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SATELLITE APPLICATIONS TO A COASTAL INLET STUDY CLEARWATER BEACH, FLORIDA

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SATELLITE APPLICATIONS TO A COASTAL INLET STUDY CLEARWATER BEACH, FLORIDA

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Report Submitted to City of Clearwater, Clearwater, Florida

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ABSTRACT

Two sets of Landsat magnetic tapes were obtained and displayed on the screen of an IMAGE 100 computer. Spectral analysis was performed to produce various signatures, their extent and location. Subsequent ground truth observations and measurements were gathered by means of hydrographic surveys and low-altitude aerial photography for interpretation and calibration of the Landsat data. Finally, a coastal engineering assessment based on the Landsat data was made. Recommendations to the City of Clearwater regarding the navigational channel alignment and dredging practice are presented in the light of the inlet stability.

ACKNOWLEDGEMENTS

We gratefully acknowledge the active participation of many others in the course of the study. These include the sponsorship of the University Relations Division of NASA, Mr. Andrew Nicholson of the City of Clearwater, Mr. Paul L. Bumiller of Pinellas County for making the historical photographs available, the field work of Mr. Sidney Harrell and Mr. Ray O'Quinn of our Laboratory, graduate assistant Mr. Steven Hughes and Mr. Michael Marco, Janet Degner, for assistance in photo interpretation and report preparation and the General Electric Company for use of the IMAGE 100 computer.

I. INTRODUCTION

1. Introductory Note: It is known that longshore drift of alluvial material occurs along sandy barrier islands. Inlets between these barrier islands intercept the normal littoral drift, resulting in a net loss of sand from the beaches. During a flood tide, sand is brought into the inlet and part of it is retained to form the inner bar; during the ebb cycle, part of the sand is jetted out into the ocean to form an outer bar. The reversing flows of flood and ebb cycles may also cause deposition or scouring on the bottom of inlet channels.

There are two sets of parameters pertinent to the behavior of inlets. The first set deals with the changes in the dynamic bottom configuration (i.e., the movement of inner and outer bars, the choking or scouring of the inlet channel). The second set of parameters regards the driving forces of the coastal system (i.e., wave climate, tide, wind and currents). Understanding the interrelationship of these two sets of parameters leads to the solution of stabilizing the inlet. The time sequential dynamic interrelationships and natural tendencies of inlets are well-portrayed on available aerial photographs.

The techniques of mapping the sand bars and their movements, and the bay circulation patterns are traditionally done by a sounding boat and survey team. The derived point and line information are then used to produce the contour map of the bottom current chart. Extensive interpolations are needed because many details between the points and lines are missing. The operation is expensive and the procedures are time consuming. Techniques using remote sensing especially aerial photography can be used to monitor the changes that take place, reducing costs and increasing efficiency.

2. Previous Work: Even though standard procedures have not yet been established, the satellite sensing of the marine environment has progressed considerably in recent years. The techniques of hydrographic charting and bathymetry application have been significantly improved. Polcyn and Lyzenga (1975), Sherman (1975), Middleton and Barber (1976), and Hubbard (1977) all demonstrated that it is possible to correlate the radiance values of multispectral imagery, such as Landsat imagery, with the depth related information. The present study is one more example of such an effort.

3. Purpose and Scope of the Present Investigation: The present work is mainly to assess the Gulf/Clearwater Harbor system with regard to its instability and navigational problems at Clearwater Pass, Florida; and to recommend to the City of Clearwater the necessary measures for correcting the problems. At the same time, effort has been made to establish procedures for solving similar engineering problems frequently encountered on beaches and inlets elsewhere.

The inner and outer bar system at Clearwater Pass encompasses an approximate area of 87,000 square feet. The embayment of the tidal prism and active littoral zone are four miles long and two miles wide. This eight square mile study area is part of the nature system bounded by Indian Rocks Beach to the south and Anclote Key to the north. A general study area and location map is shown as Figure 1.

II. ANALYSIS PROCEDURE

A Landsat magnetic tape covering Pinellas County shoreline was obtained and displayed on the screen of an IMAGE 100 computer at NASA Headquarters, Cape Canaveral. Spectral analysis was performed to produce various signatures, their extent and location. Subsequent ground truth observations were gathered

