MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A
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Technical Report No. 17-CRD

Influence of Wave Refraction on Coastal Geomorphology

Bull Island to Isle of Palms, South Carolina

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INFLUENCE OF WAVE REFRACTION ON COASTAL GEOMORPHOLOGY -- BULL ISLAND TO ISLE OF PALMS, SOUTH CAROLINA

by

Cary Fico

December, 1978

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cover diagram: refraction diagram of 10 second period wave from the east
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ABSTRACT

In order to determine the effects of the continental shelf bathymetry on coastal geomorphology, a series of wave-refraction diagrams were generated for the S. C. coast from Bull Island to the Isle of Palms. Wave rays, as they approach the shore, converge or diverge depending on the uneven offshore bottom topography. Therefore, zones of magnified or reduced wave energy are created from the interaction between waves and the offshore topography. REFRAC, a computerized wave-refraction program developed for this study, generates refraction diagrams which delineate the patterns of longshore variation in wave energy. A variety of input wave conditions were used in REFRAC to model the various possible wave conditions existing in nature. Data input included waves propagated in deep water from the east, southeast and south for several different periods. To improve the accuracy of the refraction diagrams, bathymetric charts of increasing detail near the shore were used in tracing the path of a wave onto the shore. Qualitatively, zones of potential erosion or deposition can be inferred to correspond to converging or diverging wave rays respectively.

The results indicate that the offshore bathymetry does partially control the coastal geomorphology by creating zones of potential erosion and deposition and by influencing the direction of sediment transport. An analysis of the refraction diagrams reveals the following observations. (1) Bull Island and Capers Island, areas of long-term erosion, are located in zones of higher than average wave energy. (2) The southern section of the Isle of Palms has undergone extensive accretion due to its location in a zone of lower
than average wave energy and to a sediment supply from the north. (3) The oblique orientation of Dewees Inlet, as compared to the normal orientation of Price Inlet, results from the increased wave energy noted at Dewees Inlet, especially for a 10-second wave from the east. (4) The large downdrift offset of Dewees Inlet appears to be related to a sudden reduction in the southward directed longshore drift at the Isle of Palms as compared to Dewees and Capers Islands.

Additional information on the sediment transport patterns at the ebb-tidal delta of Price Inlet was gained from the increase in detail of the refraction diagrams for Price Inlet. For waves from the east and southeast, the predominant direction of littoral drift is to the south. Sediment transport reversals to the north were seen on the south side of the inlet. These reversals in transport direction, resulting from refraction around the ebb-tidal delta, are capable of reintroducing sand into the inlet and building up the beach and shoals south of the inlet. On the other hand, shorter period waves from the east, because of their oblique angle of approach to the shoreline, may enhance sediment bypassing around the distal portion of the ebb-tidal delta at Price Inlet.
ACKNOWLEDGEMENTS

This study was partially funded by the Army Research Office, Division of Terrestrial Sciences, through contract no. DAAG-29-76-G0111. The principal investigators were Miles O. Hayes and Dag Nummedal.

I would like to thank Dag Nummedal for his critical review of this text and for his support throughout the study. Jim Crabtree, through his patient help in the computer programming aspects of this project, has stimulated my interest in computer applications. During the several stages of writing, constructive criticism was sought from Bob Ehrlich, Miles Hayes and Bjorn Kjerfve. Burk Scheper and Nanette Muzzy offered many helpful suggestions in preparing the drafts and figures. I especially wish to thank Priscilla Ridgell for typing the final copy of this manuscript.
INTRODUCTION

The relationship between the nonuniform wave-energy distribution along a coastline and the coastline's stability, both past and future, is of primary importance in coastal management. A graphical method, based on the principles of refraction, set forth by Snell's Law, is commonly used in displaying wave-energy distribution. These wave-refraction diagrams serve as a useful tool in the interpretation of coastal processes when used in conjunction with field data (Colonell et al., 1973). Goldsmith and others (1970) concluded from refraction computations on Monomy Island that the interaction between incoming waves and variations in the offshore bathymetry may be able to predict changes in the configuration of the shoreline. Fico (1977) depicted areas on the S. C. coast of varying susceptibility to storm damage by refracting waves from several different directions.

This study exemplifies the significance of the offshore bathymetry in modifying the configuration of the S. C. coast from Bull Island to the Isle of Palms (Fig. 1). Through the interaction of waves and the offshore topography, which results in an uneven longshore wave energy distribution, differential rates of deposition or erosion occur along the coast. A series of wave-refraction diagrams were generated to show the correspondence between the variation in the wave-energy distribution and the resulting coastal geomorphology. Furthermore, detailed refraction diagrams of Price Inlet were able to illustrate the effects of the offshore bathymetry on the morphology and sediment transport patterns of an ebb-tidal delta.

A computerized wave refraction procedure, REFRAC, has been implemented on the IBM System 370/168 at the University of South
Figure 1. Location map of the study area.
Carolina. Dobson (1967) developed the initial program and based the refraction of incoming waves on linear wave theory. Since he assumed bottom friction to be insignificant, the wave height at any point of interest (usually the breaker zone) is a function of the initial deep water wave height and the refraction and shoaling coefficients at that point. Modifications of this program made by Senter (1972) at the Waterways Experiment Station include the addition of Calcomp plot routines and a window feature which allows wave data generated from a small-scale map to be used as input into a larger-scale map for a more detailed refraction analysis.

REFRAC, including the above modifications, has been further altered in the current study to accept digitized bathymetric input for generation of a depth grid. Previously, areas of interest were overlain by a grid and the depths interpolated from a hydrographic chart at grid points. Next, the interpolated depth data were keypunched onto cards. When using large areas or a series of desired large-scale window plots, this was a very time-consuming process. These tasks are eliminated by digitizing the shoreline and the bathymetric contours onto magnetic tape. The digitized data are processed by the program which creates a grid of depth values by using the straight-line slope formula for depths between the contours.
LINEAR WAVE THEORY

General Description

Linear wave theory, as developed by Airy (in 1845) is a first-order theoretical approximation describing wave behavior. The theory assumes long trains of uniform waves with long unbroken wave crests. Obviously, this condition is not met in areas of locally generated seas, where wave forms may consist of several periods and directions and broken wave crests. However, swell waves, which are outside the area of generation, approximate the above assumption (Komar, 1976). Higher-order theories, usually referred to as finite amplitude theories, increase the number of successive approximations in order to describe more closely the actual wave behavior. These successive approximations serve as correction factors for preceding terms (Coastal Engineering Research Center, 1973, p. 2-2).

Linear wave theory is more commonly used in the study of wave behavior because it is reliable over a number of wave conditions and mathematically easy to apply. Dobson (1967), using linear wave theory in the refraction of incoming waves, developed the original version of the computer program used in this study. Therefore, the celerity of the wave is dependent on the water depth. Refraction or the bending of wave orthogonals (rays or lines parallel to the direction of wave propagation) are a result of the different speeds along the wave crest as it passes over an uneven topography. Simply stated, a wave ray will refract toward shallower water. Because of this interaction between waves and the offshore topography, there is a variation in wave characteristics (height, energy, etc.) in the nearshore zone. This spatial variation in wave characteristics may be a driving mechanism.
for nearshore circulation patterns (Noda, 1974; Sonu, 1972). Qualitatively, zones of potential erosion or deposition can be inferred to correspond to converging or diverging wave rays, respectively.

Breaker wave height is a function of the deep water wave height after it has been modified by refraction and shoaling in shallow water. Although Dobson considered frictional attenuation of wave height to be insignificant, Goldsmith (1976) states that friction may cause a significant loss in wave energy and height. Because of the frictional loss of energy over the wide shallow shelf of the Virginian Sea, wave heights were reduced 50 to 75 percent for longer wave periods. This percentage will be less for smaller period waves.

A friction routine similar to the one used by Goldsmith (personal communication) and Coleman and Wright (1971) was added to REFRAC, the wave-refraction program used in this study. However, the resulting wave heights and energy are questionable. Therefore, a quantitative evaluation of wave heights was not attempted.

Assumptions and Limitations

In relation to wave refraction, the main assumptions in linear wave theory are (Coastal Engineering Research Center, 1973, p. 2-65):

1. Wave energy between wave rays remains constant. This assumption is suspect when wave orthogonals bend sharply as energy may be transferred along the wave crests. Caustics, which are rays that bend sharply enough to cross, no longer present a problem. According to Chao (1972), wave rays continue on the same path after they pass through a caustic as before the caustic, the only difference being a phase shift.
(2) Wave celerity is a function of water depth. This holds true in linear theory but not necessarily in higher-order theories. An increase in wave height, resulting from either shoaling or refraction will cause a slight increase in the wave velocity. This effect is small (Komar, 1976).

(3) The bottom slope is gentle (less than 1:10). Linear theory is strictly valid only for constant depths, but it will successfully predict wave velocities over a gently sloping bottom (Dobson, 1967).

(4) Waves are long-crested, constant period, and of small amplitude. This is not true for 'confused seas' in their area of generation but does approximate swell conditions. In refraction studies, a spectrum of swell conditions needs to be analyzed to simulate the real world (Goldsmith, 1976).

(5) Reflection of wave energy from a gently sloping bottom is negligible. Caldwell (1949) supports this assumption for slopes of four degrees or less.
South Carolina Wave Climate

Brown (1977) used SSMO data (U.S. Naval Weather Service Command, 1970) to derive wind and wave-energy-flux diagrams for the South Carolina coast. As expected, seasonal trends in wind and wave conditions were noted (Fig. 2). The average annual wave energy flux on the South Carolina coast is $1.7 \times 10^6$ g-m/s$^3$, with a maximum of $3.1 \times 10^6$ g-m/s$^3$ from the northeast. Wave energy flux is defined as the rate at which wave energy per unit surface area is transmitted in the direction of wave propagation.

The dominant winds (highest velocities) from the north and east during fall and winter are reflected in the direction of the deep water wave-energy flux. Strong storm winds from the northeast are generated by northward passing extratropical storms and are considered by Finley (1976) to be the "most important wave generators". Finley documented 7.3 meters of foredune erosion on Debidue Island in a two-week period following an extratropical cyclone in February 1973. Kana (1977) recorded process measurements during a minor northeast storm in September 1974. An average of $3.8 \ m^3$ of sand per foot of shoreline at Debidue Island was eroded in a 6-hour period. During this short period of erosion, breaker heights were approximately 120 cm (4 ft) with an average wave period of 6 seconds.

In spring and summer, an increasing frequency of winds are observed from the south and southwest. These winds are generated by an anticyclonic circulation pattern associated with a high pressure zone settling over Bermuda. According to Crutcher and Quayle in Brown (1977), an average of 1.4 hurricanes and tropical storms affect South Carolina's
Figure 2. Seasonal and annual wind and wave energy flux ($P_{1s}$) roses computed from the 1970 version of SSMO data. Bar length in the wind roses represents the percentage of time the wind blows from any given direction. Bar length in the energy flux roses is a relative measure of the wave energy coming from a given direction (from Brown, 1977).
coast annually. The probability of a tropical storm of hurricane force, winds in excess of 74 mph, striking the South Carolina coast, was determined by Nummedal and Humphries (1977) to be about .2, corresponding to one every 5 years. The highest breakers recorded on the coast were approximately 12 ft. They were recorded at Myrtle Beach during a hurricane in 1958 (Nummedal, 1977). Nummedal and Humphries (1977) also noted, from numerous observations at Debidue Island, an 11 cm decrease in wave height for the spring and summer as compared to fall and winter.

