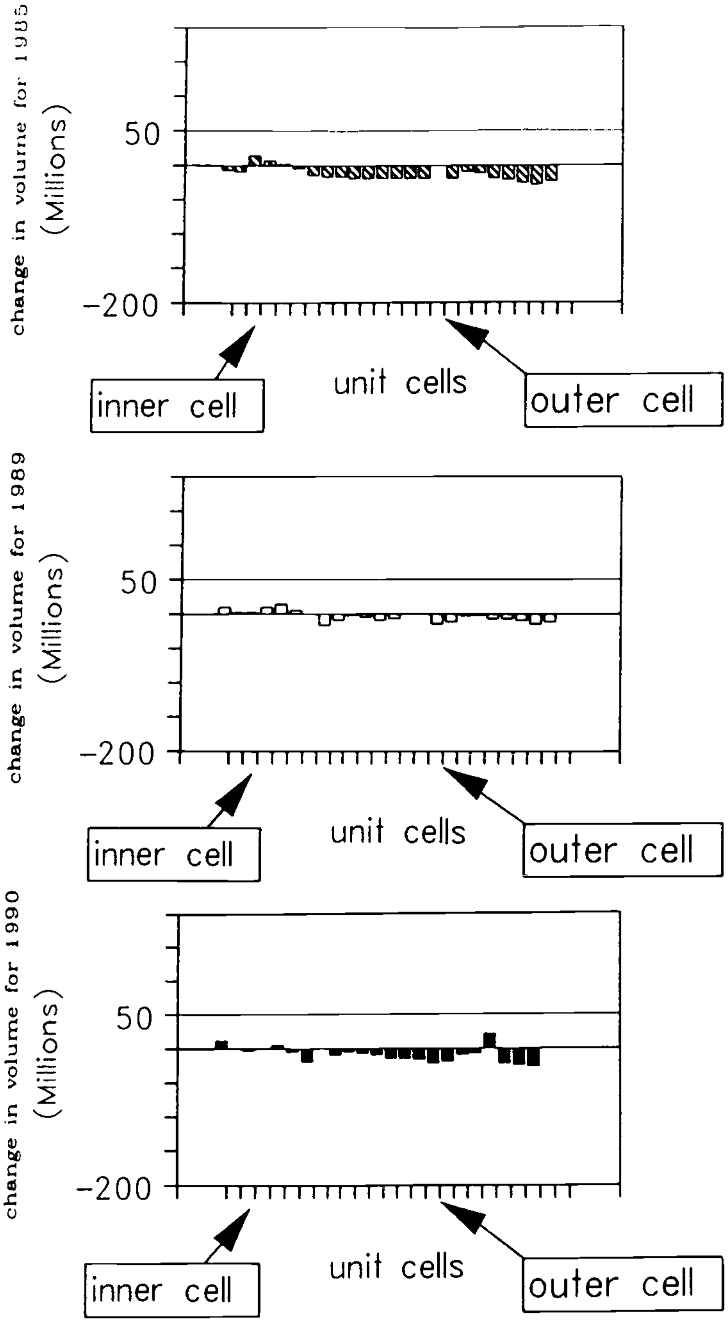
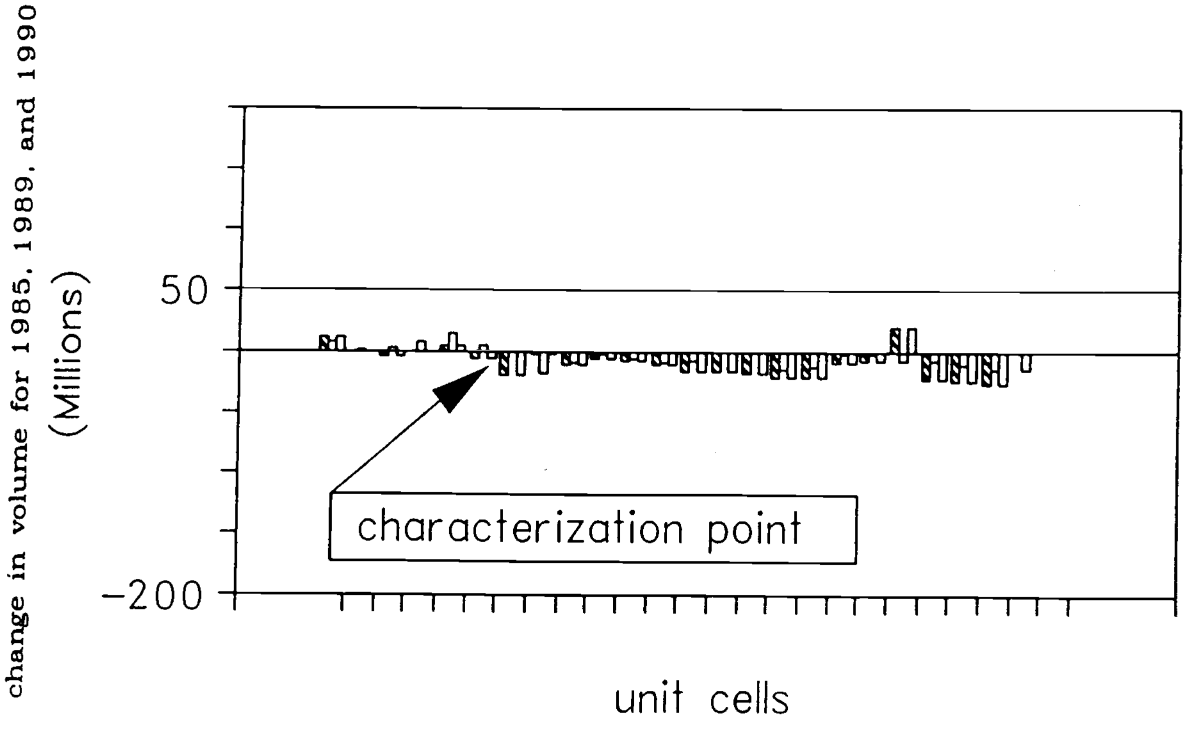


Figure 8d. Combined bar graph of all years for the Southbeach data cell. The arrow indicates the characterization point where volume change increases in magnitude. This point correlates with the topographic expression of the nodal point.