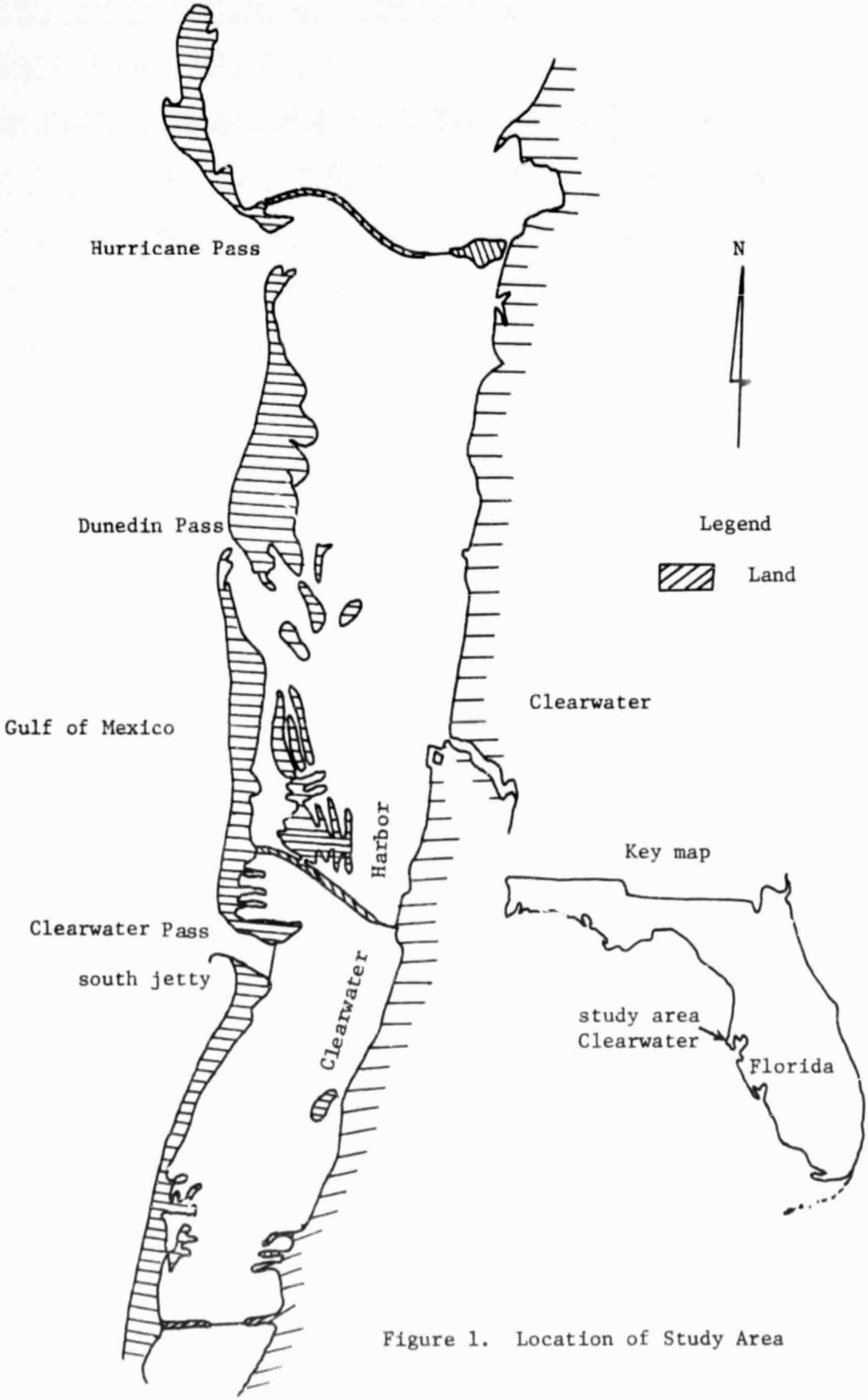

Figure 1. Location of Study Area

by means of boat surveys and low altitude aerial photography. Later, a second Landsat magnetic tape covering the same area was acquired and analyzed by the IMAGE 100 computer at General Electric in Daytona Beach. Ground truth measurements were again collected for calibration and interpretation of the Landsat data. Finally, the coastal engineering assessment, based on the Landsat data, was made. Recommendations regarding the navigational channel and dredging practice are presented in the light of the inlet stability.

III. GROUND TRUTH AND DATA ACQUISITION

1. Hydrographic Measurements: A team equipped with survey instruments and sounding gear were sent to the field to determine shallow water bottom conditions. The inlet's cross sectional area and the shoaling region were measured by sounding and survey. These ground truth observations are presented in Figures 2, 3, and 4 and were used for the comparison with radiance values of the Landsat imagery.

The difficulty encountered during ground truth operations was the identification of the bottom conditions. An analogy to this would be best described by an old saying: "When you are in the forest, you don't see the trees." To improve the situation, two flights were scheduled to collect low altitude photography.

2. Low Altitude Aerial Photos, Past and Present: To understand the geomorphology and historical events of the Clearwater Pass, a collection of photographs were reduced to approximately the same scale and then superposed to show the relative changes through time (see Figure 5).