The dominant deep water wave-energy flux in the summer, as calculated by Brown (1977), is from the southeast and lower in magnitude than the winter flux values from the northeast and east. Finley (1976) computed the highest sea and swell which could affect the S. C. coast to be from the northeast and east. Figure 3 graphically displays the frequency of occurrence of sea and swell and their approach direction. These SSMO-based wave climate evaluations support the morphologic evidence of a net southward sediment transport.

Based on the above information and 1975 SSMO data, it was decided to use Goldsmith's (1976) "scatter gun" approach with respect to wave input conditions. In this way, a variety of conditions are modeled. Unfortunately, SSMO data have several inherent biases which make it difficult to determine percentage of occurrence for a given wave condition (Goldsmith, 1976; Nummedal and Stephen, 1976).

The initial deep water wave conditions consist of waves propagating from the east (90 degrees), southeast (135 degrees), and from the south (180 degrees) at periods of 10, 8, 6 and 4 seconds with a wave height of 1 foot. An initial wave height of one foot was used at the time of this analysis because frictional attenuation of the wave height in
Figure 3. Frequency of occurrence of sea and swell and their approach direction for SSMO observation square off South Carolina (from U.S. Army Corps of Engineers, 1970). (from Finley, 1976).
shallow water was not considered. Therefore, these diagrams are of qualitative value. Calculations of energy and longshore transport can be used for relative comparisons between sections of the coast but should not be used as indicators of absolute magnitudes.

**Bathymetry**

*Shelf morphology.* - According to Swift (1976), the Atlantic shelf sands are predominantly generated by erosional shoreface retreat during the Holocene transgression about 11,000 B.P. Two constructional features formed from this sand sheet were shoal retreat massifs which are overlain by linear sand shoals (Swift et al., 1972; Duane et al., 1972). Refer to Figure 4.

Shoal retreat massifs are broad sand ridges of subdued relief, transverse to the shelf, which mark the retreat of nearshore depositional centers. These depositional centers form off capes or cuspatate forelands and are the result of littoral drift convergence (Swift, et al., 1972). Because of the closely-spaced forelands south of Cape Romain, the shoal retreat massifs tend to coalesce.

Overlying the shoal retreat massifs are northeast trending linear shoals. These shoals form an angle of approximately 35 degrees with the shoreline, exhibit up to 30 feet of relief and may extend for many miles (Duane et al., 1972). The shoals may be connected to the shoreline or isolated. Duane et al. hypothesize that the shoreface connected ridges are formed by storm-generated currents interacting with the shoreface. These ridges become isolated as the shoreline retreats in response to sea level rise. Because of the similarity in orientation of both shoreface-connected and isolated shoals with respect to the shoreline, Duane et al. propose that the shoreline orientation pro-
Figure 4. Cuspate forelands and cape shoal–retreat massifs (stippled) of the South Carolina shelf. Note overprinting of ridge and swale topography. Contours are in fathoms. (from Swift, 1976).
bably remained essentially the same during the Holocene marine transgression.

**Hydrographic charts.** - Depth data is obtained by contouring hydrographic charts and boat sheets printed by NOAA (National Oceanic and Atmospheric Administration). The contoured depths are hand digitized on a Bendix Datagrid Digitizer and stored on magnetic tape. This tape is read by a routine in REFRAC, which constructs a depth grid by interpolating depths between the digitized contours. (For more details, refer to Appendix II)

A first-order chart of the South Carolina shelf (scaled at 1:432,720 to 1:449,659) was used to generate input data onto a larger scaled second-order chart (1:80,000) of the section of coast between Cape Romain and Folly Island. This chart generated data for the larger scaled third-order charts (1:20,000) of Price Inlet. Refer to Fig. 5 and Table 1.

The advantage of this technique lies in the use of more detailed bathymetric data for second and third order charts. This allows increased detail and greater accuracy in the resulting wave-refraction diagrams.

In relation to depth data, two considerations are necessary. First is the accuracy with which the depths were measured. Accuracy criteria for the depths and navigational positioning has been compiled by Sallenger et al. (1975). Refer to Figure 6 and Table 2 for a graphical summary and explanation of this information. Second, the amount of area distortion produced by the Mercator projection from a sphere to a flat map need be insignificant or corrected for. Goldsmith et al. (1974) had a special Mercator projection constructed for the Virginia shelf to minimize distortion. Robinson (1969) and Green-
Figure 5. Graphical representation of the 1st-, 2nd-, and 3rd-order charts and their relation to each other.
<table>
<thead>
<tr>
<th>Charts</th>
<th>Area</th>
<th>Year</th>
<th>Scale</th>
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</thead>
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<tr>
<td>1ST ORDER</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11520</td>
<td>S.C.</td>
<td>1975</td>
<td>1:432,720</td>
</tr>
<tr>
<td>11480</td>
<td>coast</td>
<td>1975</td>
<td>1:449,659</td>
</tr>
<tr>
<td>2ND ORDER</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1238</td>
<td>Cape Romain to Folly Is.</td>
<td>1973</td>
<td>1:80,000</td>
</tr>
<tr>
<td>3RD ORDER</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H-8779</td>
<td>Price</td>
<td>1963</td>
<td>1:20,000</td>
</tr>
<tr>
<td>H-4179</td>
<td>Inlet</td>
<td>1921</td>
<td>1:20,000</td>
</tr>
<tr>
<td>H-4180</td>
<td></td>
<td>1921</td>
<td>1:20,000</td>
</tr>
</tbody>
</table>
Figure 6. Maximum accuracy criteria used for soundings on hydrographic charts since 1860. Modified from Sallenger (1975). Refer to Table 2 for detailed explanation of this figure.
Table 2. Historical Review of Sounding Accuracy Criteria

<table>
<thead>
<tr>
<th>Date</th>
<th>Criteria</th>
</tr>
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<tr>
<td>1860</td>
<td>allowable error at sounding-line crossings was not to be more than 3 percent of the depth, with a limiting error of 5 percent.</td>
</tr>
<tr>
<td>1878</td>
<td>depth at sounding line crossings were not to exceed in depths of 15 feet and under, two-tenths of a foot; between depths of 15 and 30 feet, three tenths; and 30 and 48 feet, five tenths; between 48 and 72 feet, three-fourths of a foot; between 72 and 96, one foot and a half; and between 96 and 150, two feet. In the sea depths, the limit of error should not exceed 1 percent.</td>
</tr>
<tr>
<td>1894</td>
<td>the allowable error at sounding line crossings was 1.5 percent of the depth.</td>
</tr>
<tr>
<td>1942</td>
<td>in general, in the lesser depths, the differences at sounding line crossings should average not more than 5 percent of the depth and in greater depths not more than 2 percent of the depth.</td>
</tr>
<tr>
<td>1960</td>
<td>maximum errors: (1) 0 to 11 fm (0 to 20 m.): 1.0 ft. (0.3 m); (2) 11 to 55 fm (20 to 100 m.): .5 fm. (1.0 m); (3) 55 fm. (100 m) and deeper: one percent of depth</td>
</tr>
</tbody>
</table>
hood (1964) state that the amount of distortion decreases closer to the equator and that for small areas (as compared to the whole globe) may be negligible. The South Carolina coast lies between $32^\circ N$ and $34^\circ N$ and so qualifies as a small area. Therefore, the standard Mercator projections issued by NOAA were used without modification.
DATA OUTPUT – WAVE-REFRACTION DIAGRAMS

Description

A complete description of the types of output, including sample listings of the wave parameters printed by REFRAC, can be found in Appendix II. Refraction diagrams referred to in this section are in Appendix I. (Arrows refer to direction of sediment transport.)

Wave-refraction diagrams are a graphical representation of the bending of wave rays as the waves interact with the continental shelf. This interaction results in an uneven distribution of wave characteristics along the shoreline, as inferred by zones of converging and diverging wave orthogonals. Converging wave orthogonals depict areas of increased wave height and energy commonly correlative with areas of erosion. Conversely, diverging orthogonals depict areas of lower wave height and energy commonly correlative with areas of deposition. To accurately delineate these areas of erosion and deposition for a segment of the S. C. coastline, a set of first-, second-, and third-order wave-refraction diagrams have been generated.

A first-order diagram shows the gross energy distribution over an extended area. Figure 1, for example, shows the over-all wave-refraction pattern on the S. C. continental shelf for waves with a 10-second period from the east. The shelf break ranges from between 47 km and 75 km offshore at the 75 to 100 fathom contour. Figure 2 is a second-order diagram showing the energy distribution between Bull Island and the Isle of Palms. This figure was generated from the first-order diagram shown in Figure 1. The increase in detail is the result of an increase in the density of wave rays refracted and the greater bathymetric detail of the 2nd-order chart. The rays were started in deep water.
about 1 km apart. A subset of the rays refracted in Figure 2 generated the third-order diagrams in Figures 6a and 6b. The deep water spacing between these rays is the same as in Figure 2. These third-order diagrams show the detailed wave-energy distribution on Price Inlet's ebb-tidal delta.

The bathymetry of Price Inlet was surveyed in 1921 (PI - 1921) and again in 1963 (PI - 1963). The maximum depth of both surveys is between 25 and 30 feet. Incoming waves with periods of 6 seconds or greater have already felt bottom and begun to refract by the time they reach the maximum depth of the above surveys. Therefore, what is being observed on these charts is the 'fine tuning' of a process that has already begun in water deeper than 30 feet. Since the same second-order hydrographic chart generated input data at the seaward extent of both 3rd-order charts, wave refraction diagrams for PI-1921 and PI-1963 are similar. Changes of the inner shelf bathymetry have been noted by Goldsmith et al. (1975) off the southern Delmarva Peninsula, Virginia. Unfortunately, a smaller scale chart for 1921 was unobtainable.

Only 2nd- and 3rd-order refraction diagrams will be described in detail. Figures 2-5 are 2nd-order diagrams of waves approaching from the east. These waves, typical of winter months, are generated by extratropical storms passing north of South Carolina. A study of these figures reveals the strong effect offshore bathymetry has on an easterly wave approach. Waves with a period of 10 seconds (Fig. 2), after interacting with the continental shelf, have an exceptionally nonuniform distribution of wave energy. A very strong zone of convergence exists at Capers and Dewees Inlets and Capers Island. A dramatic decrease in wave energy is observed south of Dewees Inlet.
and north of Price Inlet. The direction of sediment transport was calculated by REFRAC to be predominantly to the south. In analyzing these diagrams, it is important to remember the variability in the amount of sand being transported as a result of the nonuniform distribution of wave energy. For example, in Figure 2, more sand is capable of being transported at Capers and Dewees Islands and their adjoining inlets because of the increased wave energy than further south on the Isle of Palms. Therefore, from Figure 2 alone, deposition may be expected on the Isle of Palms because of the lower wave energy and the resulting decrease in competency of the longshore currents.

Figure 3 is a wave refraction pattern for 8-second waves from the east. The wave energy, as compared to Figure 2, is more evenly distributed. A strong zone of convergence exists in the central section of the Isle of Palms and the northern tip of Bull Island. Price Inlet and the remainder of Bull Island seem to be in a zone of reduced wave energy for both 10- and 8-second waves. The predominant direction of sediment transport for an 8-second wave is to the south.