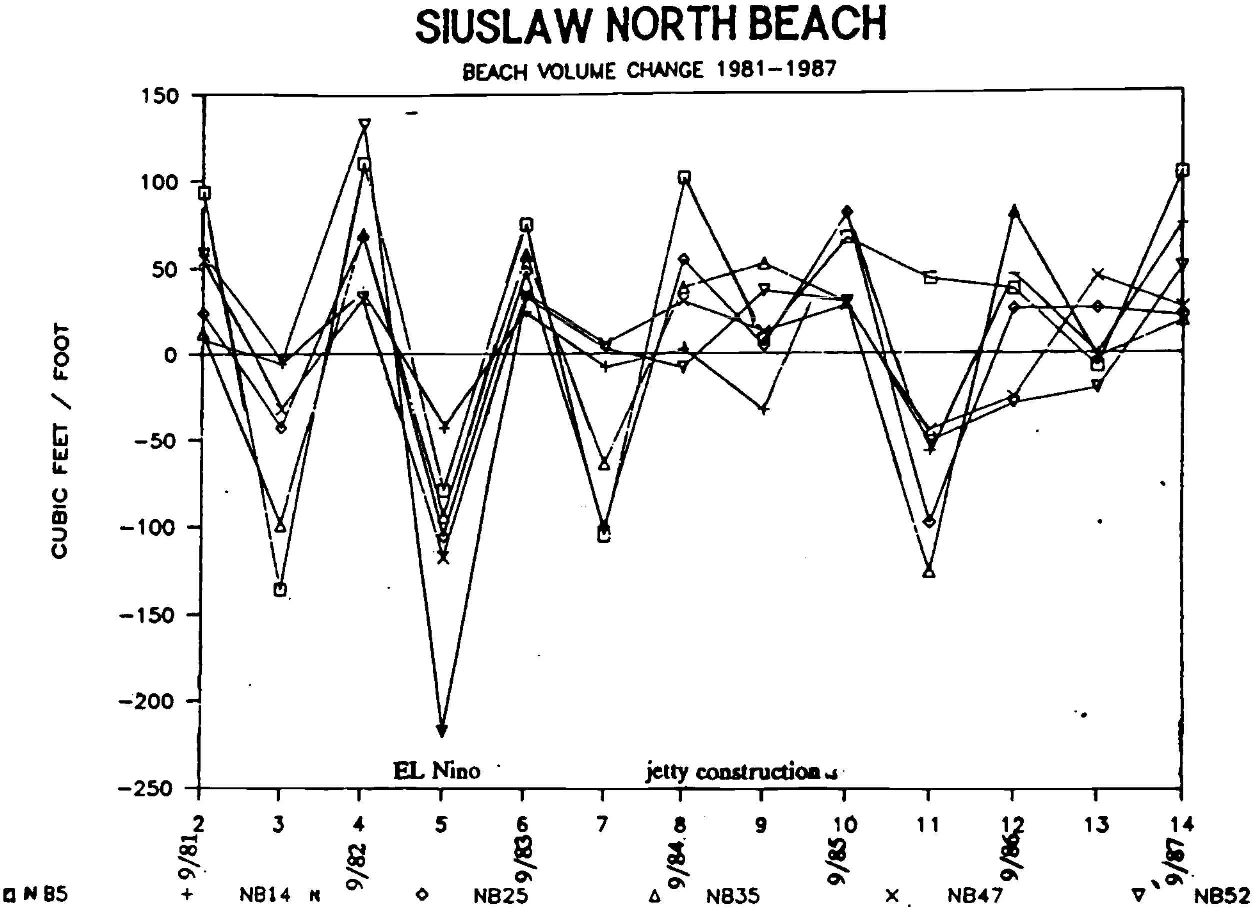


variance between the inner and outer cell is not disturbed. This was shown by Chesser(1987) qualitatively by comparing beach erosion/accretion cycles for several individual profiles (fig 9). This figure has spring as well as fall comparisons, shpwong the intreannual changes in beach erosion/accretion. Notice that prior to 1984 the volume variance between seasons rotates around the 0 volume line. After jetty construction, this pattern is completely disturbed. If indeed the jetty extension alters the nearshore processes, then the variance between the inner and outer cell will change in respect to the observed natural variance of 1981

Assuming that the two effects are separated, an analysis of variance for these years comparing volume differences between the outer and inner cell and how the variance of volume changed or didn't change through the El Nino and Jetty event can be completed. If the jetty event caused no alteration of the nearshore environment then 1981 (outer and inner)=1985 (inner and outer)=1989(inner and outer)=1990(inner and outer). This previous statement is the Null Hypothesis, with an Alternate Hypothesis that at least one mean differs.

To accomplish this analysis the Tukey Test for difference was implemented. This test is part of the analysis of variance,attained through a comparison of means. The Tukey-Kramer method is used when a multiple coparison of means is being implemented and there is no prior bias, no **planned** comparisons to be made. In this case I was asking, "which means differ from which others".

Figure 9. Volume Comparison for 1987 U.S. COE report (Chesser, 1987). Chesser has chosen specific profile lines along the northbeach cell and compared their volume change over time including spring and fall plots. Prior to the jetty construction spring profiles are a mirrored image of the fall profiles. At the time ofjetty construction these plots are no longer symmetrical. The fall surveys are labeled, with the spring profile in between.



OBSERVATIONS AND CONCLUSIONS

Observing the graph from Chesser (Fig 9) one of the most striking pattern is the mirrored image of volume change between spring profiles and winter profiles. Prior to the jetty construction the volume changes almost invert perfectly over the 0 datum line. After jetty construction this pattern is disrupted. The profile most proximal to the jetty, NB5 is the only profile representative of my inner cell. NB5 shows great variation from that previous fall/spring pattern. To answer the first question posed by my study: This study area has volume variations on a scale that is graphical. In addition, the changing morphology of the surface is present on the topographic maps (see Appendix I) in terms of moving shoreline, changing position and geometry of the offshore bar as well as the location of the rip currents which add to the dynamic nature of this environment.

Several decisions were made during the approach towards answering the question of the source of this changing volume. After surveying the three dimensional diagrams and topographic maps it was evident that the offsore bar was not always present within the DATA CELL. Because of this, I based volume comparisons on fall to fall only.

Morphological assessment of change indicates that shoreline position varies drastically on the north after 1982-1983, due to a great volume change following the El Nino winter. The shoreline position of the north cell retreats after the EL Nino winters, but seems to regain most of it's lost volume. The zero data line of the topography maps which designate the shoreline hovers around 1000 feet from survey baseline =/- 150 feet. The South Cell's shoreline is relatively stable throughout the entire time period.

The north and south nodal point, located as a "zone " on the topography maps,stays stationary until 1990, indicating no change in the erosion-accretion regime of the shoreline up to this point. A change in the nodal point is observed in the topography of 1990 when accretion is accentuated around the jetty in the south cell, and the North Cell shows a shift of the nodal zone, 2000 feet to the south. no change in the erosion-accretion regime of the shoreline up to this point. A change in the nodal point is observed in the topography of 1990 when it's position shifts south almost two thousand feet.

Is this shift a threat? Because of the erosive nature of the North Cell (Komar, 1975), developed areas will always have the threat of beach recession, but this erosive nature is not necessarily correlated with the jetty extension. The North Cell has exhibited extreme erosion prior to the Jetty extension (Komar, 1975). If anything the shift in the Nodal position southward will keep the zone of erosion away from the Heceta Community.

In 1990 a change of the nodal position on the south or at least an attenuation of accretion around the jetties occurs.

These fall to fall comparisons indicate that the overall volume change for 1981 and 1989 is minimal, while the volume change between these two years and 1985 is large. The statistical analysis would not have been possible had I not found a way to separate the jetty effect from the climatic forcing event. The statistical analysis suggests that the null hypothesis should be rejected (See Appendix), because 1981≠1985≠1989≠1990. This suggests that some modification of the nearshore environment due to the 1985 jetty extension has occurred. The Tukey-Kramer test is **suggestive.** It is recommended that the statistical analysis be strengthened by including all of the data years in order to establish a significant trend. With the inclusion of more data in a statistical analysis it would be possible to not only give a multiple comparison of means by way of an ANOVA, but it would also be possible to complete a regression analysis that would include the climatic forcing event and the jetty constuction. As it stands four years does not exhibit a significant trend for regression, and does not lend any strong conclusive statistics.

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APPENDICES

APPENDIX I

The following are the topography map plots for both surveys from 1981,1985,1989, and 1990. The contour spacings are in four-foot increments, with the 0 contour line marking the shoreline position. Because of the way the data were entered originally from the field surveys, these plots are mirrored images of what they should be.

The following should be noted as these topographic maps are examined:

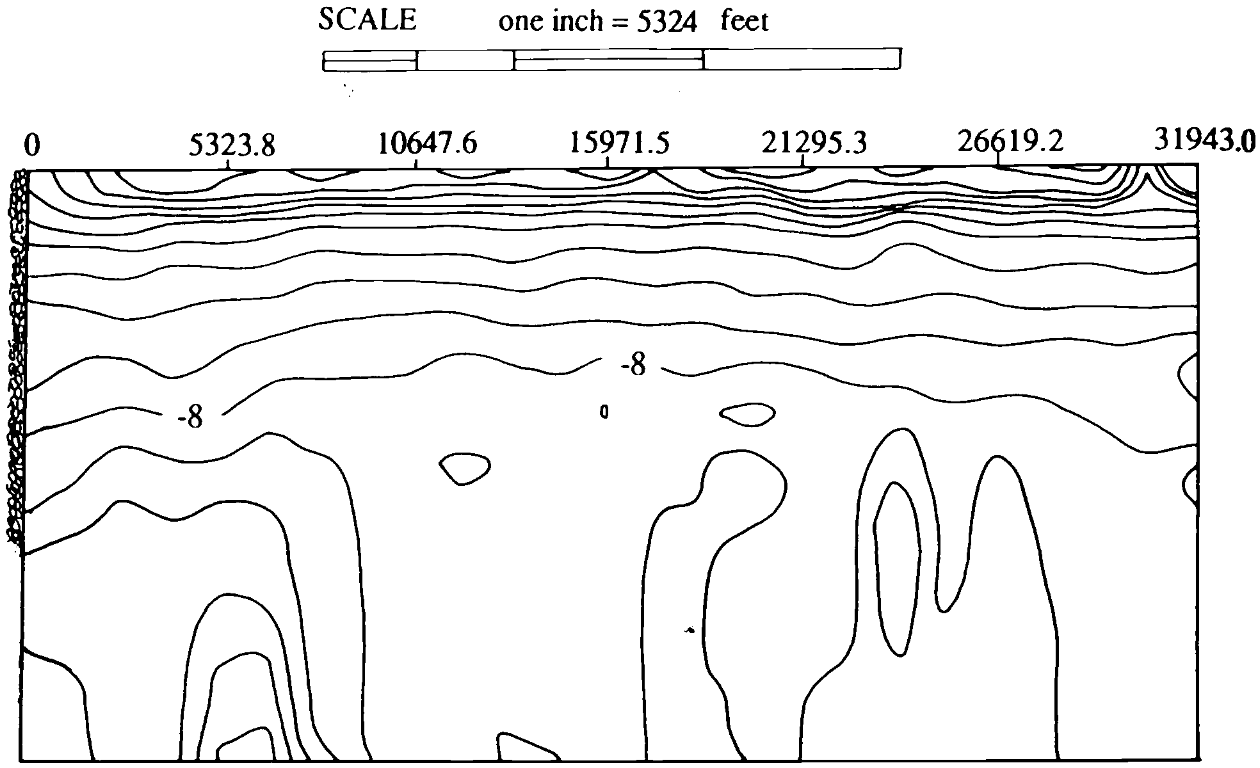
(1) the dicotomy in the Northbeach plots of sand volume between spring plots and fall plots.

(2) the general shift of the shoreline basinwasrd during spring and landward in fall.

(3) the large effect of rip currents controlling the offshore topography of Northbeach 5-81 that does not appear in any of the otehr plots.

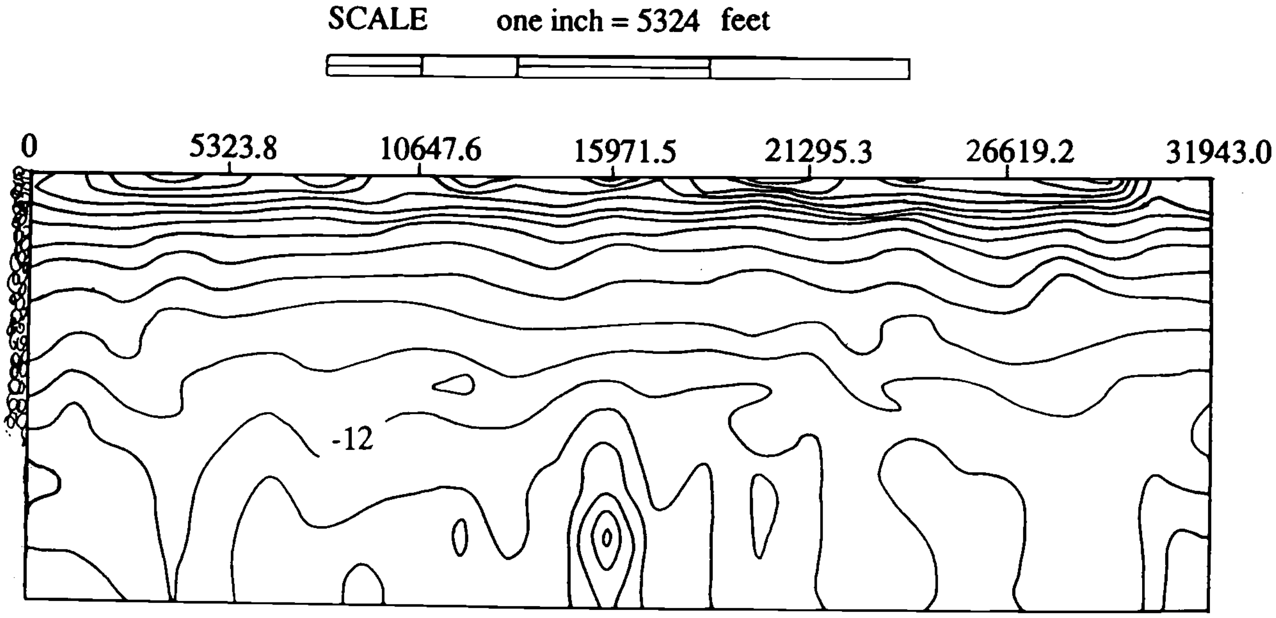
(4) a data discrepency with the COE Data set causing an anomalous Northbeach 9-89 topographic plot.

(5) the southbeach shoreline doees not shoe the vairance exhibited by the Northbeach plots.