To improve the identification of bottom conditions, two flights were

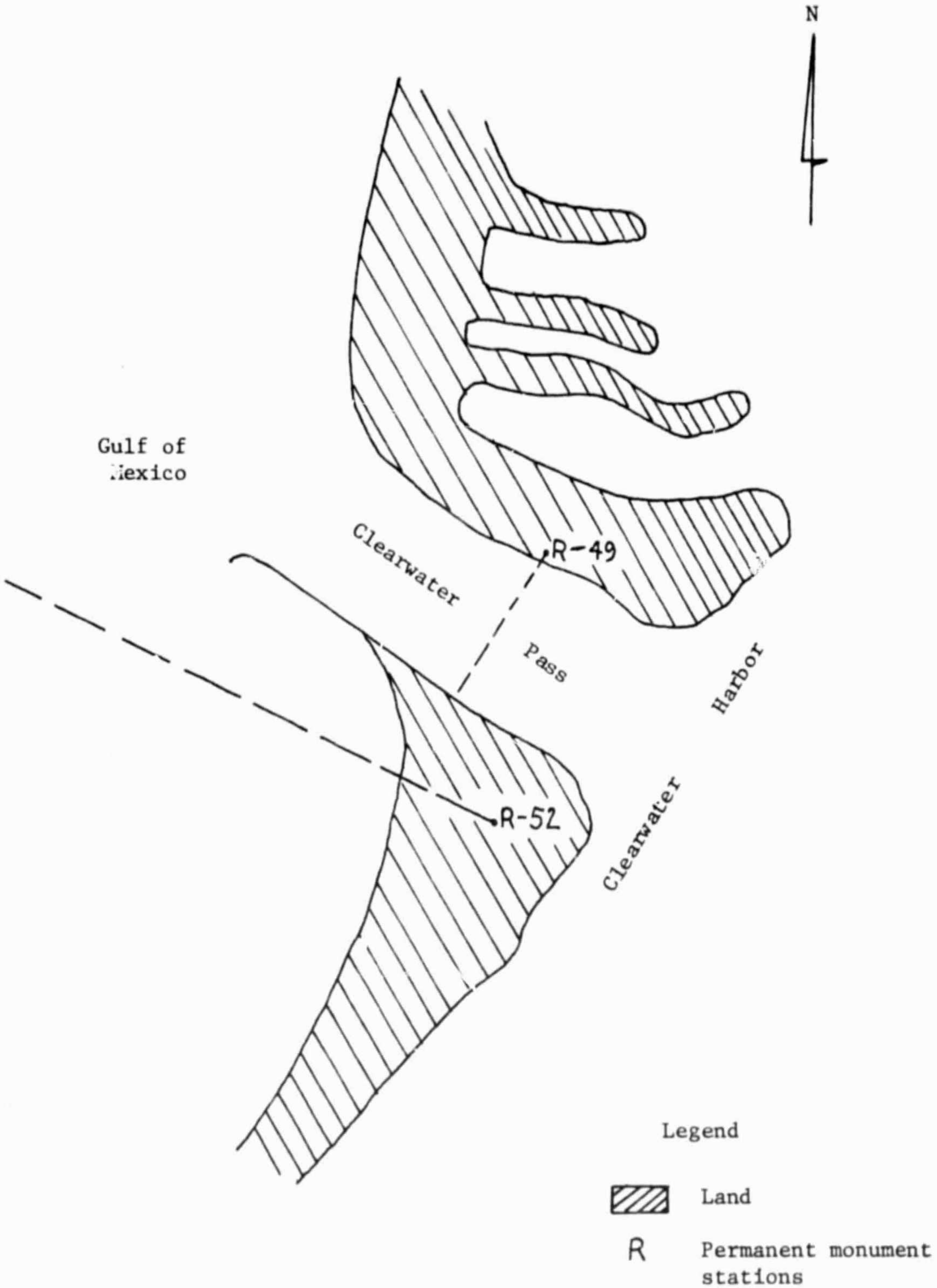

Figure 2. Location Map of the Profile Lines

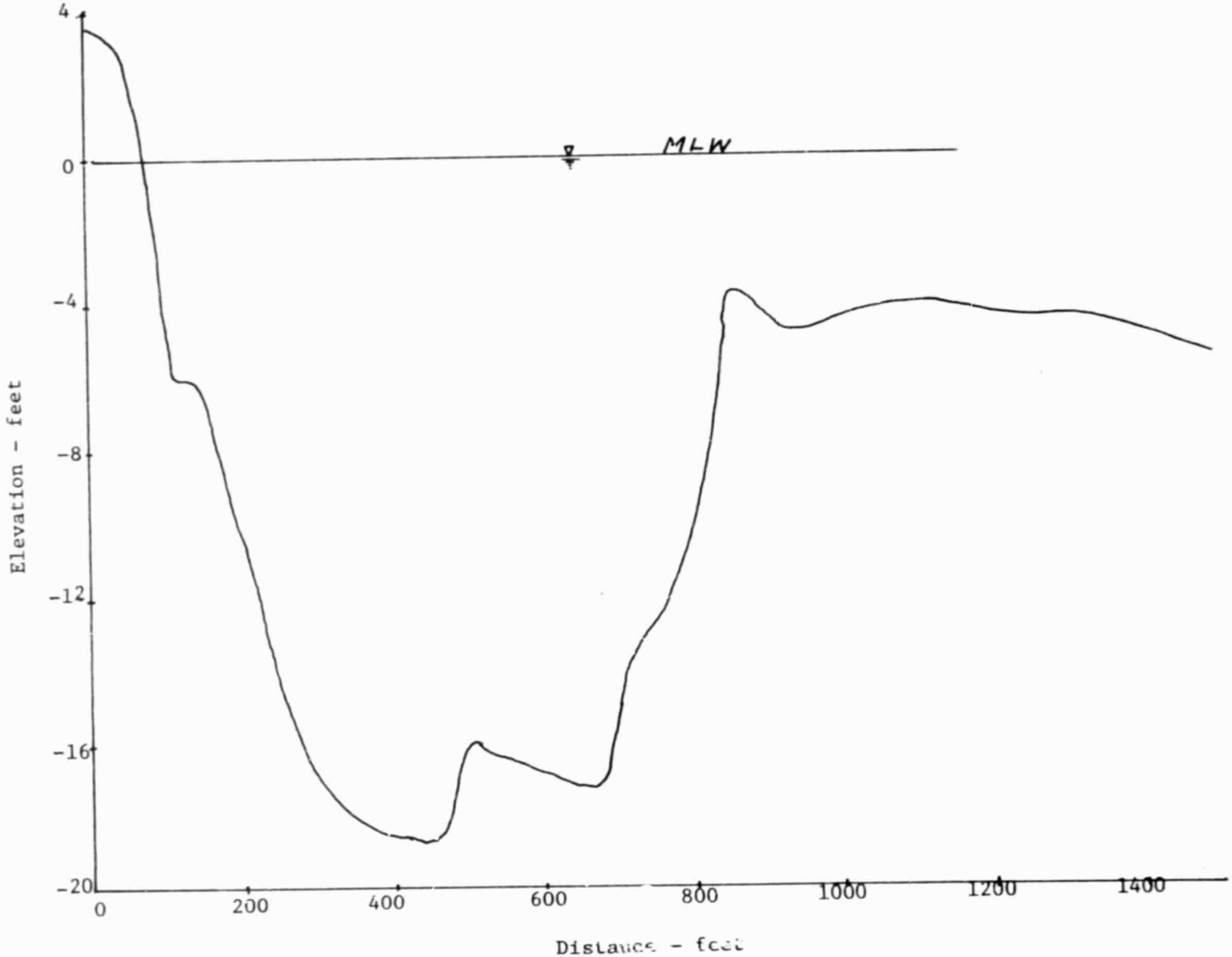

Figure 3. Cross Section of Clearwater Pass at Station R-49

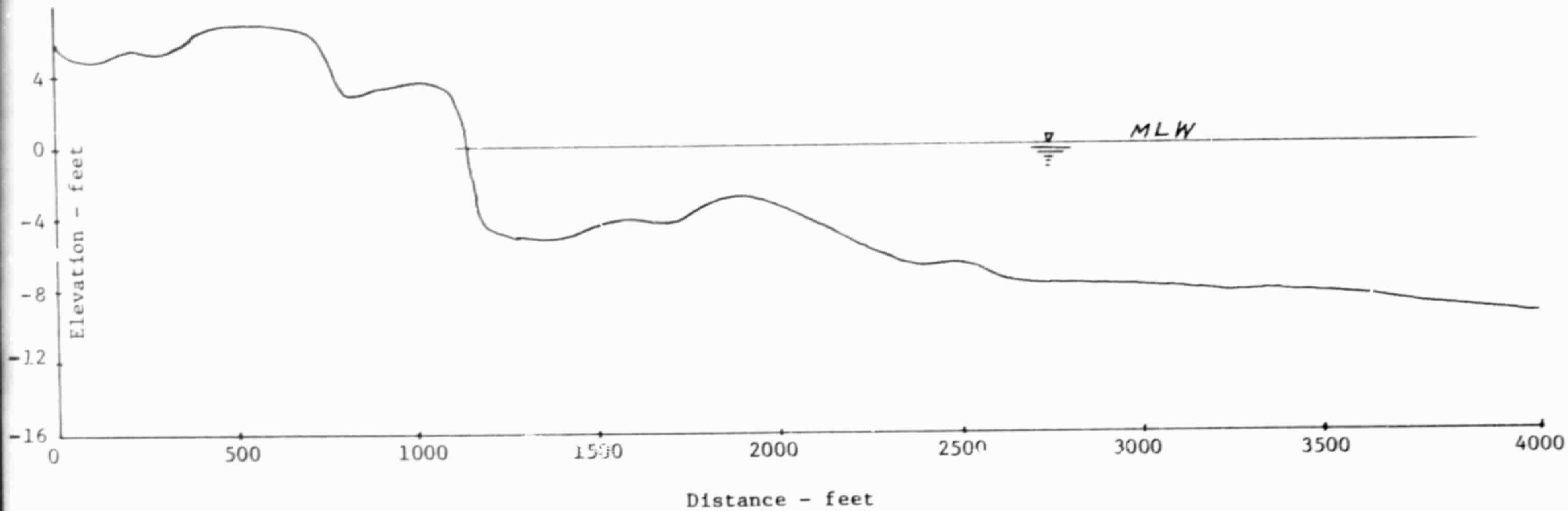

Figure 4. Beach and Offshore Profiles at Station R-52

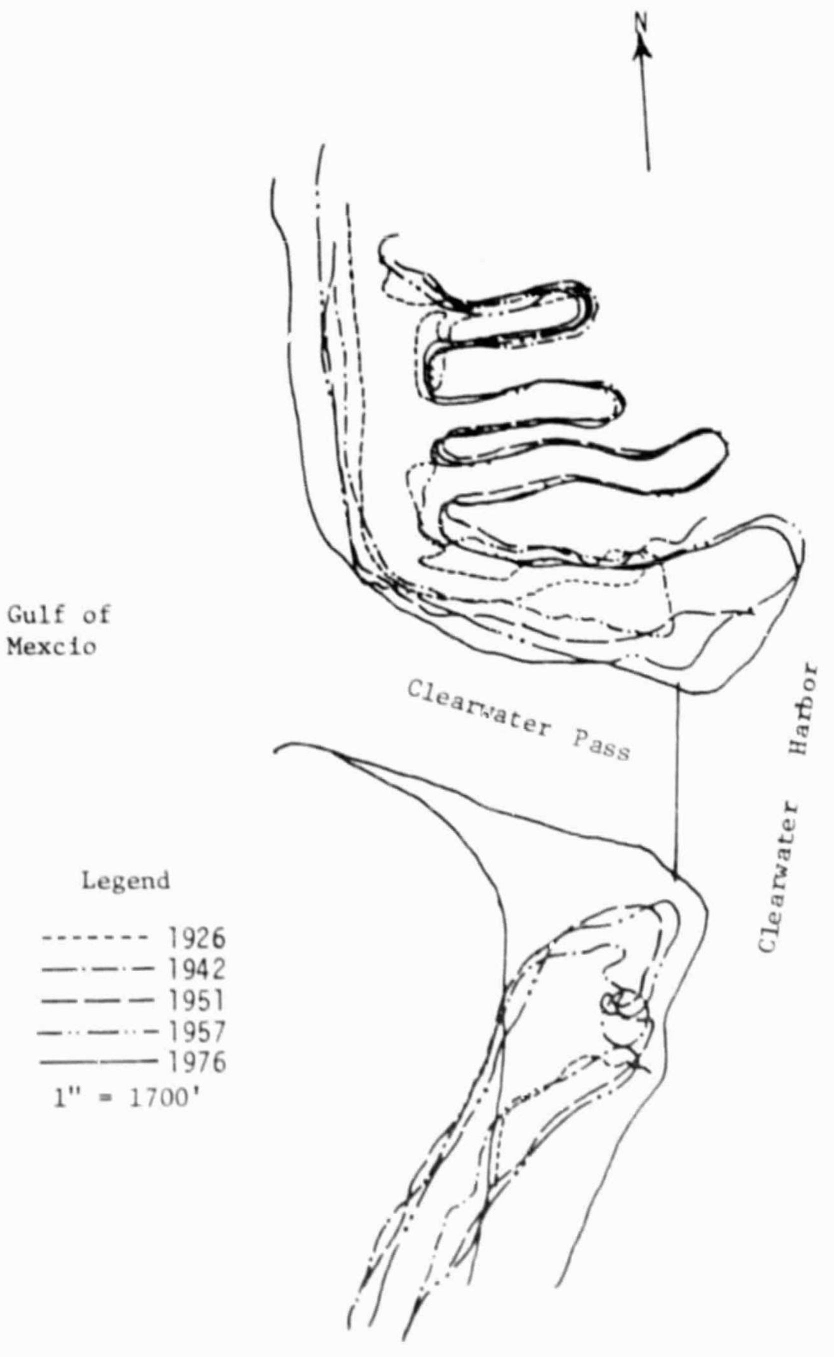

Figure 3. Superposition of Aerial Photography, 1926-1976
Clearwater, Florida

flown to obtain stereophotograph coverage.[1] The first set of photos was obtained on July 20, 1977. The flight line was along the beach with a photographic reach of 2200 feet on each side of the water line. Hurricane Pass was at the north end and Clearwater Pass on the south end of the flight line, covering a shoreline of approximately ten miles in length. The second flight took place on November 22, 1977 with emphasis on Clearwater Pass and on the bay area.

The hydrographic measurements together with the aerial photos constitute the basis of ground truth for interpretation and calibration of the Landsat imageries.

3. Spectral Analysis of Landsat Imageries: Spectral radiance values were derived from the 1974 and 1976 magnetic tapes for various key locations in the Clearwater area and used to compare with ground truth. Binary prints were also generated to show various signatures of water depth with different themes. Figures 6, 7 and 8 are sample binary prints showing the results of Golay Cluster techniques. These figures show the land/water boundaries with Anclote Key in the upper left corner and the northern tip of Sand Key in the bottom left. The boxed area in the upper right corner is an enlargement (ten X) of the Clearwater Pass region which is located on the bottom left of these figures. The results derived from the IMAGE 100 computer are significant and useful towards the understanding of the Clearwater Pass region.

IV. ANALYSIS AND INTERPRETATION OF DATA

1. Historical Boundary Changes: Superposition of aerial photograph, 1926-1976, Figure 5, shows that the width of the inlet has narrowed from

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[1]Photos are not included in this report, but available at the Coastal and Oceanographic Engineering Department's Archives, University of Florida.