Refraction diagrams for waves with periods of 6- and 4-seconds (Figs. 4 and 5, respectively) have a progressively more uniform wave energy distribution than the energy distribution for 8- and 10-second waves. This results from longer period waves beginning to refract in deeper water. Furthermore, as a result of the different depths in which waves of varying periods begin to refract, the orthogonals of waves with longer periods tend to be more perpendicular to the coast (compare Figs. 2-5). Figure 4 (period (T)=6 seconds) shows a zone of convergence on the shoals north of Price Inlet. Sediment transport is predominantly to the south except on these northern shoals.
where it is to the north. In Figure 5 (T=4 sec), the zone of convergence has shifted to the southern shoals of Price Inlet and the northern end of Capers Island. The sediment transport is predominantly to the south, including the northern shoals of Price Inlet. The difference in transport direction on the northern shoals of Price Inlet is explained by the more perpendicular orientation of the wave rays with the shore, for waves with a longer period. This implies that shorter period waves may actually enhance sediment bypassing at Price Inlet.

Third-order refraction diagrams show the energy distribution and resulting sediment transport at Price Inlet in greater detail. The direction of sediment transport at the northern shoals of Price Inlet is to the south in Figures 9a and 9b (T=4 sec); whereas, for 10-, 8-, and 6-second waves (Figs. 6-8) transport is to the north. Comparing the direction of sediment transport in Figs 6a-9a and 6b-9b reinforces the above observation that sediment bypassing at the distal margin of the ebb-tidal delta of Price Inlet may be enhanced by waves with a shorter period. Further analysis of these diagrams reveals the existence of sediment transport reversals south of the inlet (Figs. 7a and 9b). Sediment transport reversals are caused by the refraction of waves around an ebb-tidal delta. Finley (1976) documented a similar transport reversal at North Inlet, South Carolina. Another observation, seen in Fig. 8a (T=6 sec), is the strong convergence of wave rays at the seaward extent of the northern marginal flood channel.

During the summer months, storms generate waves from the southeast and south. Second-order diagrams of waves from the southeast are shown in Figs. 10-13. The influence of the offshore bathymetry on these waves is evidenced by the alternate zones of converging and
diverging wave rays. Contrary to waves from the east, the zones of wave energy concentration do not shift with a change in period. For waves from the southeast with periods of 10-, 8-, and 6-seconds (Figs. 10-12), strong zones of convergence occur at the southern end of the Isle of Palms (Breach Inlet) and the northern section of Capers and Bull Islands. A weaker concentration of wave energy is seen at Dewees Inlet. The only difference between periods is the degree of concentration; smaller period waves are usually not as focused. Zones of reduced energy, such as Price Inlet, exist between the above zones of concentration. Waves with a 4-second period show a comparatively even wave-energy distribution.

The direction of sediment transport was determined to be the same for all 4 periods. Transport is predominantly to the south with an indication of transport to the north at the northern shoals of Price Inlet and Capers Inlet. As seen from the third-order refraction diagrams (Figs. 14-17), the predominant sediment transport is also to the south, but with one important difference. A sediment transport reversal to the north exists at the southern shoals of Price Inlet in all the diagrams except Figure 17b, which is for a wave with a period of 4-seconds.

Waves from the south are not affected as much by the offshore bathymetry as waves from the east and southeast. As a result, wave energy is more evenly distributed (Figs. 18-21). Fig. 18 (T=10 sec) shows zones of minor concentration at the southern and northern ends of the Isle of Palms. Bull Island experiences a slight increase in wave energy at the southern and central sections of the island. A more even energy distribution is seen in Fig. 19 (T=8 sec), except
for a strong concentration of wave rays on the mid-section of the Isle of Palms. This zone is surrounded on either side by a reduction in wave energy. Figs. 20 (T=6 sec) and 21 (T=4 sec) have a fairly uniform energy distribution. The only difference is seen in the direction of sediment transport. Figs. 18-21 show a dominant transport to the north. However, for waves with a 10-, 8-, and 6-second period, the sediment transport on the southern shoals of Price Inlet is to the south (Figs. 18-20). Transport is to the north for a wave with a 4-second period (Fig. 21). By comparing the above 4 figures with the more detailed third-order diagrams, Figs. 22-25, it is apparent that the lack of detail in Fig. 21 accounts for the discrepancy in the transport directions. Fig. 25a and b shows a sediment transport direction to the south for 4-second waves on the southern shoals of Price Inlet.

Discussion

Wave-refraction analysis provides an efficient method for interpreting coastal processes. When used in conjunction with field data, refraction diagrams aid in the understanding of coastal geomorphology. Stephen et al. (1975) measured the rates of shoreline change from vertical aerial photographs between the years 1939 and 1973 for Charleston County, South Carolina. The resulting classification scheme has four categories: areas of long-term erosion, long-term accretion, unstable areas and stable areas. Refer to Fig. 7 for an explanation and the geographical location of these categories. Included in this figure are the locations of the zones of wave energy concentration and reduction described in the previous section. A careful analysis of Fig. 7 reveals a relation between the zones of high and low wave energy, as depicted by wave-refraction diagrams, and the coastal geo-
Figure 7. Classification scheme of the shoreline changes for the S. C. coast, based on aerial photographs from 1939 to 1973. Modified from Stephen et al. (1975).

- long-term erosion: areas which have undergone relatively continuous erosion over the study interval.
- long-term accretion: areas which have undergone relatively continuous deposition over the study interval.
- unstable: areas with fluctuations greater than 50 ft over the study interval.
- stable: areas with fluctuations of less than 50 ft over the study period.

Superimposed on these shoreline changes are the various degrees of wave ray concentrations observed from the wave refraction diagrams.

- exceptionally high concentration
- high concentration
- uniform distribution of wave rays
- low concentration or diverging rays
- exceptionally low concentration.
There is a dynamic interaction between the tidal currents and long-shore currents generated by waves which affects the orientation and morphology of ebb-tidal deltas (Oertel, 1975; Oertel and Howard, 1972; Hubbard, 1977). Tide-dominated inlets have well-developed shoals forming a high oblique angle with the shoreline. Waves have a tendency to straighten a coastline by focusing energy on headlands. As a result, wave-dominated ebb-tidal deltas have a relatively parallel orientation with the shoreline. Coleman (1976) cites similar behavior in river deltas, only the interaction is between sediments supplied by the river and the wave regime.

Analysis of Fig. 7 shows the orientation of Price Inlet's ebb-tidal delta to be more normal to the shoreline than the orientation of the Capers-Dewees shoal complex further to the south. One explanation for this is obtained by comparing the refraction patterns on these inlets. Price Inlet exists essentially in a shadow zone of reduced wave energy for waves from the east, which is the direction of dominant energy flux. Therefore, tidal currents play a more active role in the development of the ebb-tidal delta, resulting in an almost perpendicular orientation to the shoreline. The Capers-Dewees complex, however, lies in a zone of exceptionally high wave energy concentration for a 10-second wave from the east. As a result, waves tend to push the sand up against the shore causing a more oblique or parallel orientation with the shoreline.

Besides the oblique orientation of Dewees Inlet, a large downdrift offset is exhibited. The ebb-tidal delta will act as a barrier against wave attack, but the downdrift offset is probably more
related to a sudden reduction in southward directed longshore drift at the Isle of Palms. This reduction in longshore drift, caused by the nonuniform energy distribution, allows the deposition of sediment on the northern end of the Isle of Palms. The area is unstable because of its proximity to Dewees Inlet.

Figure 7 shows long-term erosion further north at Bull Island. North Bull Island has no protecting shoals and is therefore open to wave attack, especially from an 8- or 6-second wave from the east. Figs. 10-13 (in Appendix I) show a concentration of wave energy on Bull Island for all waves from the southeast. This concentration of wave rays results from the interaction of waves and the section of the shoal retreat massif off the northern end of Bull Island (30 foot contour and shallower). Also, there is no apparent sediment source to allay the erosional trend on Bull Island.

Capers Island is also undergoing long-term erosion. As seen from Fig. 7, strong concentrations of wave energy are noted for waves from the east with a wave period of 10-seconds and waves from the southeast with a period of 10-, 8-, or 6-seconds.

A maximum accretion of 400 feet since 1941 has occurred on the southern end (spit) of the Isle of Palms. This area is one of the few areas on the S. C. coast categorized as long-term accretion. An analysis of Fig. 7 reveals this section of the Isle of Palms to be in a zone of reduced wave energy for most wave conditions. Therefore, deposition and spit growth would be enhanced.

A comparison of Figs. 1-5, 10-13, 18-21 (in Appendix I) and Fig. 7 suggests that longer period waves have more effect on the shape of the coast than shorter period waves. Because of the more
dramatic concentration or divergence of wave rays for longer period waves, sections of the coast will accrete or erode at different relative rates, therefore influencing the gross morphology of the coast to a larger degree than shorter period waves. Shorter period waves will have relatively even rates of erosion or deposition because of their more uniform wave energy distribution. The accretion on the Isle of Palms, the downdrift offset at Dewees Inlet, and the orientation of Dewees Inlet as compared to Price Inlet support this observation. The possibility that longer period waves have more effect on coastal geomorphology implies that the deeper offshore bathymetry (greater than approximately 48') affects the coast more than the nearshore bathymetry. To determine the validity of this observation, more precise data on the frequency of various wave conditions is necessary.

To gain an understanding of wave refraction and its possible effects on the morphology of an ebb-tidal delta, refraction diagrams with greater detail were generated for Price Inlet. Price Inlet is an example of a model developed by Hayes (1975) on ebb-tidal deltas (Fig. 8). Basically, waves will bend toward the inlet. The angle the wave makes with the shoreline is of critical importance in determining the direction of sediment transport. Waves from the east and southeast have a predominant sediment transport to the south. A careful examination of Figs. 6-9, 14-17 (in Appendix I) shows sediment transport reversals south of the ebb-tidal delta. Transport reversals result from the sharp bending of wave rays around the delta and provide a means for both reintroducing sand into the inlet, through the marginal flood channels, and building the beach and
Figure 8. General ebb-tidal delta model (from Hayes, 1975).
shoals south of the inlet. This mechanism was proposed by Hayes et al. (1970) as being responsible for downdrift offsets.

The angle at which waves strike the ebb-tidal delta may enhance or inhibit sediment bypassing around the distal shoals of the delta. Sand may be transported landward onto the swash platform or along the shoal margins depending on the tide level. At low tide, the shoals are subaerial. As a result, sand transport will occur along the shoal margins. For waves from the east, the net longshore transport is to the south. However, an analysis of Fig. 6-9 (in Appendix I) reveals that on the northern shoals of the delta, sediment transport is to the north for waves with a period of 10-, 8-, and 6-seconds. Therefore, sand transport to the south around the distal end of the delta is inhibited. For a 4-second wave, sediment transport on the northern shoals is to the south and, therefore, may actually enhance sediment bypassing. This is explained by the more oblique approach of a 4-second wave to the shoreline than the longer period waves.

Many of the ebb-tidal deltas on the S. C. coast exhibit channels which run parallel to the shore. During early flood when the swash bars are exposed, these marginal flood channels provide an avenue for water flow and sediment transport into the inlet. In the vicinity of the marginal flood channels, Figures 6-9, 14-17, 22-25 (in Appendix I) show converging sediment transport directions. This convergence may create a hydraulic head at the seaward extent of the marginal flood channel, thereby enhancing water flow and sediment transport through the channels. The larger size of the northern marginal flood channel probably reflects the effects of the direction of dominant wave energy flux from the northeast and east. The wide funnel
shape of this channel may result from the strong convergence in wave rays noted in Fig. 8 (in Appendix I). This convergence of rays would cause both an increase in wave setup and energy resulting in increased sediment transport and erosion at the seaward extent of the flood channel.