Southbeach 9/81

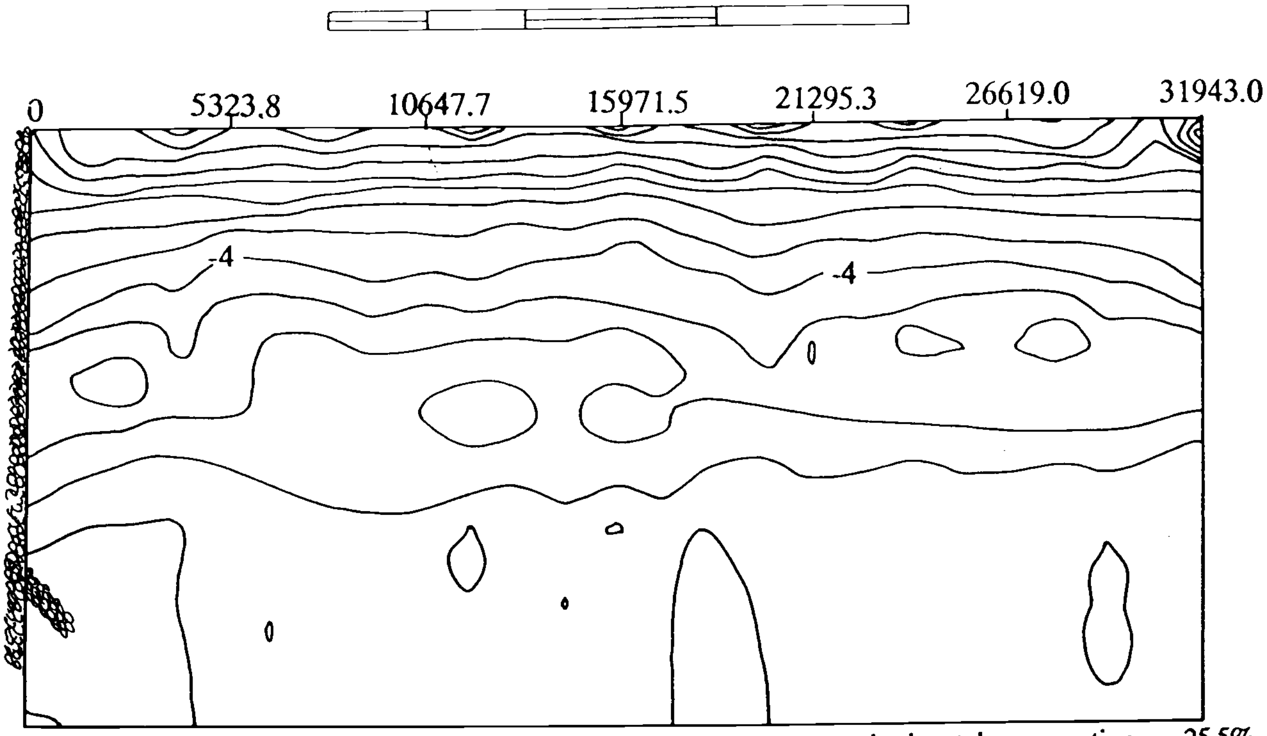
horizontal exagerration = 24.5 %



Southbeach 5/81

horizontal exagerration = 24.8%

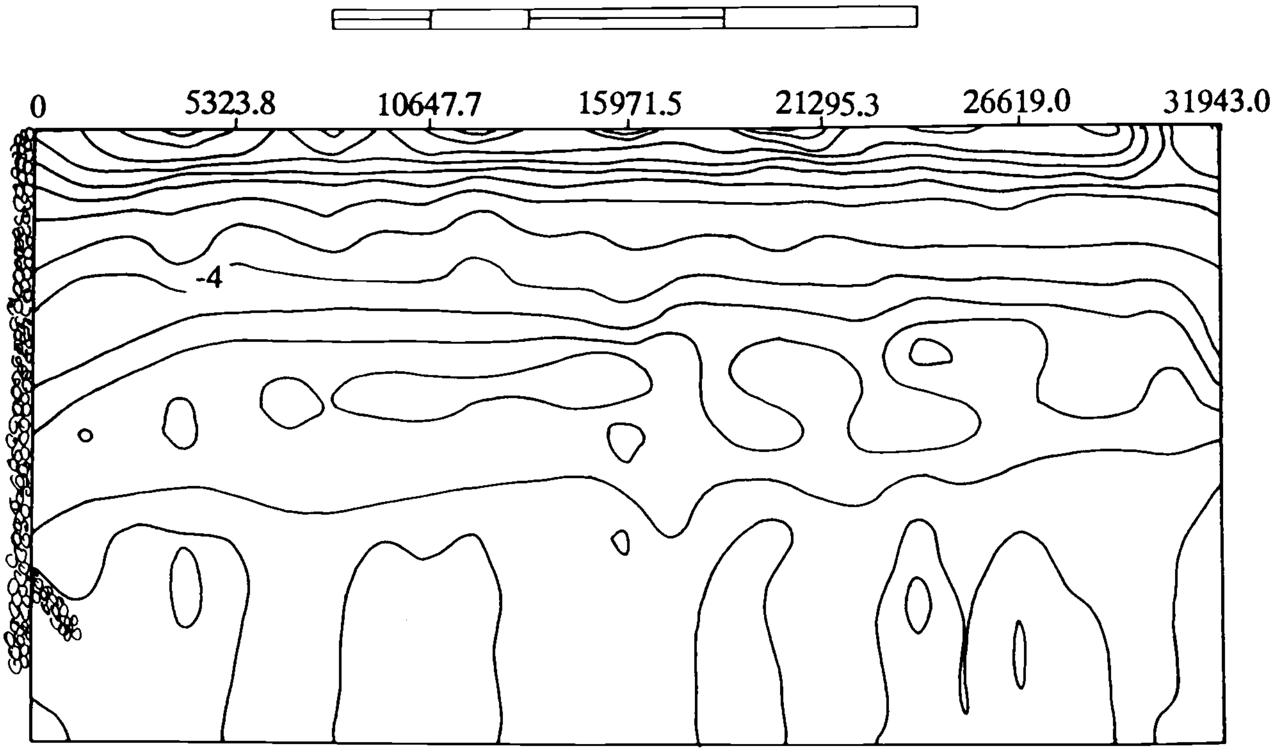
SCALE one inch = 5324 feet



horizontal exagerration = 25.5%

Southbeach 9/85

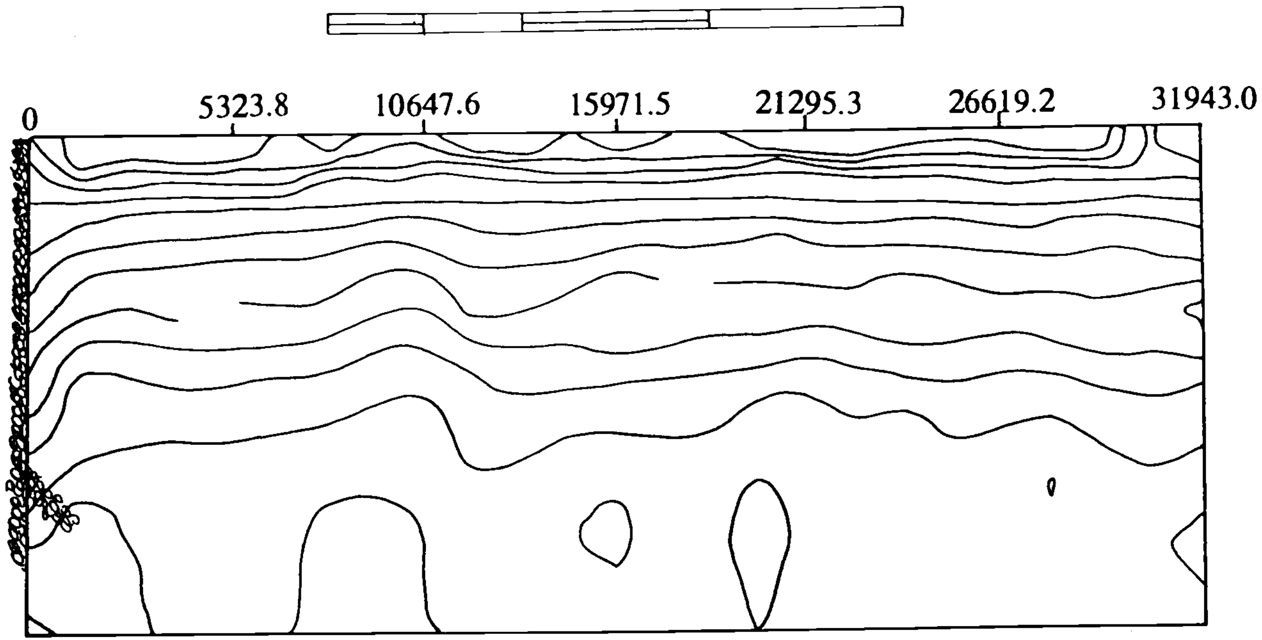
SCALE one inch = 5324



horizontal exagerration = 25.5 %

Southbeach 3/85

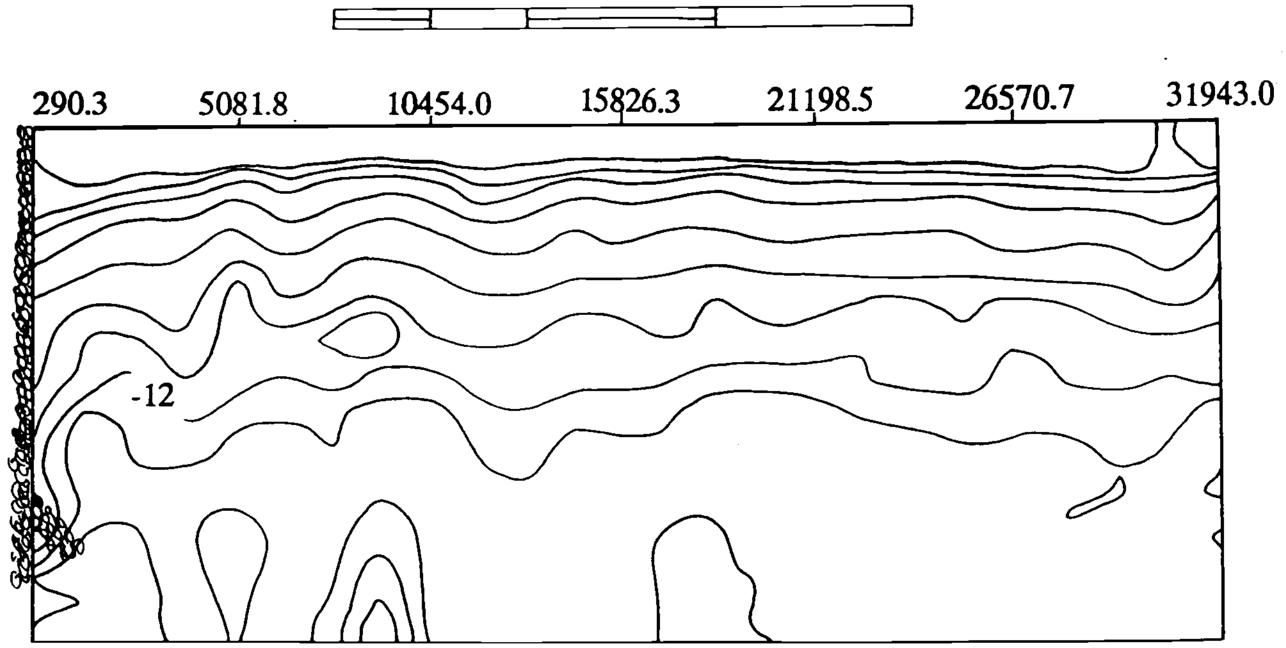
SCALE one inch = 5324 feet



Southbeach 9/89

horizontal exagerration = 25.5%

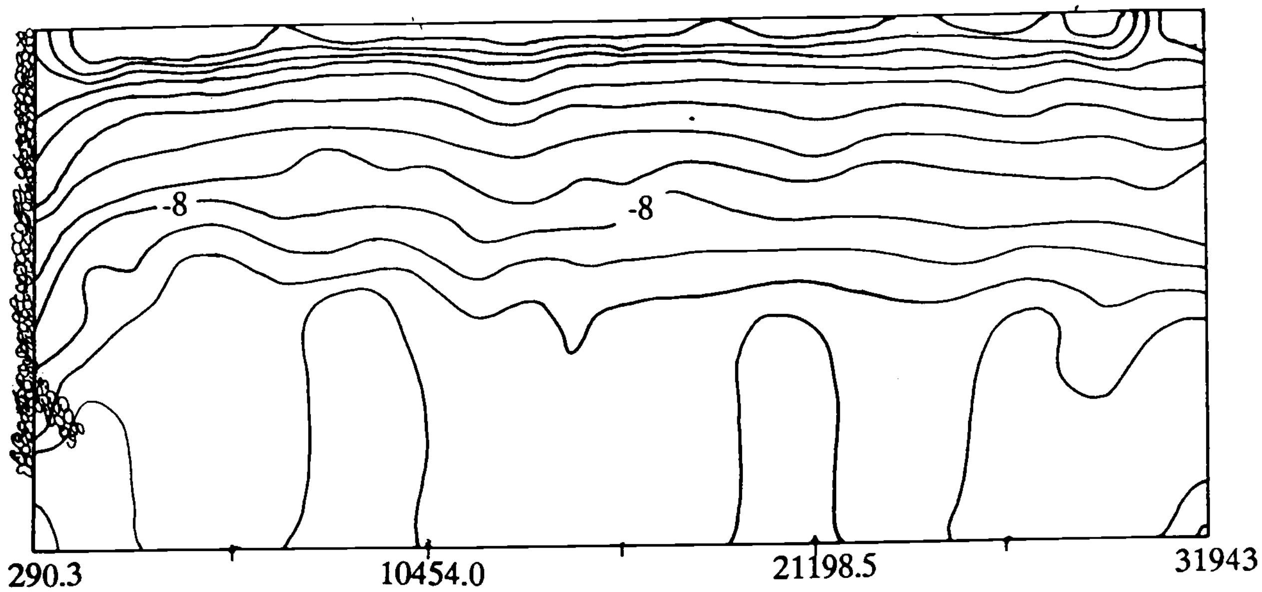
SCALE one inch = 5372 feet



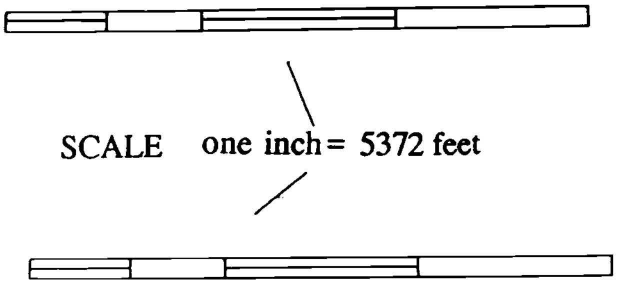
Southbeach 3/89

horizontal exagerration = 24.4 %

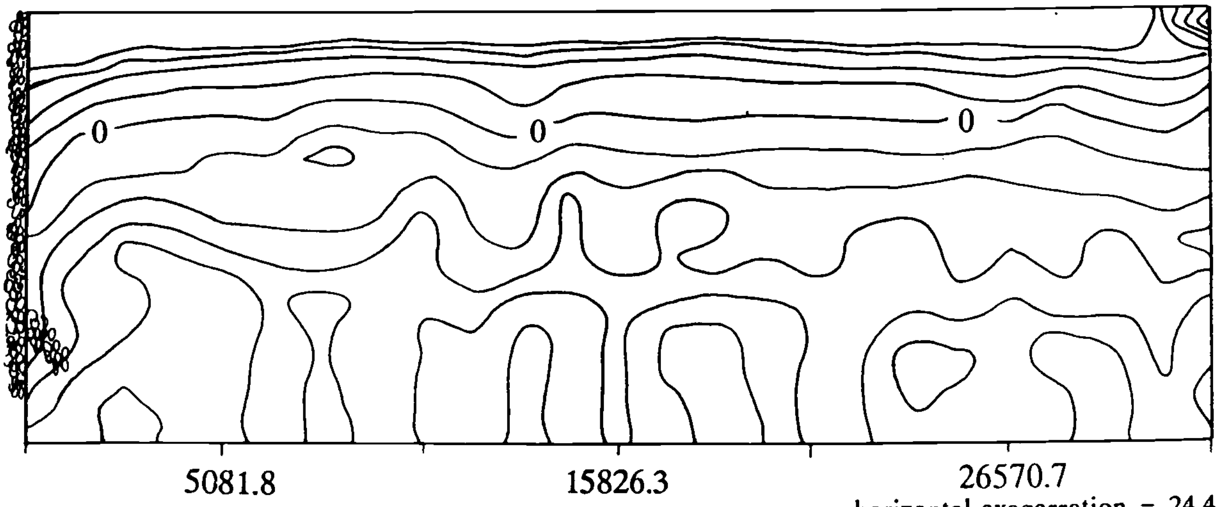
Southbeach 9/90



horizontal exagerration = 25.5%



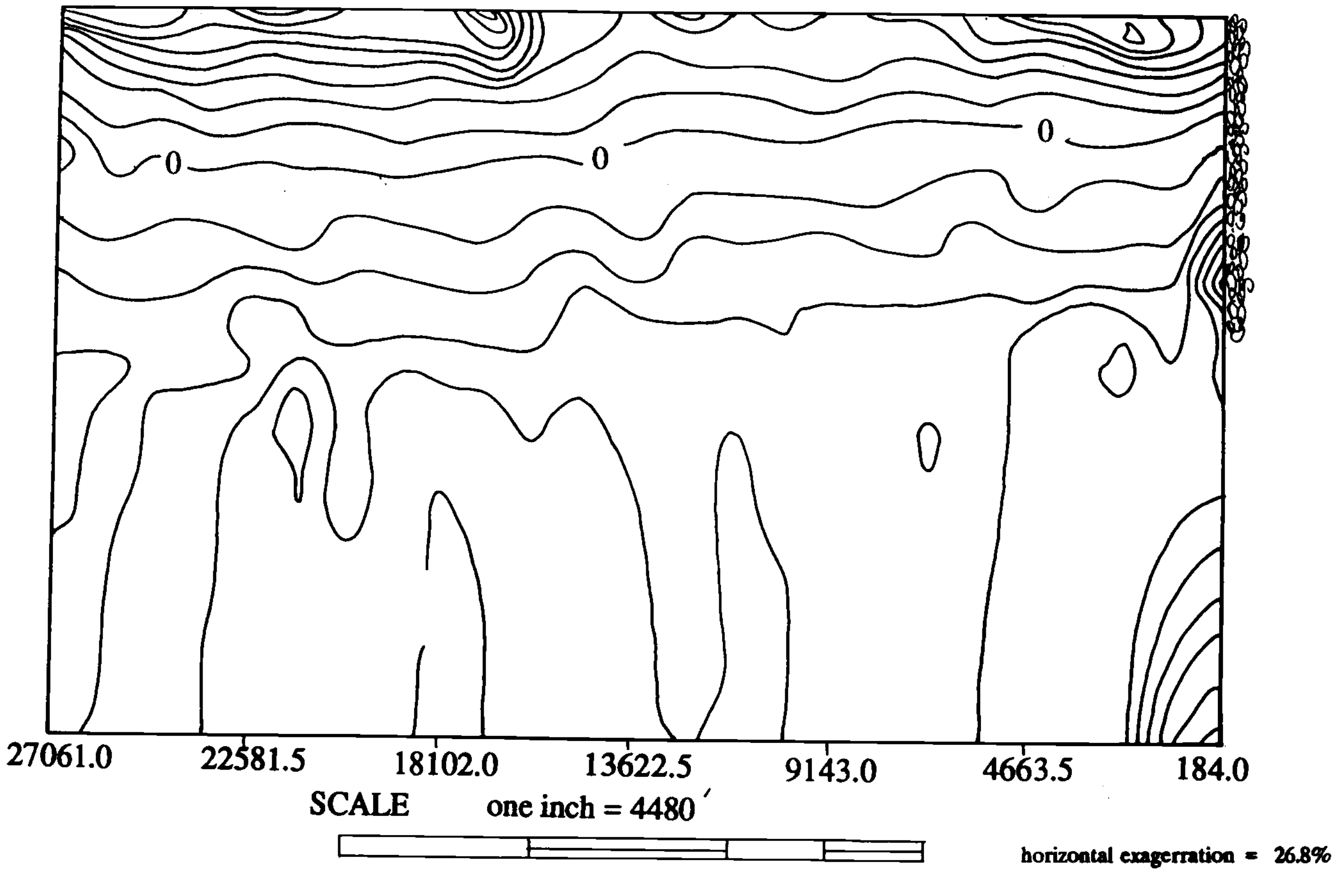
SCALE one inch = 5372 feet



horizontal exagerration = 24.4 %

Southbeach 3/90