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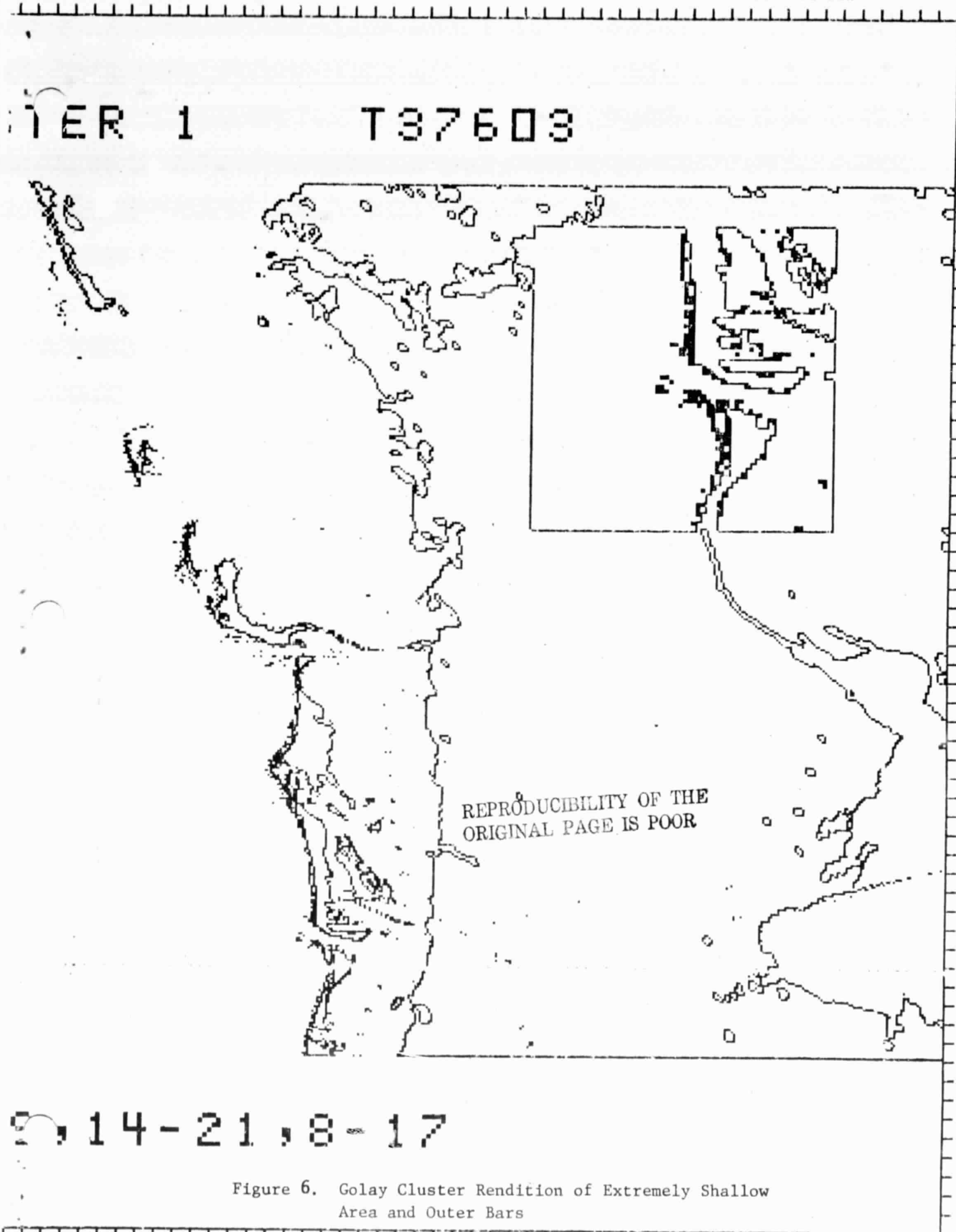