In nature, a spectrum of wave conditions strike the shore at any one time. Each component of this spectrum (different period and direction) has its own distribution of wave height and energy. This nonuniform distribution of wave characteristics, caused by wave refraction, may partially explain the intermittent character of the flood-directed stresses noted by Huntley and Nummedal (pers. comm.) in the marginal flood channels. These authors made a series of along-channel and cross-channel velocity measurements in both channels. An analysis of the variability of these two directional velocities provided a measure of the radiation stress available to drive longshore currents in the channels. These stresses were intermittent and related to obliquely incident waves.
The offshore bathymetry creates zones of converging and diverging wave rays by interacting with waves of different periods and directions. The importance of this interaction of coastal geomorphology is seen in the following observations from wave refraction diagrams of the S. C. coast from Bull Island to the Isle of Palms:

1. Zones of high and low wave energy, as depicted by converging and diverging wave rays, tend to have corresponding zones of erosion and deposition. Both Bull Island and Capers Island which are undergoing long-term erosion, are located in areas of wave convergence. Bull Island lacks an apparent sediment source which may partially account for the erosion. Further south, the southern tip of the Isle of Palms has undergone extensive deposition. This section of the Isle of Palms corresponds to a zone of reduced wave energy.

2. The large downdrift offset of Dewees Inlet appears to be related to a sudden reduction in the southward-directed longshore drift at the Isle of Palms as compared to Dewees Island and other barriers further north.

3. The orientation of Dewees Inlet and Price Inlet is related to the balance between wave energy and tidal energy. Price Inlet, being in a zone of wave energy reduction, is relatively dominated by the tidal current resulting in a normal orientation to the shoreline. Dewees Inlet exhibits an oblique orientation with the shoreline. This orientation is strongly related to the exceptionally high concentration of wave energy received from a 10-second wave from the east.

4. This study suggests that longer period waves and, therefore, the deeper offshore bathymetry may have a stronger effect on the
coastal geomorphology than shorter period waves and the nearshore bathymetry. Evidence for this is seen by the accretion on the Isle of Palms, the downdrift offset at Dewees Inlet, and the shore-parallel orientation of Dewees Inlet.

5. Sediment transport reversals are seen at Price Inlet for waves from the east and southeast. The calculated direction of transport implies that these reversals provide a means for reintroducing sand into the inlet and depositing sand on the beach and shoals south of the inlet.

6. Sediment bypassing around the distal portion of the ebb-tidal delta at Price Inlet may be enhanced by shorter period waves from the east.

7. In relation to marginal flood channels at Price Inlet, the following observations were made:
   a) Hydraulic heads resulting from the convergence of two different directions of transport may enhance water flow and sediment transport through the flood channels.
   b) A wave with a period of 6-seconds from the east may account for the funnel shape of the seaward extent of the northern marginal flood channel because of the strong zone of convergence in the vicinity.
   c) The pulsating flood currents recorded by Huntley and Nummedal (pers. comm.) may partially be explained by the variations in wave height produced at a point due to the simultaneous refraction of several different wave conditions.
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APPENDIX I

Refraction Diagrams
APPENDIX II

REFRAC--User's Guide
PROGRAM DESCRIPTION

Module Description

REFRAC is divided into a MAIN routine and several subroutines: RAYCON, REFRAC, CURVE, DEPTH, HEIGHT, REFDIA, ENERGY, BOTTOM and SORT1. The subroutine ENERGY is similar to the subroutine used by Colonell and Goldsmith (personal communication) for calculations of wave power and energy.

MAIN Routine. - This routine reads the input wave parameters such as initial wave height, period, direction and starting grid coordinates. Calculated refraction coefficients need be supplied if the wave starts in shallow water. Controlling program parameters such as window specifications, number of wave rays and so on are also read. Output includes a title page listing the input parameters for quick referral and comparisons between sets of rays. The shoreline, depth contours and plot title information are plotted at this time. Calculations of deep water wave celerity and length and the depth at which refraction will begin are performed. Further calculations include printing and plotting intervals based on a time step. Time was chosen as the independent variable in the governing equations because in deep water where effects of refraction are small, the celerity and, therefore the distance, between two points decreases. This coincides with the area in which the greatest detail is desired. The first subroutine called in this program is BOTTOM which sets up the depth grid for later calculations. Nested loops control the number of sets of rays and the number of rays per set to be analyzed. In the inner loop, control is passed to subroutine RAYCON which cal-
calculates each ray's path across the depth grid.

Subroutine RAYCON. - RAYCON controls each individual ray as it progresses across the grid. Initially, the wave is advanced one step and the depth calculated (from DEPTH subroutine) at this point. If the depth is greater than one-half the deep water wave length, deep water conditions exist signifying no changes in the wave. Printing and plotting options are then checked. The above steps are repeated until transitional water depths are reached, that is, until the wave feels bottom. Wave height and boundary positions are continuously checked for breaking wave or out of bound conditions. As the wave progresses through transitional water depths, the ray begins to refract. RAYCON repeatedly calls CURVE, REFRAC, and HEIGHT to calculate the curvature, step length and wave height resulting from increased refraction and shoaling. The ray may be stopped for a variety of reasons: there is no convergence in the calculation for curvature, the wave breaks, the ray reaches one of the boundaries, the maximum number of points calculated has been exceeded, or the incremental distance between steps is less than the minimum specified. As mentioned previously, RAYCON controls the printing and plotting for each ray. At user-determined intervals, a tick mark is plotted on the wave ray, and corresponding wave information, denoted by an asterisk, is printed. Subroutine ENERGY is called before each line is printed in order to calculate wave power and energy at that point. The boundaries for a more detailed window are calculated if a window has been specified in the input parameters. As a ray crosses these boundaries, values are generated and stored on disk to be used as input data into a later, more detailed refraction analysis.
Subroutine REFRAC. - This routine and the following subroutines are called repeatedly after the wave ray has entered transitional water depths. REFRAC calculates the step length which is a function of the wave celerity and time. If the step length is greater than the minimum value specified in the input, the curvature (through CURVE subroutine) and next X,Y coordinates are calculated. The initial curvature is used to project the next point on the ray. A new curvature at this point is calculated and compared to the original curvature, thus giving a better estimate of the position for this point. This process is repeated until the difference between two successive calculations is acceptably small; then the new point is considered fixed. Two conditions of instability can arise. One condition results in the curvature being averaged between solutions; a message is printed to this effect. The other condition results from the failure of the calculations to converge, in which case the ray is stopped.

Subroutine CURVE. - Based on the depth of the water, one of two equations is used to calculate the wave celerity. Five one-thousandths (.005) of the wavelength is the program's boundary between shallow water and intermediate depths. The curvature of the ray is then calculated. The curvature is a function of the ratio between local speed and deep water wave speed, the depth and several depth-related coefficients, plus the azimuth of the ray.

Subroutine DEPTH. - A second degree polynomial fitted locally (instead of on the complete depth grid) provides an accurate method for interpolating depths at intermediate points (Dobson, 1967). The equation is:

\[ \text{DEPTH} = e_1 + e_2x + e_3y + e_4x^2 + e_5xy + e_6y^2 \]
The local grid system consists of 12 points (Fig. 1) which are filtered through a matrix of weighting terms derived from the relative positions of the data points. This local grid system traces the ray's path shoreward across the depth grid. The six coefficients in the equation result from a summing of the different filtered depths and remain constant within the local coordinate system. Calculation of the curvature and refraction coefficient for a point are based on these six coefficients.

Subroutine HEIGHT. - This subroutine calculates the shoaling and refraction coefficients, which are used in the computation of the local wave height. The shoaling coefficient is equal to the ratio of the group velocity in deep water to local group velocity and therefore dependent on the water depth. The refraction coefficient is determined by the change in separation of wave rays. Dobson (1967) created a separation factor which is a function of wave celerity, azimuth of the ray and the six depth coefficients. As a result, the calculation of the refraction coefficient for the present time step is dependent on the refraction coefficient of the previous time step.

Subroutine REFPLA. - This subroutine plots the X, Y coordinates of the ray as it progresses shoreward. The grid coordinates are multiplied by the length of a grid side to convert them into plot inches before plotting. The data input variable BOUND is subtracted from the deep-end of the y-axis if this part of the plot is not desired.

Subroutine ENERGY. - The equations used in this routine and their derivations may be found in the Shore Protection Manual (Coastal Engineering Research Center, 1973). As part of each printed line of output, the total wave power and energy, the longshore power and direction (left or right) are calculated and printed. Longshore transport
Figure 1. Local grid system used in surface fitting procedure for depth calculations.
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A
Area of Interest

\((x,y)_n\)

Local Origin,
i,j in Main Grid
rates based on wave energy flux and Calvin's (1972) gross longshore transport rates based on breaker height are calculated at the breaker points. These transport rates are in cubic yards per year and the wave energy flux transport rate is further converted to cubic meters per year.

**Subroutines BOTTOM and SORT1.** BOTTOM creates an evenly-spaced depth grid from a digitized bathymetric map. A maximum of 20,000 grid points may be generated depending on the spacing interval between grid lines which is user determined. The digitized data includes the X,Y coordinates of the map perimeter and the bathymetric contours and their associated depths. Up to 100 different contours can be digitized.

The digitized data is read and converted into a numeric or character format for the program. As the data is read, two temporary disk files are created. These files store the X,Y coordinates for the shoreline and contours and will be plotted when program control returns to the MAIN routine. The points on the perimeter are read first, and the incremental distances and depths calculated. The depths are computed from the straight-line slope formula. These calculations occur between two corners of the map unless contours cross this section of the perimeter, in which case calculations occur between the corner and the first contour; between contours (if more than one crossed the perimeter); and the last contour and far corner. Upon completion of the perimeter, the coordinates of the contours are read and converted into the proper format. After the digitized tape is read, the tape is rewound and the SORT1 routine called.

Subroutine SORT1 written in Assembler language, links a system utility sort to REFRAC. The depths and their coordinates are sorted
to build the desired depth grid. Note that, at this point, the only depths are the incremental depths along the perimeter and the depths located at the contours. After the sort is completed, BOTTOM is re-entered and the remaining depths calculated.

Grid depths are calculated parallel to the y-axis, one grid line at a time. The distance between two points on two contours or a contour and perimeter with the same x-coordinate is completed. The depth distance between these two points divided by their distance determines the slope which is used to calculate the incremental depths between the two points. Because of the method of interpolation described, the y-axis should be drawn as perpendicular to the contours as possible.

Upon completion of the grid, program control returns to the MAIN routine and refraction calculations as described in the previous sub-routines begin. Fig. 2 is a generalized diagram of the flow of control in the program REFRAC.

Output Description

REFRAC has two types of output to describe ray refraction. The first, printed information includes a title page per set of rays. Title of the area being analyzed and date of analysis are printed on top of the page. An echo print of all input parameters allows a quick referral when comparing sets of rays. The date of the hydrographic chart and its units of measurement are also printed.

Information on individual rays is printed next. At the start of a ray, a variable GRINC is calculated and printed. GRINC is the deep water step length expressed as a fraction of the grid square and should equal approximately .5. Calculation of GRINC is further discussed in the section on PROGRAMMING CONSIDERATIONS (Determination of Input Param-
Figure 2. Program flow.
meters). Points along the ray are printed at a user specified interval. Asterisks printed beside the point number correspond with tick marks plotted perpendicular to the ray orthogonal. Point information includes: location of point on the grid, azimuth of the ray, water depth, length, speed and height of wave, refraction and shoaling coefficients, bottom and mid fluid particle velocities, total wave energy and power, the longshore component of power and direction (left or right as the observer faces the ocean). If the wave breaks, the longshore energy flux factor and longshore transport rates are printed. For convenience, the transport rates are converted into metric units. Also, the gross longshore transport rate as derived by Galvin (1972) is printed.