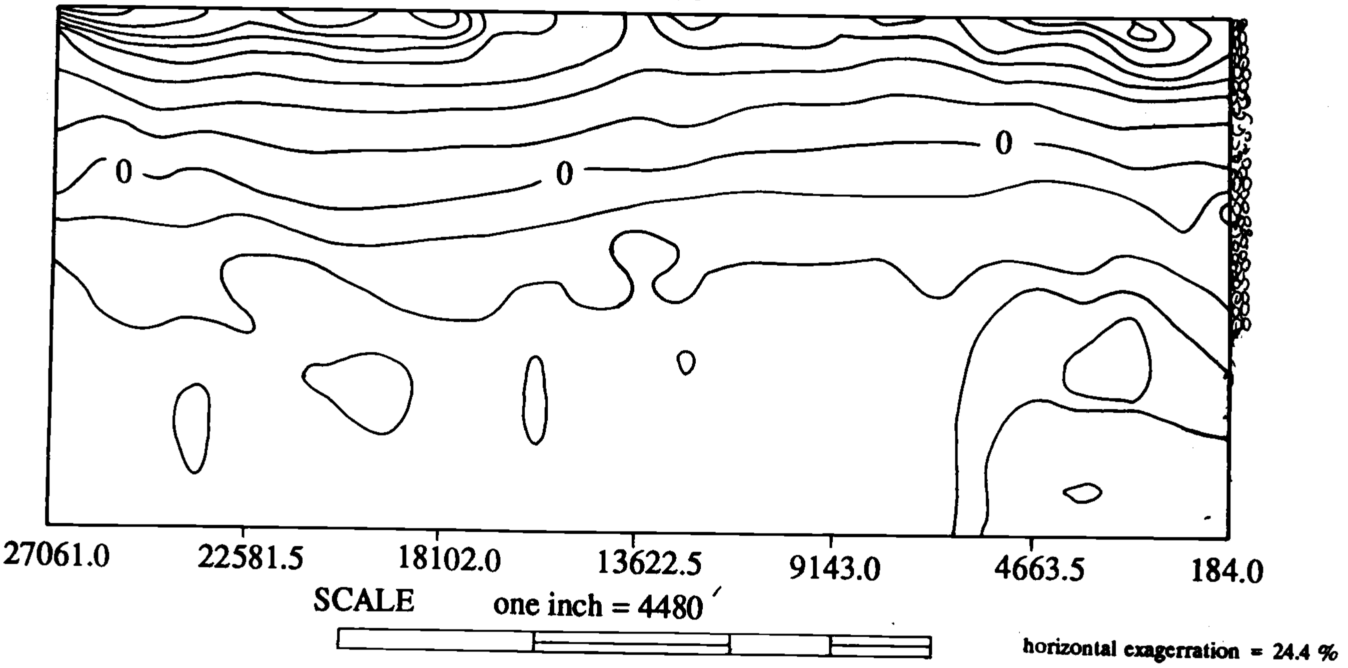
Northbeach 5/81



SCALE one inch = 4480′

horizontal exagerration = 26.8%

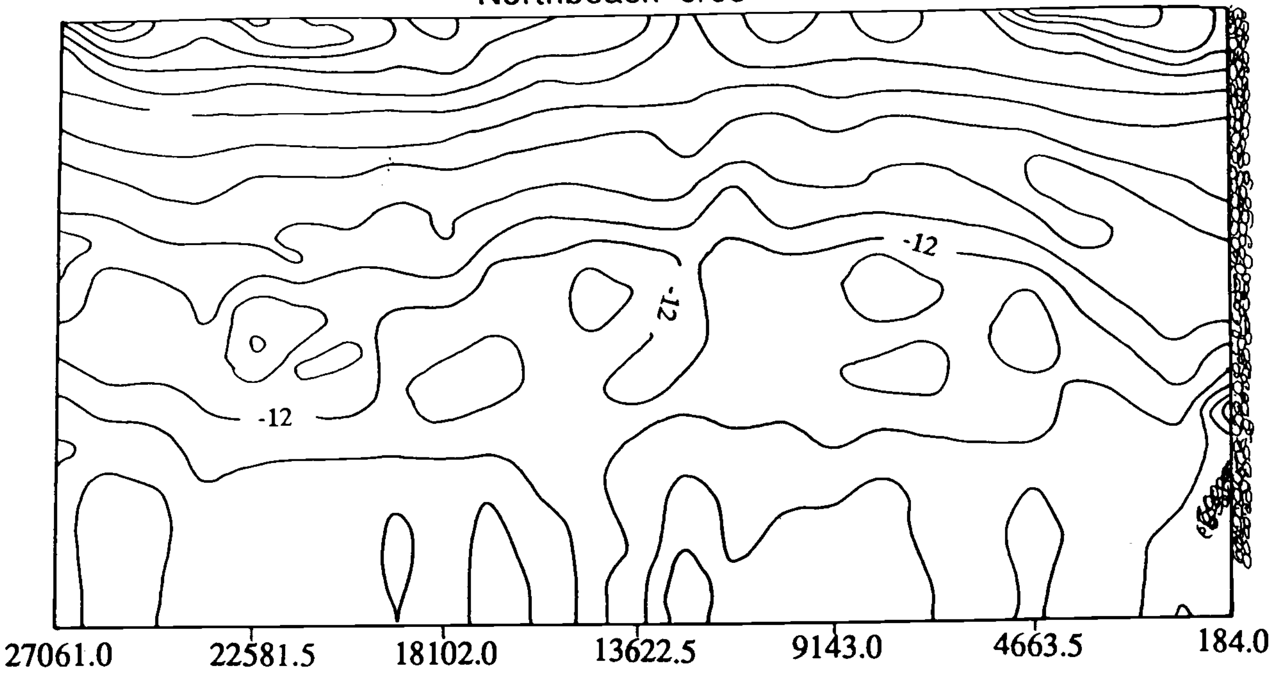
Northbeach 9/81



SCALE one inch = 4480′

horizontal exagerration = 24.4 %

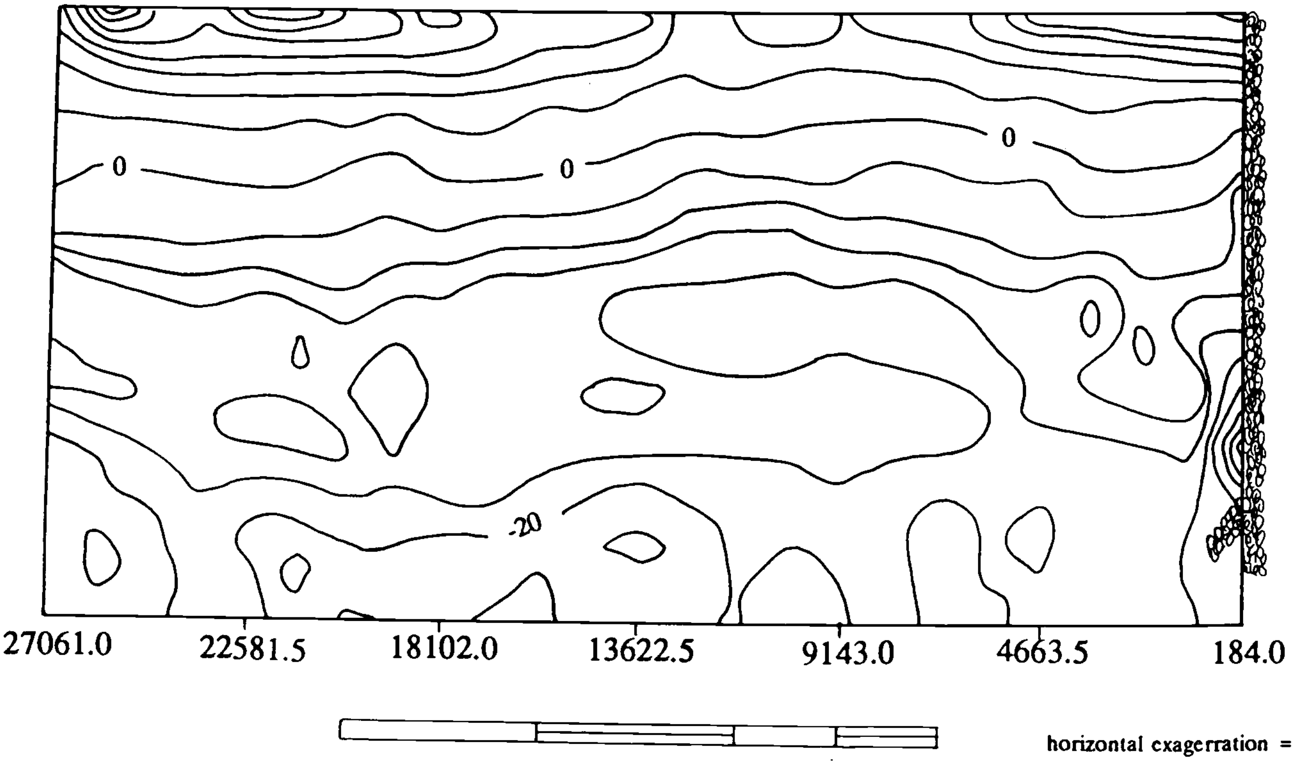
Northbeach 9/85



horizontal exagerration = 25.5 %

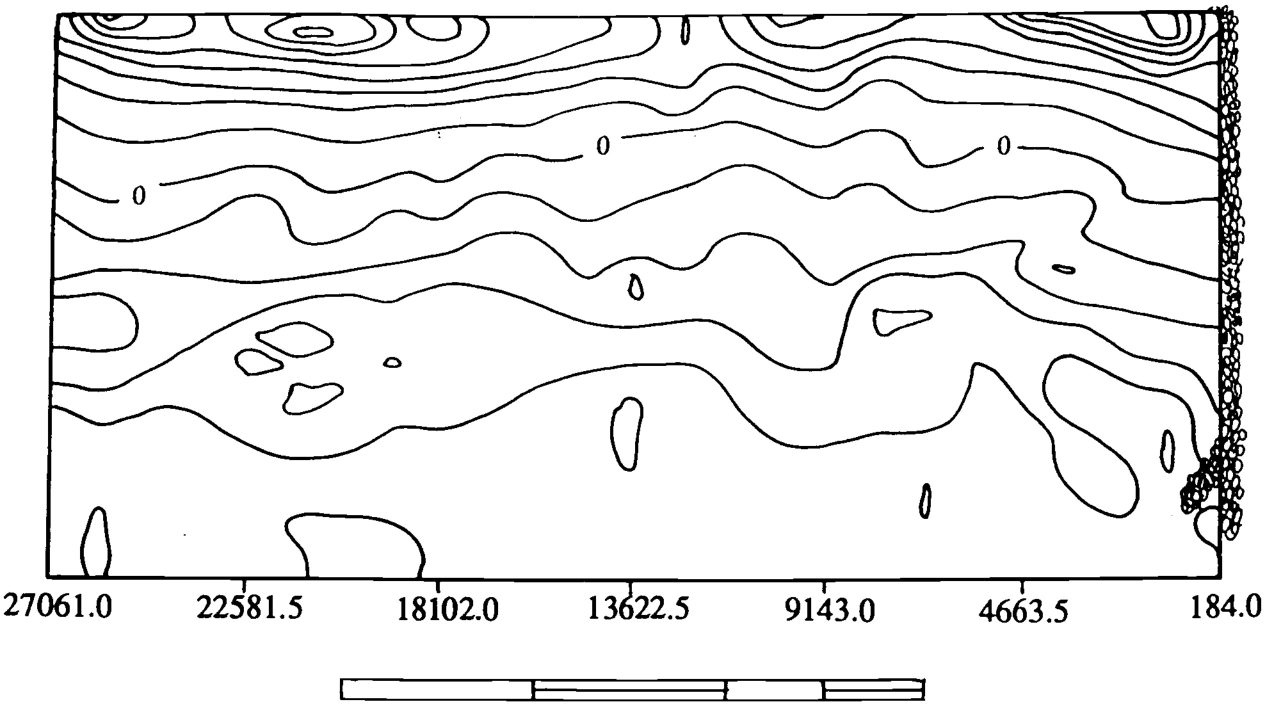
SCALE one inch = 4480

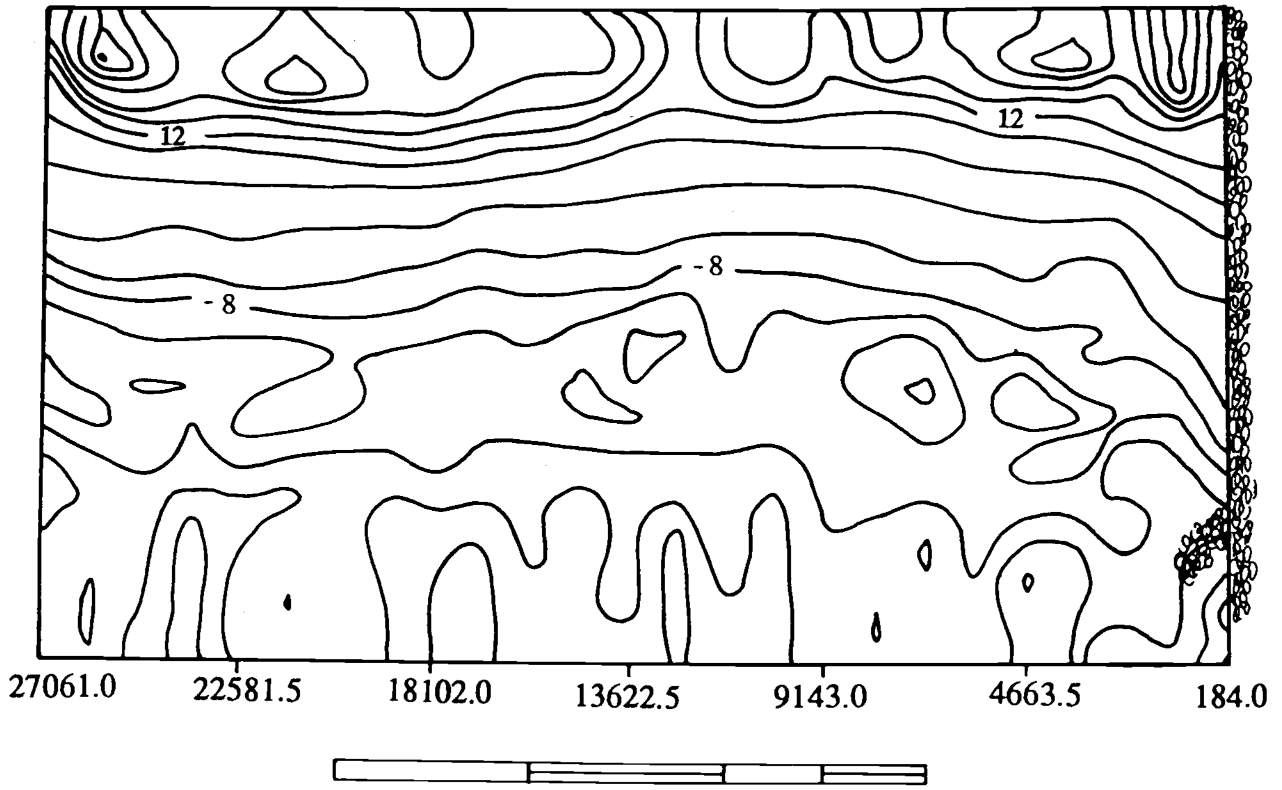
Northbeach 3/85



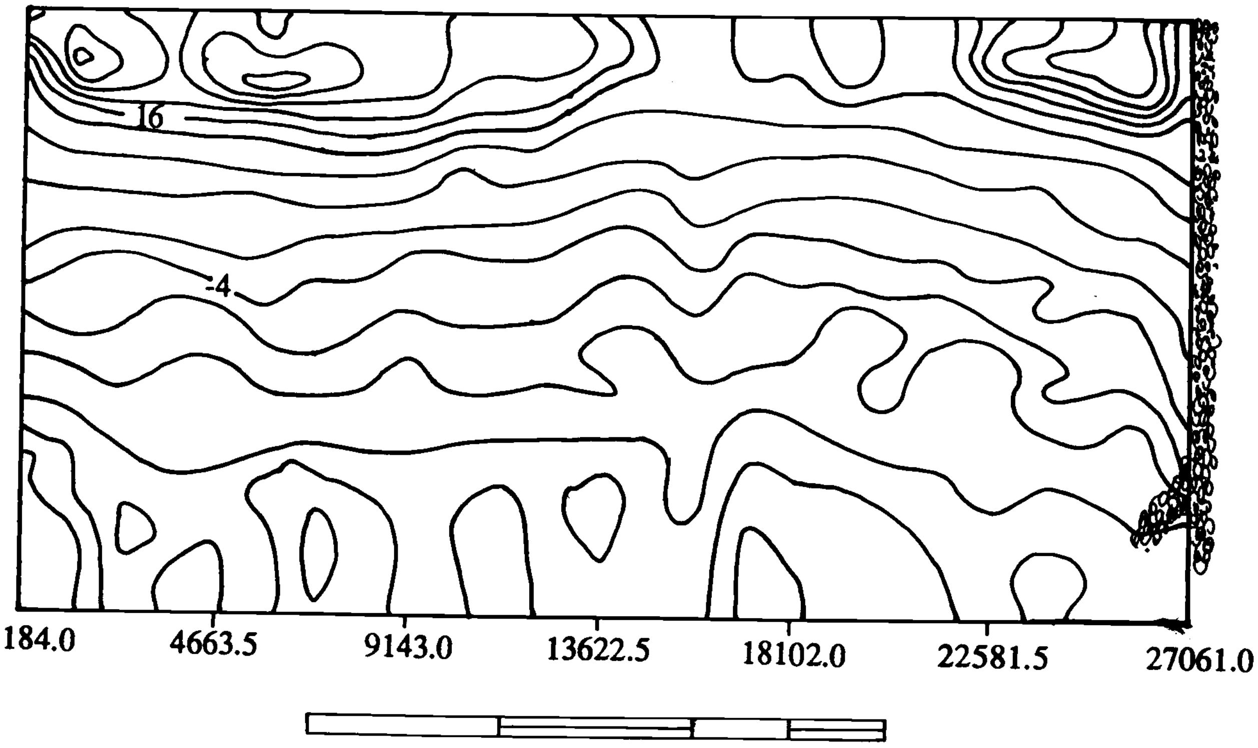
horizontal exagerration = 25.5%

SCALE one inch = 4480 ′


Northbeach 3/89


Northbeach 3/90

Northbeach 9/90



SCALE one inch = 4480 feet

horizontal exagerration = 25.5%

APPENDIX II

The following data sheets show the delineation of the unit cells in terms of their distance from the jetties. Each years volumes comparison is listed, unit cell for unit cell, with the characterization point noted.