Figure 6. Golay Cluster Rendition of Extremely Shallow Area and Outer Bars

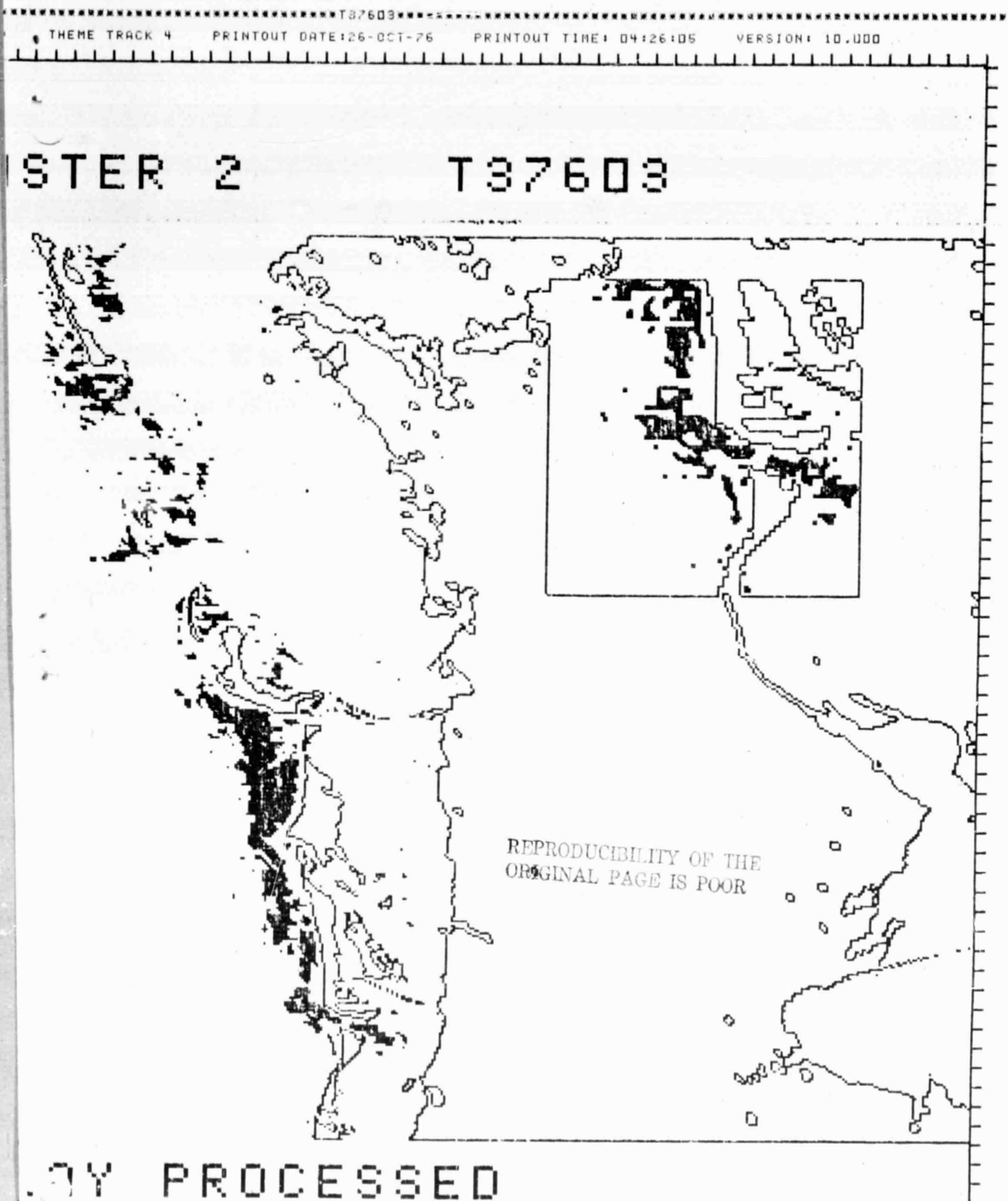

Figure 7. Golay Cluster Rendition of Areas Four to Ten Feet in Depth

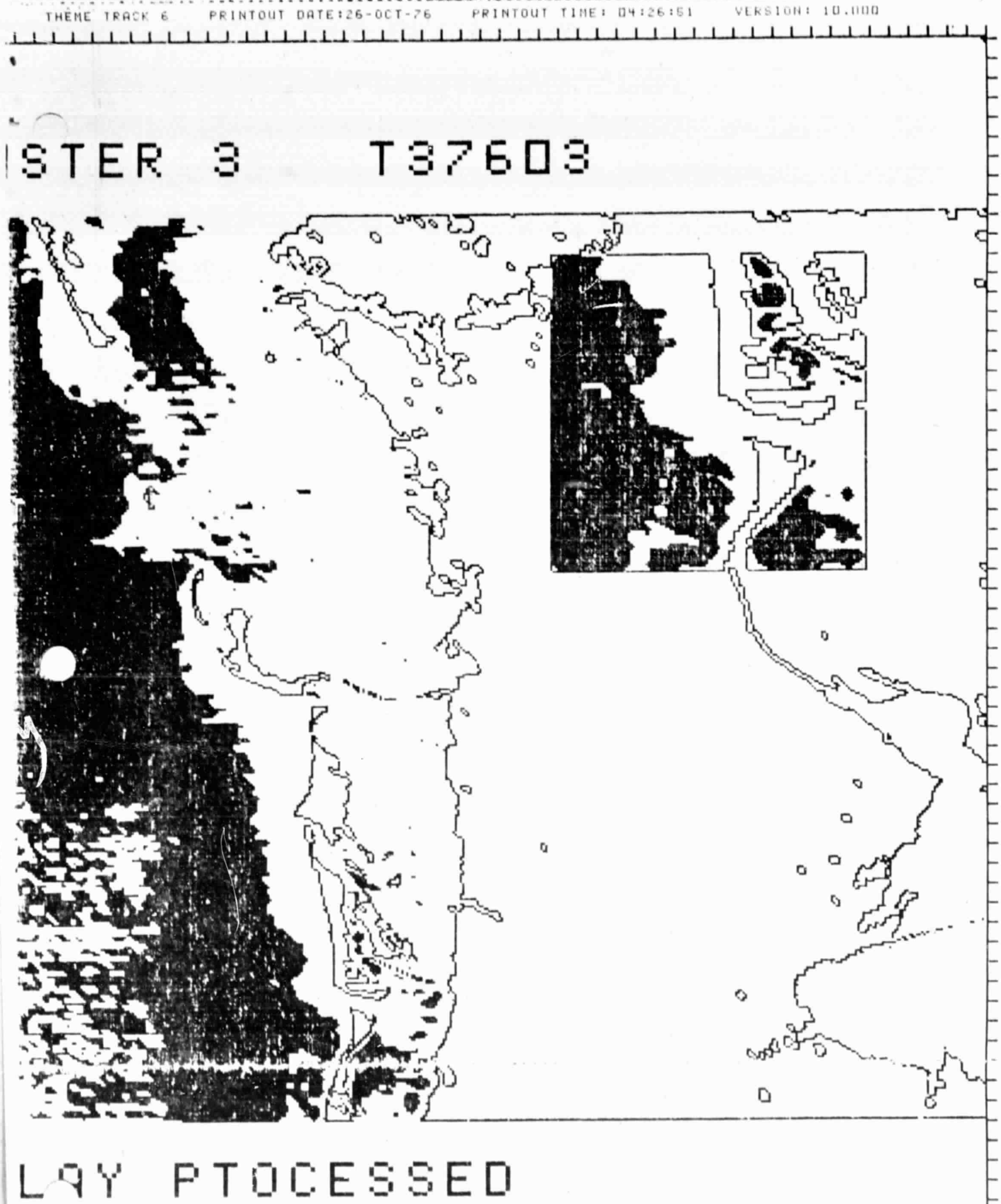

Figure 8. Golay Cluster Rendition of Areas Greater than Ten Feet in Depth

approximately 4400 feet in 1926 to 3200 feet in 1942. Further decrease of the inlet width to approximately 2500 feet is noted by the year of 1951. Between 1951 and 1970, the inlet maintained its width. In the early 1970's, the northern tip of Sand Key started to accrete, further narrowing the inlet. In 1973, a jetty was constructed to stop the northward migration of Sand Key.

2. Identification of the Pass's Natural Channel: Spectral analysis of the Landsat imagery, dated March 1974, has revealed the width and direction of the natural course of the inlet channel. The green band binary computer printout is shown as Figure 9. It is clear that the dredged navigational channel deviates from its natural channel course west of the inlet mouth.

3. Location of Shoals: The outer bars and extremely shallow region, such as the bathing zone and the second bar parallel to shoreline, are identified by the shaded regions in Figure 6. These regions correspond well with the area identified on the aerial photos. The identification of the bar location at the inlet mouth has helped reveal the need for realignment of the navigational channel for the following reasons: (1) the existing dredged navigational channel turned towards the outer bar and cut through the middle of the outer bar; this means the dredged channel may be filled with sand more rapidly and therefore will require more frequent dredging, (2) the 35° turn that the channel made at the inlet mouth would create navigational hazards, since the current at the inlet mouth is strong and the wave field is variable there, particularly in bad weather, (3) since the bar location is known, the realignment of the navigation channel should be chosen in such a way that a straighter course cutting through the trough between two shoaling areas is possible.

The shaded regions in Figure 7 correspond to a shallow water depth area ranging between four and ten feet deep. The "empty holes" within the shaded