The second type of output is a plot of the refracting rays as they travel shoreward. Plot output includes the digitized shoreline and bathymetric contours. Wave orthogonals or rays (lines parallel to the direction of wave propagation) are plotted with perpendicular tick marks. Title information on the plot includes: the period and deep water wave height and azimuth, date of hydrographic chart, date of plot, water level height of chart and relative water depth of plot to chart.

Input Description

Card input formatting. - Input values are of three types: integer (1) - numeric values without a decimal point; floating point (F) - real numeric values which include a decimal; and alphanumeric (A) - alphabetic or numeric. A field refers to the columns of a punch card where a value is to be found. Integer and real values are to be right-justified; that is, punched in the columns furthest to the right in their particular field. Alphanumeric data should be left-justified.
Blank data fields are interpreted as zeros by the program. The number in parenthesis following the variables description are suggested values.

Card Sequence:

<table>
<thead>
<tr>
<th>Card #1</th>
<th>Columns</th>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-40</td>
<td>ITITLE</td>
<td>(A)</td>
<td>Title of wave refraction analysis</td>
</tr>
<tr>
<td>Card #2</td>
<td>1-5</td>
<td>FAC</td>
<td>(F) Size of plot desired relative to original chart.</td>
</tr>
<tr>
<td>Card #3</td>
<td>1-4</td>
<td>DATE1</td>
<td>(A) Year of hydrographic chart soundings.</td>
</tr>
<tr>
<td></td>
<td>7-18</td>
<td>MEAS</td>
<td>(A) Units in which depth of chart is expressed.</td>
</tr>
<tr>
<td></td>
<td>21-24</td>
<td>W</td>
<td>(A) Water level chart was sounded at (e.g. MLLW, MLW LSL, MHW, MHHW).</td>
</tr>
<tr>
<td>Card #4</td>
<td>1-5</td>
<td>MI</td>
<td>(I) Number of grid lines in X-direction.</td>
</tr>
<tr>
<td></td>
<td>6-10</td>
<td>MJ</td>
<td>(I) Number of grid lines in Y-direction.</td>
</tr>
<tr>
<td></td>
<td>11-15</td>
<td>LIMNPT</td>
<td>(I) Maximum number of steps to be calculated for a ray (4000).</td>
</tr>
<tr>
<td></td>
<td>16-20</td>
<td>NPRINT</td>
<td>(I) Printing interval (10).</td>
</tr>
<tr>
<td></td>
<td>21-30</td>
<td>GRID</td>
<td>(F) Number of feet (from hydrographic chart) that equal the length of a grid square side.</td>
</tr>
<tr>
<td></td>
<td>31-40</td>
<td>DCON</td>
<td>(F) Conversion factor for depth values to feet.</td>
</tr>
<tr>
<td></td>
<td>41-50</td>
<td>DELTAS</td>
<td>(F) Minimum step length, expressed as a fraction of a grid square (.002).</td>
</tr>
<tr>
<td>Card #5</td>
<td>1-10</td>
<td>BOUND</td>
<td>(F) Number of inches to be subtracted from deepwater end of plot.</td>
</tr>
</tbody>
</table>
11-20 SCX (F) Length of a grid square in inches.
21-30 XSG (F) X-coordinate of lower left corner of window. Set equal to MI if window is not desired.

Note: If window is not desired, remainder of card is left blank.

31-40 YSG (F) Y-coordinate of lower left corner of window.
41-50 SCNV (F) Magnification of window.
51-60 DGXL (F) Length of window (x-direction) expressed in plot inches.
61-70 DGYL (F) Height of window (y-direction) expressed in plot inches.

Card #6
1-5 NOSETS (I) Number of sets of rays to be processed.

Note: Repeat the following cards if more than one set of rays is to be processed.

Card #7
1-5 LPLOT (I) Number of steps between plot points on a ray (10).
6-10 NORAYS (I) Number of rays in a set (Maximum 400).
11-20 T (F) Wave period for a set of rays (seconds).
21-30 HO (F) Deep water wave height (feet).
31-40 SK (F) Shoaling coefficient for first time step.
41-50 SKI (F) Deep water shoaling coefficient (usually 1).
41-60 THI (F) Clockwise angle between north on map and y-axis of grid.
61-70 STAZ (F) Deepwater azimuth of a set of rays.
71-80 UNIT (F) Timestep
| Card #8 | 1-5 | ISP (I) | Sets print option on check depth.  
|        |     |        | =-1, information printed and processing of ray continued.  
|        |     |        | =0, no check depth.  
|        |     |        | =+1, information printed and processing of ray stopped.  
| 6-10   | LCK (I) | Starting position for set of rays.  
|        |     |        | =0, rays start in deep water.  
|        |     |        | =+1, rays start in shallow water.  
| 11-20  | WPI (F) | Number of wave periods between tick marks on a ray.  
| 21-30  | CKDEP (F) | Check depth, ray information will be printed for step nearest this depth.  
| 31-40  | DF (F) | Factor to convert depth values from one water surface datum to another. The factor will be added to the depth values. If not needed, leave blank.  
| 41-45  | IWR (I) | Specifies if starting coordinates for a set of rays is the same as a previous set.  
|        |     |        | =0, new wave information to be read off of cards or disk.  
|        |     |        | =+1, wave information same as previous set.  
| 46-50  | PD (F) | Depth at which printing of ray information will begin. If left blank, PD will equal first depth value on grid.  
| 56-65  | YFA (F) | Factor added to the y-coordinate of the starting point of a ray in order to decrease the amount of deep water region the wave travels over, thereby decreasing computation time.  

II-14
Card #9 4-5 IRED (I)
If IWR=0 and the information for card deck #10 resides on disk, set IRED to 25, otherwise leave blank. IRED equals 25 implies that the ray information was generated by a previous run on a smaller scale map through a window and stored on disk.

The following card must be repeated for each ray in a set. (Note: for any set other than the first set, if IWR = 1, these cards are not needed. The information is taken from the previous set.)

Card #10 1-10 X (F) X-coordinate for starting position of ray.
11-20 Y (F) Y-coordinate for starting position of ray.

Note: The following variables are needed if the ray is starting in shallow water, otherwise leave blank.

21-30 AZIMTH (F) Azimuth of a ray.
31-40 RK1 (F) Refraction coefficient of wave ray at the time step previous to starting location.
41-50 RK (F) Refraction coefficient of wave ray at starting location.

Digitized depth input. - This section describes in a step by step format how to prepare a hydrographic chart for digitizing and the digitizing process.

Step 1 - Outline the area of interest. Enclose the area of interest in a rectangular outline. This outline is the perimeter of the grid system which will be generated from the digitized contours. The perimeter should be oriented so that the wave rays travel from deep to shallower water. In other words, the Y-axis is more or less perpendicular to the shoreline or contours. Figure 3 shows the perimeter orienta-
Figure 3. Hypothetical hydrographic chart to be digitized. Contours are in feet.

\begin{align*}
  \text{X-axis} &= 8 \text{ inches} \\
  \text{Y-axis} &= 5.5 \text{ inches} \\
  \text{If SCX} &= .1 \\
  \text{MI} &= 81 \\
  \text{MJ} &= 56 \\
  \text{MI} \times \text{MJ} &= 4536 \text{ (Total no. of grid points).}
\end{align*}
tion on a hypothetical hydrographic chart.

Before drawing a perimeter, two questions need to be considered. First, what are the directions of wave approach? If the waves will be starting from the perimeter sides, extra distance along the X-axis will be needed to give the rays time to refract into the area of interest. Second, how many grid points will be generated? The number of grid lines crossing the X and Y axis (MI and MJ respectively) are given by

\[
\begin{align*}
\text{MI} \quad \text{and} \\
\text{MJ} \\
&= \frac{\text{Length of respective axis in inches}}{\text{Spacing interval between grid lines (SCX) also in inches}} + 1.
\end{align*}
\]

As interpreted from the above equation, the origin of the grid is (1,1). The value of SCX is user determined and will depend on the complexity of the bathymetry. The number of grid points generated is the result of multiplying MI and MJ together and must be less than the maximum of 20,000. The values of MI, MJ, and SCX will be entered into the program as card input.

STEP 2 - What to digitize. First the perimeter and the points where the contours cross the perimeter are digitized. Next, the contours are digitized. A problem arises in digitizing the shoreline. In Figure 3, for example, if the island is super-tidal, then primary breakers will be oceanward of the barrier. The application of the linear wave theory stops at the line of primary breakers. So for refraction purposes, the barrier acts as the shoreline. Figure 5 shows the resulting digitization of the shoreline. Notice the inlet to the right of the barrier was truncated.

The orientation of the shoreline with respect to a breaking wave is critical in calculations dependent on breaker height and breaker an-
gle. Two such calculations used in the program are the longshore energy flux factor and longshore sediment transport rate. To maintain the proper shoreline orientation, a constant slope is assumed from the first oceanward depth contour onto the beach. This is accomplished by digitizing a mirror image of the first contour onto the landward side of the shoreline (see Figure 5, the -6 foot contour). A second mirror image of the shoreline may be digitized landward of the first mirror image if changes in tidal elevations are to be considered. It is suggested these lines be drawn in before digitizing.

STEP 3 – Digitization preparation. Instructions on setting up the digitizer have been previously written by Jim Crabtree (personal communication) and only slightly modified in the following explanation.

The digitizer is turned on by a switch located near the upper center of the back panel. Before using the digitizer, the following switches on the Operator's Display Panel should be checked:

1. The IRG switch should be in the on position.
2. The switch labeled DIST POINT TIME MODE should be in the DIST mode.
3. The switch labeled ΔX - ΔX + ΔY should be in the ΔX + ΔY position.
4. The magnetic tape unit on-off switch should be turned off.
5. The DISTANCE thumbwheels should be set to .050 – that is, a coordinate will be recorded every 5 hundredths of an inch.

To mount a magnetic tape reel on the tape unit, the following procedure should be followed:

1. The magnetic tape unit must be turned off during the loading of a tape reel. If the unit is on during the loading process, it is possible to blow a fuse.
2. Open the front plastic cover to the tape unit.
3. Mount the tape reel on the right-hand hub by depressing the button in the center of the hub and sliding the tape reel completely onto the hub before releasing.

4. Then, using one hand to rotate the tape reel, follow the arrows indicated in Figure 4 to thread the tape to the receiving reel. Make sure that the tape passes between the metal plate and the write head at point A in Figure 4.

5. Wrap the tape around the receiving reel twice and make sure that all slack is taken up. The easiest way to wrap the tape around the receiving reel is to rotate the receiving reel with the left hand until the index finger can be inserted through the finger hole and press the tape against the center of the reel. Then rotate both reels clockwise with the right hand giving slack and the left hand taking it up.

6. Close the front plastic cover and turn the tape unit on.

7. Press the LOAD button once and release.

8. Press the LOAD button again and hold until the READY light comes on.

9. Press the FILE GAP button and release.

10. Press the FILE GAP button again and release.

11. Press the REWIND button and release.

12. Press the LOAD button and hold until the READY light comes on.

The tape unit is now ready to record data.