Northbeach volume comparisons
Fall 1985,1989,1990

Row	distance from jetty	volume change 1990	volume change 1989	volume change 1985
1-2	184.9-1304.74	+24600000	-69000000	-7128150
2-3	1304.74-2424.57	+21600000	-79900000	-4206400
3-4	2424.57-3544.41	+19500000	-86700000	-3731560
4-5	3544.41-4664.25	+17400000	-95300000	-6252340
5-6	4664.25-5784.09	+8389270	-119000000	-11200000
6-7	5784.09-6903.25	-4162450	-155000000	-18210000
7-8	6903.25-8023.76	-8979790	-179000000	-24300000
8-9	8023.76-9143.6	-10658000	-188000000	-23700000
9-10	9143.6-10263.4	-12850000	-190000000	-20900000
10-11	10263.4-11383.3	-7725860	-187100000	-22000000
11-12	11383.3-12503.1	-6210710	-145000000	-24110000
12-13	12503.1-13622.9	-9653120	-171000000	-20680000
13-14	13622.9-14742.8	-5241580	-162000000	-17970000
14-15	14742.8-15862.6	-2370960	-158000000	-19000000
15-16	15862.6-18102.3	-4767070	-165000000	-21400000
16-17	18102.3-19222.1	-5719310	-189000000	-20200000
17-18	19222.1-20341.8	-3049420	-200000000	-18800000
18-19	20341.8-21461.8	-2385430	-198000000	-17100000
19-20	21461.8-22581.6	-1132030	-198000000	-13400000
20-21	22581.6-23701.4	+2351790	-190000000	-14500000
21-22	23701.4-24821.3	+688323	-187000000	-12400000
22-23	24821.3-25941.1	-1898320	-197000000	-14600000
23-24	25941.1-27061	-5105250	-194000000	-20600000
24-25	feet	-12597200	-176000000	-21100000

characterization point

Southbeach Volume Changes

Fall Comparisons	distance from jetty	volume change 1990	Volume Changes 1989	Volume Changes 1985
1-2	290-1052.68	+11115500	+7650260	-7749500
2-3	1052.68-2395.73	-786200	+1709010	-11642000
3-4	2395.73-3738.79	-3945390	+1763400	+13182800
4-5	3738.79-5081.85	-264084	+7696380	6297680
5-6	5081.85-6424.91	+4319220	+14103200	+887611
6-7	6424.91-7767.96	-5339340	+4660510	5388650