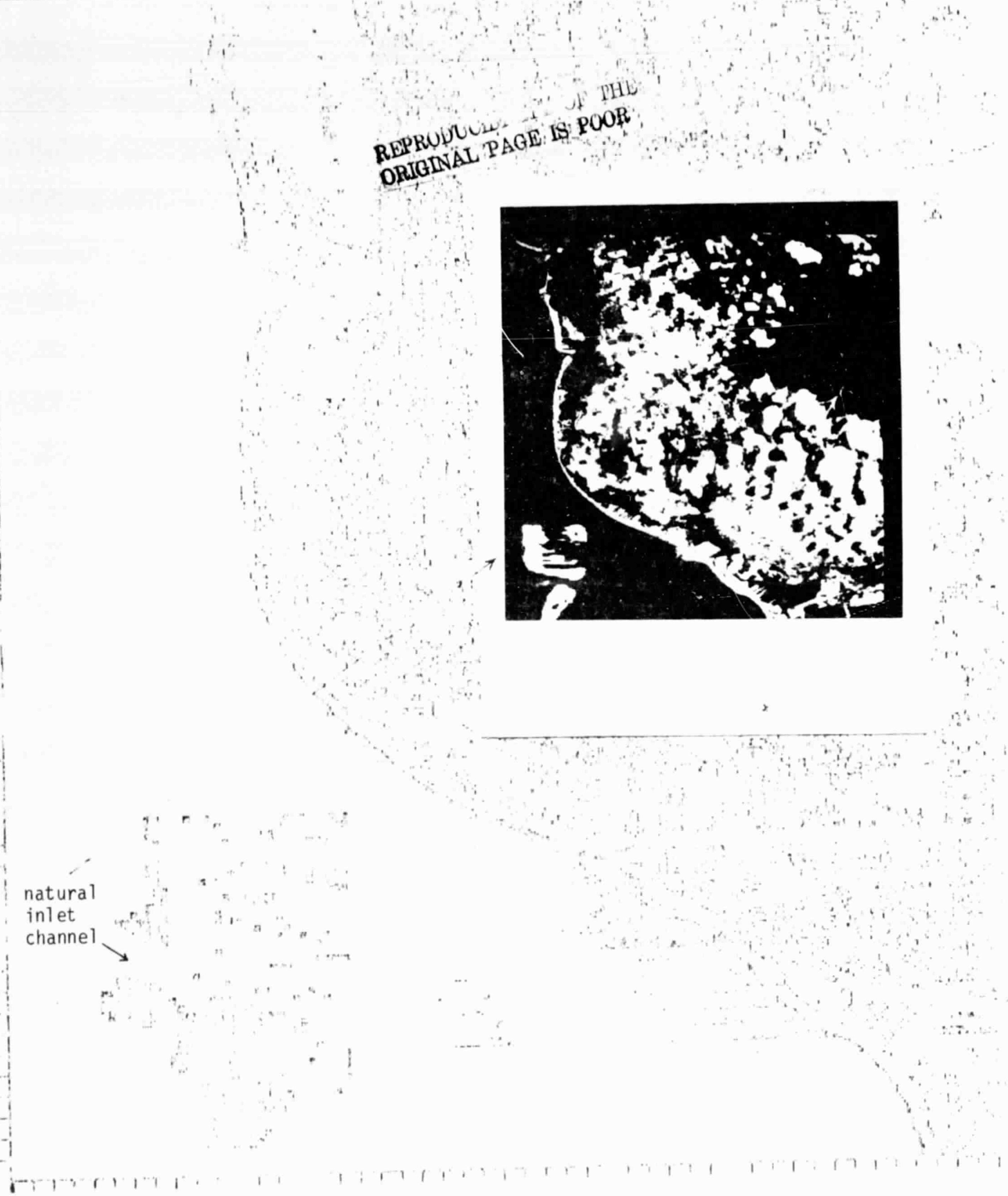

Figure 9 . Green Band Binary Computer Printout Showing the Natural Course of the Inlet Channel

regions correspond to the shoals which have an approximate submerged depth of four feet or less. This helps to identify the inner bar location in the bay area. This is important with regard to the future dredging practice in connection with the inlet stability problem. (1) The inner bar region slows down the flow by increased bottom friction. As a result, the bay flow pattern is concentrated in two streams near the inlet throat. One is along the east bay shore where the bay navigational channel is maintained, the other is parallel to the west bay shore between the bridge and the toll booth, (2) this flow concentration pattern focuses its momentum on one part and is weakened in other regions of the inlet channel. Therefore it is responsible for the scouring at the bridge pier and silting along the south jetty.

The dark areas in Figure 8 represent the deep water region, say, approximately ten feet or deeper.

V. DISCUSSION

1. The Historical Aerial Photos: Understanding the history of Clearwater Pass is very helpful. However, causes of the historical events were complicated. Major modifications of the natural environmental system were (1) the construction of the Garden Causeway (bridge across the bay), (2) the creation of the Hurricane Pass by the storm of 1927, (3) the artificial closure of Indian Pass, and (4) the extensive dredging for navigation and artificial islands for residential developments.

The significant information derived from the study of the inlet's history is that the inlet maintained a nearly stable width between the 1960's and 1970's. This leads one to suggest that the present inlet width should be in the equilibrium state. However, any additional conclusions drawn from remotely sensed information (aerial photos) must be supported by careful studies of the cause/effect relationship and may be very complicated.

2. The Navigational Channel: The natural course of the inlet channel coincides with the dredged navigational channel in the inlet portion. However, there is some deviation west of the inlet mouth were the natural channel continues in a straight and westward direction, and the dredged channel makes a 35° turn to the south. There are two consequences of this difference in the channel's path: (1) shoaling in the navigational channel requires frequent dredging, (2) the 35° turn in the channel direction is hazardous to boating operations, particularly in bad weather.

3. The Inner and Outer Shoals: Identifying the location of the inner shoals revealed the reason why the flood/ebb flows concentrate into two major streams. Stream A (Figure 10) flows along the navigational channel parallel to the east bay shoreline; it makes a 90° turn westward to the inlet channel. The stream B is parallel to the eastern shoreline of Sand Key between the inlet bridge and the toll booth. The two streams merge at the deep portion of the inlet channel.

Suppose the inlet channel is dredged to a uniform depth across its entire width, then, the existing concentrated flow patterns of streams A and B would have the tendency to restore the dredged inlet cross section to the present configuration. That is to say, a narrow and deep channel along the north bank, and accretion and silting along the south jetty would occur. As a result, scouring of bridge pier in the deep channel section would take place with potential erosion along the north bank, particularly, along the west end of the north bank where the strong ebb current exists. Silting along the south jetty would further narrow and deepen the inlet channel close to the north bank. The idea of dredging the inlet channel to a uniform depth to eliminate the flow concentration in one area and silting in another area will be significantly weakened if the inner shoals remain at their present identified locations.