Step 4 - Digitizing depth data. Tape the chart to the top of the digitizer table so that the x-axis increases to the right. Located on top of the table will be a cursor and keyboard. The crosshairs on the window of the cursor are used for guiding the cursor as the data is traced. As the cursor is moved, X and Y coordinates are recorded onto
Figure 4. Magnetic tape unit.
magnetic tape every .05 inch. The depth corresponding to the contour being digitized is entered on the keyboard.

The cursor is initially set at the lower left corner of the perimeter. Pressing the red button on the cursor resets the digitizer's X and Y coordinates to zero. Hold the cursor steady and press the blue (DATA) button. This places the digitizer into the data-recording mode. When the digitizer is in this mode, the red-orange DATA light on the Operator's Display Panel is on, and data can be recorded from the cursor or the keyboard. Next, press the yellow (HOLD) button on the cursor. The digitizer is now in the HOLD mode and locks in on the last digitized coordinate. Only data from the keyboard can be entered when the HOLD light on the Operator's Display Panel is on. The HOLD mode prevents the recording of extraneous data if the cursor is accidentally moved. The digitizer is now ready to record the first depth entry.

Depths are entered as a 5-digit number which the program converts to a number having one place to the right of the decimal. A depth entered as D+00525/s will be converted to 52.5 units below water level. Depths below water level are positive (+) and elevations above water level are negative (-). The few remaining codes will be discussed as they are used in the digitizing scheme presented below. The bracketed numbers correspond to the numbers in Figures 5, 6 and 7.

(1) This is the starting point on the chart. With the crosshairs of the cursor centered on the lower left corner, press the red button, then the blue and yellow buttons on the cursor. This point is recorded as the zero reference point. The digitizer is in the HOLD
Figure 5. Digitization of perimeter on hypothetical hydrographic chart.
mode which records keyboard data entry only. Corner depths are differentiated from depths on the perimeter by the notation 'PD'. All other depths begin with 'D'. Using Figure 5 as an example, enter PD+00400/s on the keyboard. In other words, the depth at this point is 40 feet. Press the yellow button to take the digitizer out of the HOLD mode. Cursor movement is now able to be recorded. With a steady motion, move the cursor to (2).

(2) Press the HOLD button to put the digitizer in the HOLD mode. Enter D+00300/s on the keyboard. Press the HOLD button to take the digitizer out of the HOLD mode and move the cursor to (3).

(3) Put the digitizer in the HOLD mode and enter PD+00250/s on the keyboard. Press the HOLD button to take the digitizer out of the HOLD mode and move the cursor to the first depth that crosses this section of the perimeter (4).

(4) Press the HOLD button. Enter D+00180/s on the keyboard. Press the HOLD button and move the cursor to the next point.

Continue digitizing the perimeter in the same fashion until point (21).

(21) The last point on the perimeter is the starting point. Press the HOLD button to enter the HOLD mode and enter 'LS' on the keyboard. This signifies the end of the perimeter. The contours are digitized next. Contour depths are denoted by a 'D' except for the shoreline which is symbolized by an 'H'. Refer to Figure 6 for the following discussion on digitizing the contours.

(21) Press the HOLD button to take the digitizer out of the HOLD mode. Steadily move the cursor to the first contour to be digitized, in this example (22).
Figure 6. Digitization of contours and shoreline on hypothetical hydrographic chart.

The shoals outlined by a dashed rectangle are enlarged in Figure 7.
(22) Press the HOLD button to put the digitizer in the HOLD mode. Enter D+00300/ on the keyboard. A contour is signified when an 'S' does not immediately follow '/'. Take the digitizer out of the HOLD mode and carefully trace the contour. Remember, contour traces will be plotted on the final output.

(23) Enter the HOLD mode and enter an S on the keyboard. This completes the trace of the 30 foot contour. Press the HOLD button to take the digitizer out of the HOLD mode and move the cursor to the next contour.

(24) Press HOLD. Enter D+00180/ on the keyboard. Trace the 18 foot contour.

(25) Press HOLD and enter the letter S on the keyboard. Press HOLD and move the cursor to the next contour.

The remaining contours are digitized in the same manner, except the shoreline. Replace D and an H for the shoreline and enter H+00000/ on the keyboard. As in the contour depths, the end of a segment of shoreline is denoted by an S. Refer to Figure 7 for the following bracketed numbers.

(37) After the S is entered on the keyboard signifying the end of the -6 foot trace, press the HOLD to take the digitizer out of the HOLD mode. Move the cursor to a point of one of the shoals (38).

(38) Press HOLD and enter the depth of the shoal, D+00010/, on the keyboard. Press HOLD and with a steady motion, trace the shoal.

(39) Upon returning to the starting point, press HOLD and enter an S on the keyboard. Press HOLD again and move the cursor to the next shoal.

(40) Press HOLD. Enter D+00010/ on the keyboard. Press HOLD, taking the digitizer out of the HOLD mode and trace the contour.
Figure 7. Enlarged view of shoals digitized in Figure 6.
Again upon returning to the starting point, press HOLD and enter an S on the keyboard. This being the last contour to trace, enter an F on the keyboard (after the S) to signify the end of the digitized data.

(To Finish) The trace being complete, press HOLD to take the digitizer out of the HOLD mode and move the cursor in any direction until a beep is heard on the digitizer. This will create a complete record block of 4096 characters on the magnetic tape which is necessary for proper operation of the program. On the Operator Display Panel, press the FILE GAP button twice. This will indicate the end of this data file.

Step 5 - Dismounting the magnetic tape. The following steps are to be followed when unloading the magnetic tape unit:

1. Press the REWIND button and release.
2. After the magnetic tape has finished rewinding, turn the magnetic tape unit off.
3. Open the front plastic cover to the tape unit.
4. Use the left hand to rotate the left-hand reel counterclockwise to give tape slack. At the same time, use the right hand to rotate the right-hand reel counterclockwise to take up the slack tape. Continue this process until the tape has been wound onto the right-hand reel.
5. Remove the tape reel from the right-hand hub by depressing the button in the center of the hub and sliding the reel off before releasing.
6. If no more tapes are to be mounted, make sure the front plastic cover is closed. This will help to keep dust off of the write-
head assembly.

Step 6 - Final Step. Only one bathymetric map can be digitized per magnetic tape. To avoid the problem of running out of tapes, a small program written by J. Crabtree will copy the digitized data off the magnetic tape and store it onto disk, thereby freeing the tape for later use.

The tape first has to be brought to the user's service window in Computer Services Division (CSD). At the time of this writing CSD is located at the corner of Wheat and Main Streets. Remember to copy the number of the tape as this information is needed by the program. A program listing and information on how to implement this program is provided in PROGRAMS: TTD (Tape to Disk).
Determination of Input Parameters

MI, MJ, SCX and GRID. Refer to the Digitized Depth Input (Step 1) for the calculation of MI, MJ, and SCX. GRID is the dimension of the side of a grid square expressed in map feet and is a function of SCX and the scale of the map. GRID is given by

\[
GRID (\text{feet}) = \frac{(SCX \times \text{map scale})}{12}
\]

For example if Figure 3 had a 1:80,000 scale, GRID would equal 666.67 feet \((.1 \times 80000/12)\), if SCX = .1.

XSG, YSG, SCNV, DGXL and DGYL - Window parameters. A window is an area inside the present grid being processed. This window enables the user to study a particular area in the grid in greater detail by using a larger scale grid. REFRAC will trace the rays through the window and generate the necessary input parameters to be used in a refraction run on the larger scale grid. To create the window on the small scale grid, the X (XSG) and Y (YSG) coordinates of the lower left corner of the window position, the ratio of the two scales (SCNV) and the length of the axes of the window (DGXL and DGYL) expressed in inches of the small scale grid are input in the preliminary run. XSG and YSG are given by

\[
\begin{align*}
XSG & = \text{distance (inches) from respective X or Y axis of the small scale grid to the lower left corner of the window} + 1 \\
YSG & = \frac{\text{small scale grid to the lower left corner of the window}}{SCX} + 1
\end{align*}
\]

SCNV may be calculated by

\[
SCNV = \frac{\text{small map scale}}{\text{larger map scale}}
\]

SCNV is considered a magnification factor and will always be greater than 1.
The following equation yields DGXL and DGYL:

\[
\text{DGXL or DGYL} = \frac{\text{respective axes length (inches)}}{\text{SCNV (inches) of larger scale map}}
\]

This initial run on the small scale grid will generate the starting coordinates (X and Y), the refraction coefficients of that time step (RK) and of the previous time step (RK1) and the azimuth (AZIMTH) for a ray to be used as input in a subsequent run on the larger scale grid. These wave characteristics, generated for every ray that crosses the window boundary, can be either printed onto paper, punched onto cards or stored on disk. The program is presently set up to store these values on disk under a user determined data set name, so they can be easily accessed. See JCL considerations under REFRAC in the section on PROGRAMS for further information. If RK, RK1, and AZIMTH are not the results of a previous run, they will have to be hand calculated for each ray and keypunched onto cards for input into the program. (This only applies to rays starting in shallow water.)

**NORAYS.** A maximum of 400 rays can be refracted per set. If the number of rays is not known, such as in the case of window-generated input, set NORAYS equal to 400.

**SK and SKI.** SK is the shoaling coefficient at water depth for the present time step. If a set of rays start in shallow water (SK is greater than 1), set SK to 1 on input because the program will calculate the proper value. SKI is the shoaling coefficient at water depth for starting location of a ray. Most refraction diagrams are of swell conditions; therefore, SKI usually equals 1.

**THI and STAZ.** THI is the clockwise angle between north on the map and the positive y-axis of the grid. See Figure 8. STAZ is the azimuth or the clockwise angle between north on the map and the deep-
Figure 8. THI is the clockwise angle between north on the map and the positive y-axis of the grid.
water direction of wave approach. See Figure 9.

GRINC, UNIT, WPI, GRID and KPlot. UNIT is the time step for a set of rays. WPI is the number of wave periods between tick marks on a ray. The variable KPlot is calculated in the program and determines the points on a ray where tick marks will be plotted. KPlot is dependent on the values of UNIT, WPI and GRID. GRINC is the deepwater step length, expressed as a fraction of a grid square and is given by:

\[
\text{GRINC} = \text{UNIT} \times \frac{\text{CO}}{\text{GRID}}.
\]

CO, the deepwater wave celerity, equals 5.12 times the period (T). In the above equation, UNIT is the only variable user determined and should be chosen so the resulting value of GRINC is approximately .5.

KPlot is given by:

\[
\text{KPlot} = (T \times \frac{\text{WPI}}{\text{UNIT}}) + .1
\]

WPI should be chosen so the value of KPlot is greater than or equal to 1. Optimal results are achieved if KPlot is approximately 10.

Miscellaneous

Depending on the needs of the user, there is the choice of printing or not printing the depth grid values or wave information. Refer to JCL Considerations if either of these options is desired. The amount of printed output may be decreased by both of the variables NPRINT and PD. NPRINT is the user determined printing interval for information along a ray. A suggested value for NPRINT is 10. PD is the depth at which printing will begin. The advantage of PD is that it enables the user to limit printing to where the rays are more strongly refracted - that is, in shallow depths. Over 10,000 lines of printout can easily be generated when refracting a set of more than 50 rays. Turnaround time (time it takes to get printed results) and CPU time (execution
Figure 9. Determination of deepwater azimuth for a ray expressed in degrees (STAZ). Wave approach depicted by direction of arrow.
time) are decreased when the number of lines printed is kept to a minimum.