7-8	7767.91-9111.02	-20255100	-1138400	-15194800
8-9	9111.02-10454.1	-2320800	-18011100	-18904800
9-10	10454.1-11797.1	-11797000	-9718130	-18878100
10-11	11797.1-13140.2	-5800980	-2491070	-20765100
11-12	13140.2-14483.3	-8147190	-6421570	-20131100
12-13	14483.3-15826.3	-10871000	-9864750	-19964200
13-14	15826.3-17169.4	-15955500	-8515670	-20038700
14-15	17169.4-18512.4	-15671900	-65159.30	-20128700
15-16	18512.4-19855.5	-17161100	-1129700	-19908500
16-17	19855.5-21198.5	-21601400	-14896700	-1968400
17-18	21198.5-22541.6	-21246500	-12189800	-21245800
18-19	22541.6-23884.7	-10235200	-3167860	-11880500
19-20	23884.7-25227.7	-8545130	-2711600	-12010500
20-21	25227.7-26570.8	-20000000	-8065080	- 20395100
21-22	26570.8-27913.8	-23723900	-7660120	-22153800
22-23	27913.8-29256.9	-25099600	-11586000	-27275600
23-24	29256.9-30599.9	-26639500	-14647900	-29829600
24-25			-14075600	-25093500

characterization point