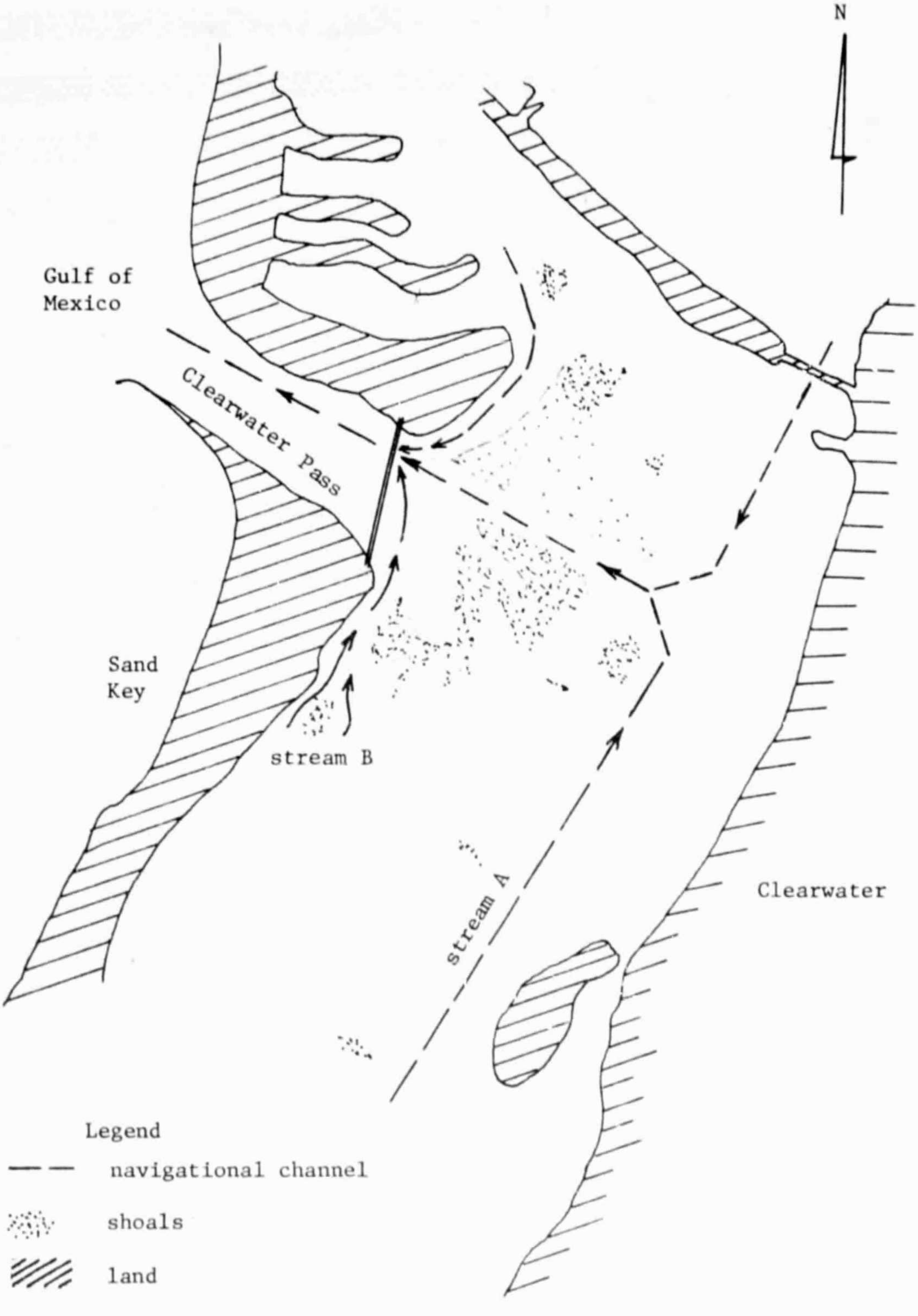

Figure 10. Inner Shoal Locations with Subsequent Stream Flow Patterns

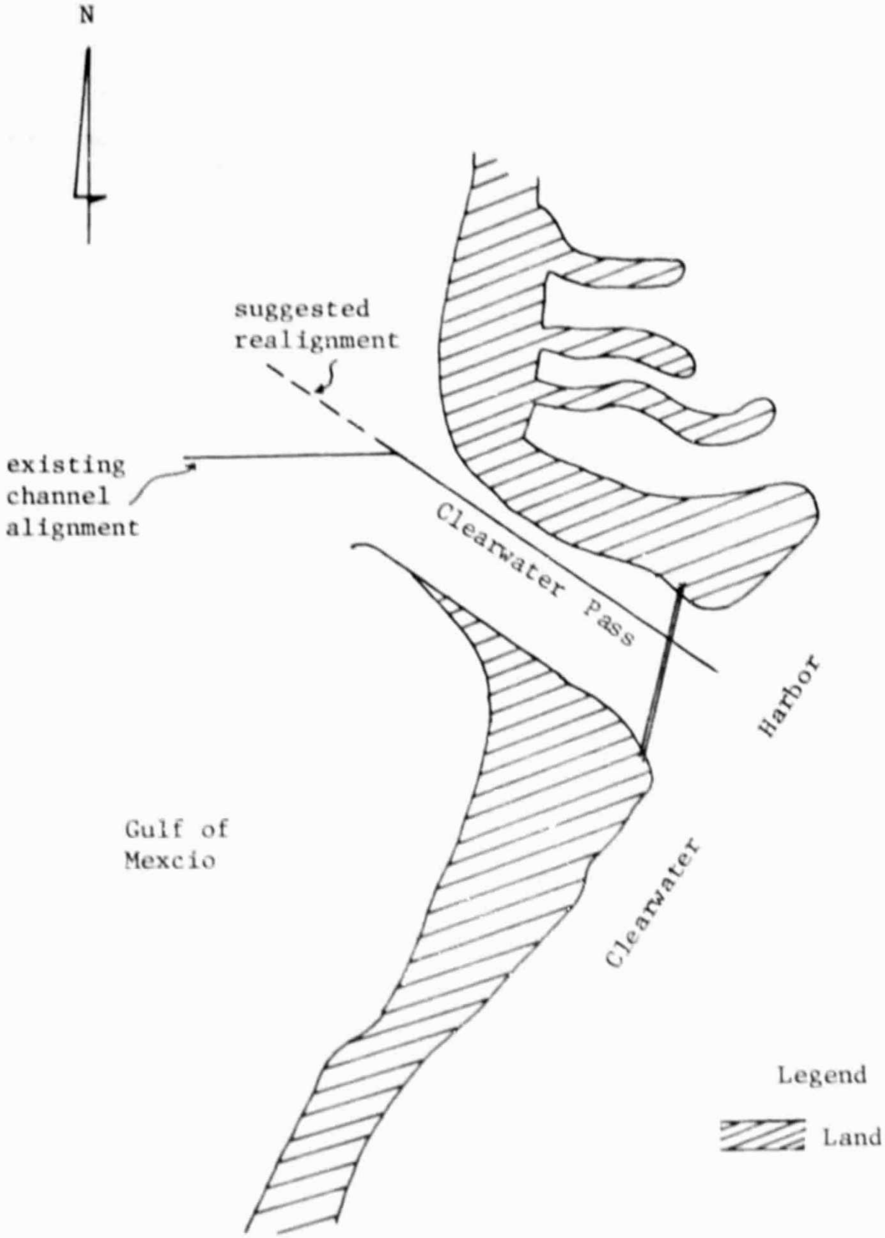

Figure 11. The Existing and Recommended Navigational Channel Alignment

From Figures 6 and 9, it is clear that the outer shoals should and can be avoided when the navigational channel realignment is laid out according to the natural course of the inlet channel. The natural channel course may be identified by following straight through the bright inlet region of the boxed area as shown in Figure 6, and also in Figure 9 (the dark inlet region in the picture).

VI. RECOMMENDATIONS

1. Realignment of the navigational channel according to its natural course is recommended. Such realignment is depicted in Figure 11. Instead of making a 35 turn to the south at the west end of the inlet's mouth, the navigational channel should be extended straight to avoid shoaling and, it is predicted that less frequent dredging will be required. The straight course of the navigational channel would also contribute to safe boating operations, particularly in bad weather.

2. The inner shoals should also be dredged when the dredging operation of the inlet is undertaken. Dredging of the inner shoals would smooth out the concentrated flow pattern in the bay, if the uniform inlet outflow produced by inlet dredging could be enhanced and maintained. Otherwise, the existing flow concentration pattern will have a tendency to restore the inlet cross section to its present configuration, i.e., scouring and deepening near the north bank, and silting and accretion along the south jetty.

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