Keypunching and computation time can be saved by the two input variables IWR and YFA. The card input falls into two categories, the information needed for a set of rays and the information on individual rays such as starting coordinates. If more than one set of rays is being processed and the individual wave characteristics will be the same, set IWR equal to 1 for the sets after the first set. The program will store the first set of ray characteristics and use the same information for the subsequent sets until all the sets of rays are processed or until IWR equals zero. If IWR equals zero, the individual wave characteristics have to be read off cards or disk. YFA adds a constant to the y-coordinates of the starting locations for a set of rays. This enables the same wave characteristics cards to be used for a variety of periods by moving the starting positions of rays relative to the shoreline.

The user has a choice between two plotting devices, the Gould electrostatic plotter or the Calcomp drum plotter. The Gould plotter is faster - minutes compared to hours - but the Calcomp plotter has better resolution. The increased resolution may be desired if the refraction diagrams are to be photographed.

The Gould plotter has a maximum length (x-axis) of 327 inches and height (y-axis) of 63 inches. The width of the plotter is only 10.5 inches; therefore, any width greater than 10.5 inches (but less than 63) will cause the plot to be 'stripped'. The input variables FAC or BOUND can reduce the plot size to avoid stripping. Because of the fast plotting time, the Gould plotter is excellent for debugging or obtaining work copies of the refraction diagram.

The maximum length of the x-axis for the Calcomp plotter is limited
to the length of paper on the roll. The maximum length of the y-axis is 29.5 inches. For purposes of photocopying the diagram, liquid ink can be requested instead of the standard black ballpoint pen.
REFRAC

JCL Considerations

The JCL (Job Control Language) presented in this section is coded for an IBM 370/168 System. Job control cards begin with a // (slash-slash). REFRAC is compiled, loaded and then stored on disk (mass storage) in a program library called WORK.

The following discussion explains how to implement REFRAC and the various options available by small changes in the JCL. (Refer to JCL listing.) The first 3 cards are the JOB card. Included on the JOB card are the account number (N3100138), maximum number of lines to be printed (50,000) and maximum number of plot records (99990). TIME has the format (minutes, seconds); therefore, the time requested in the above JCL listing is 2 minutes and 30 seconds. The time can be decreased depending on the number and size of diagrams to be plotted. USER and PASSWORD information is obtained when an account number and disk space are requested from Computer Services Division.

The remainder of the JCL between the fourth card, PROC, and the last card, PEND, is called an in-stream procedure. This procedure accesses the necessary libraries and data sets whenever it is called. A call to the procedure is made by an EXEC statement following the PEND statement. More detail is given in the several examples following the listing of the in-stream procedure.

The REFRAC procedure is set up to plot the results on the Gould plotter at the Social and Behavior Sciences Lab located in Gambrell Hall (University of South Carolina). The Calcomp drum plotter is located in Computer Services Division (CSD) and the results can be plotted there with the following minor changes to the JCL. Change:
JCL LISTING OF THE IN-STREAM PROCEDURE REFRAC

//N3100138 JOB (N3100138,50,9999),*WAVE REFRACTION*,MSGLEVEL=(1,1),
// USER=N310013,PASSWORD=CRD,REGION=600K
// TIME=(2,30)
//REFRAC PROC DEPGRID='DUMMY',*WAVDATA=NULLFILE,NEWAV=NULLFILE
//STP1 EXEC PGM=REFRAC
//STEPLIB DD DSN=N310013,WORK,DISP=SHR
// DD DSN=SM1.LINKLIB,DISP=SHR
//SYSPRINT DD SYSOUT=A
//SYSOUT DD SYSOUT=A
//SORTLIB DD DSN=SM1.SORTLIB,DISP=SHR
//SOWTK01 DD UNIT=SYSDA,SPACE=(TRK,200**,CONTIG)
//SOWTK02 DD UNIT=SYSDA,SPACE=(TRK,200**,CONTIG)
//SOWTK03 DD UNIT=SYSDA,SPACE=(TRK,200**,CONTIG)
//FT06F001 DD SYSOUT=A
//FT07F001 DD DSN=&NEWAV,UNIT=3330V,MSVGP=USCP,
// DISP=(NEW,CATLG,DELETE),SPACE=(TRK,(5,5),RLSE),
// DCB=(LRECL=50,BLKSIZE=2000,RECFM=FB)
//FT08F001 DD &DEPGRID,SYSOOUT=A
//FT11F001 DD DSN=N3100138.D00,DISP=(NEW,DELETE,DELETE),
// UNIT=SYSDA,SPACE=(CYL,10),
// DCB=(BLKSIZE=12000,LRECL=16,BUFNO=1,RECFM=FB)
//FT12F001 DD DSN=N3100318.D01,DISP=(NEW,DELETE,DELETE),
// UNIT=SYSDA,SPACE=(CYL,10),
// DCB=(BLKSIZE=12000,LRECL=12,BUFNO=1,RECFM=FB)
//SOWTK01 DD DSN=*FT12F001,DISP=(OLD,DELETE,DELETE),
// UNIT=SYSDA,SPACE=(CYL,10),
// DCB=(BLKSIZE=12000,LRECL=12,BUFNO=1,RECFM=FB)
//SOWTK02 DD DSN=N3100138.D02,DISP=(NEW,DELETE,DELETE),
// UNIT=SYSDA,SPACE=(CYL,10),
// DCB=(BLKSIZE=12000,LRECL=12,BUFNO=1,RECFM=FB)
//FT13F001 DD DSN=*SOWTK02,DISP=(OLD,DELETE,DELETE),
// UNIT=SYSDA,SPACE=(CYL,10),
// DCB=(BLKSIZE=12000,LRECL=12,BUFNO=1,RECFM=FB)
//FT14F001 DD DSN=N3100318.D03,DISP=(NEW,DELETE,DELETE),
// UNIT=SYSDA,SPACE=(CYL,2),
// DCB=(BLKSIZE=12000,LRECL=12,BUFNO=1,RECFM=FB)
//FT17F001 DD DSN=&DEPDATA,DISP=SHR,LABEL=(**,-IN)
//FT25F001 DD DSN=&AVDATA,DISP=SHR,LABEL=(**,-IN)
//FT05F001 DD DSN=SYSLIB,DISP=SYSLIB
//SYSVECTR DD DSN=&VECTORS,UNIT=SYSDA,DISP=(NEW,PASS),
// SPACE=(1320,(500,2001)),DCB=BLKSIZE=1320
//SYSOUT DD SYSOUT=A
//STP2 EXEC PGM=BTSTN50
//STP2 SYSDUMP DD SYSOUT=A
//STEPLIB DD DSN=ACAD,SUBLIB,G5005,DISP=SHR
//SYSVECTR DD DSN=&WAVEFCTORS,DISP=(OLD,DELETE)

11-44
CALLS TO AROVE PROC
1. card #5 (EXEC card) to
   //STP1 EXEC PGM=CALCOMP

2. replace the 10 cards between (excluding)
   //FT05001 DD DDNAME=SYSIN
   and
   // PEND
   with one card
   // GO.PLOTTAPE DD DSN=DRUM.PLOT,UNIT=TAPED,
   DISP=(NEW,KEEP),CH=DEN=2

If the Calcomp plotter is used, a DP number is returned on the front page of the printout. This number is the location of the plot on tape and needs to be called into CSD in order to obtain the plotted results.

Three types of data sets are of primary concern to the user. The first type is the digitized depth data, DEPDATA, which resides on disk having been previously copied from magnetic tape by the program TTD. (User must have previously requested disk space from CSD.) The second type, NEWWAV, is created during a run in which window boundaries had been specified. The output wave data, NEWWAV (X, Y, AZIMTH, RK, RK1), is stored on disk to be read in a subsequent run. As input data NEWWAV is called WAVDATA, which is the third type of data set.

Data set names (DSN) may consist of up to 44 alphanumeric characters (including periods used for separation). A period must separate each 8 characters or less and must be followed by an alphabetic character. The first 7 characters of the DSN are the first 7 characters of the 8 character account number. Data set names must be unique or an error will occur upon the creating the data set. A data set name such as N310013.PRICE.INLET could be used for the account number N3100138 and represent a data set (of any of the three types) for Price Inlet, South Carolina.
The general JCL format for the program is:

//Job Card(s)
//REFRAC PROC . . . .
  . in-stream procedure
  .
//PEND
/*
//stepname EXEC REFRAC, data set type='data set name',
  data set type='data set name'
//SYSIN DD
  . card input as described in PROGRAM DESCRIPTION
//stepname EXEC REFRAC, data set type='data set name'
//SYSIN DD
  . card input
  .
//

As mentioned earlier, a call to the in-stream procedure (REFRAC) sets up the program libraries and data sets necessary for the refraction program. A call to the procedure is made when an EXEC REFRAC card is encountered in the JCL. A job may consist of more than one call by simply adding another EXEC REFRAC card and its corresponding data cards to the last data input card from the previous call. The above example is termed a multistep job because it calls the in-stream procedure twice. The program is terminated by a // in columns 1 and 2 of the last card.

The stepname is from 1 to 8 alphanumeric characters, the first of which must be alphabetic. The purpose of the EXEC REFRAC card is to specify the data sets that are to be read or created during the execution of the refraction program. Examples of data set types are explained below. The various options are also shown.

1. A simple refraction program reads the depth data off disk, doesn't specify a window and reads all wave parameters off cards. In other words, of the 3 data types, only DEPDATA needs to be specified.

   //STP EXEC REFRAC,DEPDATA='N310013.SOUTH.CAROLINA'

2. The above example results in a refraction diagram of the South
Carolina coast. In the present example, a window is specified in the card input; therefore, a data set name will have to be given for NEWWAV to store the wave information generated. If the window is of Price Inlet, then

```
//STP EXEC REFRAC,DEPDATA='N310013.SOUTH.CAROLINA',
// NEWWAV='N310013.PRICE.INLET.WAVE'
```

This data set may now be read in a subsequent refraction analysis on a larger scale chart of Price Inlet.

3. Using the above-created data set and the digitized depth data for Price Inlet, a more detailed analysis can be obtained.

```
//STP EXEC REFRAC,DEPDATA='N310013.PRICE.INLET',
// WAVDATA='N310013.PRICE.INLET.WAVE'
```

Note: In this example, the card input variables IWR and IRED EQUAL 0 and 25 respectively (see PROGRAM DESCRIPTION (Card Input)).

4. The printing of the depth grid is suppressed unless explicitly requested. This is accomplished by punching DEPGRID= in the data set type location.

```
//STP EXEC REFRAC,DEPDATA='N310013.DEPTH.DATA',
// DEPGRID =
```

If NEWWAV is also specified then

```
// DEPGRID=,NEWWAV='N310013.WAVE'
```

5. The printing of the title page and all wave information may be suppressed if only the plot is desired. Refer to card input listing for proper positioning of cards described in examples 5 and 6. Add the following JCL card after the 'EXEC REFRAC' card and before the 'SYSIN DD *' card

```
//STP1.FT06F001 DD DUMMY
```

6. The wave parameters generated for a window may be punched on
cards instead of stored on disk by adding the following JCL card
between the 'EXEC REFRAC' card(s) and 'SYSIN DD *' card

//STP1.FT07FO01 DD SYSOUT=B

Program Listing, Card Input and Example of Output

The following listing is a deck setup including both JCL and card
input. A refraction analysis of South Carolina coast results from the
first call to the in-stream procedure. The wave information generated
at the window boundaries is used in the second call of the procedure,
thereby producing a detailed analysis of the window area. Refer speci-
ically to examples 2, 3, and 5 for further explanations.

A sample of the output includes the title page, information on one
ray and the refraction diagram. The information is from the window area
analyzed above. Following the sample output is a complete listing of
the program REFRAC and the necessary JCL to compile, load and store it
on disk (if it has not already been stored).
PROGRAMS
COASTAL RESEARCH CENTER TECHNICAL REPORTS  
(Geology Department, Univ. of Massachusetts)

1. Offset coastal inlets.  

2. Forms of sediment accumulation in the beach zone.  
M. O. Hayes; Tech. Rept. No. 2-CRC, 1972

3. Hydraulic equivalent sediment analyzer (HESA).  
F.S. Anan; Tech. Rept. No. 3-CRC, 1972


5. Sedimentation and physical limnology in proglacial Malaspina Lake, Alaska.  
T.C. Gustavson; Tech. Rept. No. 5-CRC, 1972.

COASTAL RESEARCH DIVISION TECHNICAL REPORTS  
(Dept. of Geology, Univ. of South Carolina)

6. Coarse-grained sedimentation on a braided outwash fan, northeast Gulf of Alaska.  
J.C. Boothroyd; Tech. Rept. No. 6-CRD, 1972.


8. Selected environmental criteria for the design of artificial structures on the southeast shore of Lake Erie.  

9. Coastal dynamics and sediment transportation, northeast Gulf of Alaska.  

10. Morphologic and hydrodynamic characteristics of terrestrial fan environments.  

11. Terrigenous clastic depositional environments.  


15. Coastal morphology, sedimentation and oil spill vulnerability - Northern Gulf of Alaska.  

16. Two years after the Hetula oil spill, Strait of Magellan, Chile: oil interaction with coastal environments.  

17. Influence of wave refraction on coastal geomorphology - Bull Island to Isle of Palms, South Carolina.  
FORMATTING OF CALLS TO PROCEDURE REFRAC (JCL) & SAMPLE OF CARD INPUT

FIRST CALL -- REFRACTS A SET OF WAVES (READ FROM CARDS) ON THE S.C. SHELF THROUGH THE WINDOW AREA OF CAPE HOMAIN TO FOLLY ISLAND. THEREFORE, WAVE INFORMATION IS GENERATED & STORED ON DISK TO BE USED IN A SUBSEQUENT RUN.

SECOND CALL -- READS THE ABOVE CREATED DATA SET FROM DISK & REFRACTS THE CONTINUED WAVES ACROSS THE MORE DETAILED GRID OF CAPE HOMAIN TO FOLLY ISLAND.

THE SAMPLE OUTPUT FOLLOWING THIS LISTING INCLUDES THE TITLE PAGE & WAVE INFORMATION ON WAV #1 FROM THE SECOND CALL TO REFRAC. ALSO INCLUDED IS THE RESULTING WAVE REFRACTION DIAGRAM.

// USER=L310013+PASSWORD=CHID+REGION=600K+
// TIME=(2.30)
//N3100138 .JOM (N3100138.509999)*WAVE REFRACTION*,=SINGLE=(1,1),
//REFRAC PROC DEPGRID=DUMMY**,WAVDATA=NULLFILE*,NEWWAV=NULLFILE

* IN-STREAM PROC

* PEND
//SC EXEC *REFAC*DEPUATA=T31001U,SOUTH,CAROLINA*,
// NEWWAV=T310010.SC.SC1973.T10A135*
//STP1,F06F001 DD DUMMY
//SYSIN DD *
SOUTH CAROLINA WINDOW==SC1973
.5
1975 FATHOMS MLW
<p>| | | | | | | | |</p>
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//SCTF EXFC RFFPAC DEHPDAT=\"T310010.ROMAINE.FOLLY\"\
//SYSIN D06
SC-1973

1973 FFET MLW
191 101 4000 10 1333.333 1.0 .002
   .2 141.0
|   |   |   |   |   |   |   |
| 1 |   |   |   |   |   |   |
| 10 | 170 | 10.0 | 1.0 | 1.0 | 1.0 | 318.0 | 135.0 | 12.0 |
|   | 1 | 12.0 | 25 |   |   |   |   |
WAVE REFRACTION PROGRAM--COASTAL RESEARCH DIVISION

WAVE REFRACTION ANALYSIS SC-1973
05/04/78

INPUT PARAMETERS:

M1 = 191
DELTAS = 0.002

BOUND = 0.0
DGY = 0.0
SCA = 0.26000
SCALE = 6666.666
XSG = 191.00
WSET = 1

LPL = 10
TH1 = 316.00
ISP = 0
PO = 60.00

NOR = 170
STA = 135.00
LCK = 1
YFA = 0.0

T = 10.00
UNIT = 12.00
#PI = 12.00
CKUEP = 0.0

HOG = 1.00
SM = 1.00
OF = 0.0

MAP DATE: 1973
DEPTH IN FEET
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<th>POINT</th>
<th>A (°)</th>
<th>Y (°)</th>
<th>AZIMUTH</th>
<th>DEPTH</th>
<th>SPEED</th>
<th>HK</th>
<th>SK</th>
<th>HEIGHT UMI</th>
<th>UHUT</th>
<th>TOTAL ENERGY</th>
<th>VELOCITY</th>
<th>GROUP POWER</th>
<th>TOTAL POWER</th>
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<td>0.29</td>
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<td>49.1</td>
<td>272.8</td>
<td>135.3</td>
<td>107.9</td>
</tr>
</tbody>
</table>

RAY STOPPED, WAVE DIES AT X = 47.08 Y = 32.71

LONGSHORE ENERGY FLUX FUTON: PL = 0.496570E0 FT-LBS/SEC/FT OF BEACH FRONT
LONGSHORE TRANSPORT RATES:

METRIC CONVERSIONS:

<table>
<thead>
<tr>
<th>FT-SEC</th>
<th>YD-SEC</th>
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<tbody>
<tr>
<td>0.305</td>
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</table>
LISTING OF THE PROGRAM REFRACTION AND THE NECESSARY JCL TO
COMPILE, LINK AND STORE IT ON DISK

//SETUP JOB (M10013H9),SFTUP,MSLEVEL=(1,1),REGION=250K,
// TIME=(1,15),USEX=M10013,PASSWORD=CHD
// EXEC FTGIC,PAHM,FORT=LOAD,NOCHECK,NOSOURCE
//SYSIN DO,*
C
C WAVE REFRACTION DIAGRAMS
C PROGRAM TO COMPUTE, PRINT, AND PLOT WAVE REFRACTION
C DIAGRAMS

DEFINITION OF INPUT PARAMETERS

AZIMTH - AZIMUTH OF AY.
C HOUND - DIMENSION I, DIRECTION OF PORTION OF MAP THAT WILL NOT
RE SHOWN ON PL. EXPRESSED IN INCHES AND ALWAYS IS
SUBTRACTED OFF DEEPWATER END.
C CKDEP - CHECK DEPTH. PROGRAM WILL PRINT WAVE INFORMATION FOR THE
TIME STEP NEAREST THIS DEPTH.
C DATE1 - DATE OF HYDROGRAPHIC CHART
C DCON - CONVERSION FACTOR FOR DEPTH VALUES TO FEET.
C DFLTAS - MINIMUM STEP LENGTH, EXPRESSED AS FRACTION OF GRID
SQUARE.
C DFP - WAVE DEPTHS AT EACH GRID POINT.
C DF - FACTOR TO CONVERT DEPTH VALUES FROM ONE WATER SURFACE
DATUM TO ANOTHER. THE FACTOR WILL BE ADDED TO THE DEPTH
VALUE, IF NOT NEEDED LEAVE BLANK.
C DGAL - LENGTH OF WINDOW (X DIMENSION) EXPRESSED IN INCHES.
C DGAL - HEIGHT OF WINDOW (Y DIMENSION) EXPRESSED IN INCHES.
C FAC - SCALING FACTOR BY WHICH ALL POINTS ARE MULTIPLIED
BEFORE BEING PLOTTED.
C GRID - DIMENSION OF A SIDE OF A GRID SQUARE, EXPRESSED IN
MAP FEET.
C GPINC - DEEPWATER STEP LENGTH, EXPRESSED AS FRACTION OF GRID
SQUARE.
C HO - DEEPWATER WAVE HEIGHT
C ISP - SETS PRINT OPTION ON CHECK DEPTH. IF =1, PROGRAM WILL
PROVIDE WAVE RAY INFORMATION AT TIME STEP NEAREST
CHECK DEPTH AND CONTINUE PROCESSING OF WAVE. IF = 0,
PROGRAM DOES NOT LOOK FOR CHECK DEPTH; AND IF = 1,
PROGRAM PROVIDES DESIRED INFORMATION AND STOPS
PROCESSING OF RAY.
C ITITLF - ALPHANUMERIC TITLE TO APPEAR ON PRINTER OUTPUT AND PLOT
FOR JOB IDENTIFICATION.
C IWR - IF = 0, NEW WAVE INFO TO RF READ
C IF = 1, WAVE INFO IS PREVIOUSLY READ INPUT
A WINDOW IS AN AREA inside the grid being processed.
THIS WINDOW WOULD BE USED FOR CASES WHERE IT IS DESIGNED TO STUDY A PARTICULAR AREA IN GREATER DETAIL BY USING A LARGER SCALE GRID. THE PROGRAM WILL TRAVERSE THE RAY THROUGH THE WINDOW AND PRINT OUT STARTING INPUT PARAMETERS FOR THE RAY ON THE LARGER SCALE GRID.

COMMON DEP(20000), H1, H2, H3, SCALE, GHAID, PD
COMMON P1, P2, HOUND, CKDEP, CD, CXY, U(12), DCON, DCON
1DELTAS, F1, T1, L1, OXY, F(L1), GRINC
2H, HH, H1, ICN, IGO, IRET, ISP, JGO, KFIRST, KPL0T
3LIMNP, LPL0T, NPRINT, NPT, PHX, PHY, K90, RADIUS, RAYNO
4HCC0, KHC, PK, S0N, SIG, SK, SKI, T, THI, TOP
5V, W1, W2, XP, XSG, YSG, YSG, YS
COMMON HPL, P0R, P06, UH, UMID, ET, CGH, POW, PL, OS
DIMENSION IOATE(2), ITITLE(10), IVVIF(5000), LEGEND (IS)
DIMENSION LEG1 (11), LEG2 (6), MFAS (3)
DIMENSION XC(400), YC(400), AAZ(400), PK1(400), PKK(400)
DATA HLEG(000), 112/
DATA LEG1='WAVE', 'PER', 'JOE', 'SEC', 'S', 'DEEP', 'WATE'
1, 'AZ', 'MUN', 'H', '
2, LEG2= 'NEE', 'RES', 'DATE', 'PLOT', 'TED', '

FORMAT STATEMENTS IN MAIN PROGRAM
80 FORMAT (*15, 'RAYS EXCEEDS THE MAX LIMIT OF 175*)
90 FORMAT (*.15, 'THE VALUE OF KPL0T IS TOO SMALL.*)
100 FORMAT (10A4)
110 FORMAT (4I5, 3F10.4)
120 FORMAT (6F10.5)
130 FORMAT (15)
140 FORMAT (F5.0)
160 FORMAT (215*3F10.2, F10.6)
170 FORMAT (215*3F10.4, 15*2F10.3)
171 FORMAT (15)
178 FORMAT (184*2X, 3A4, 2X, A4)
180 FORMAT (1H*2A4)
190 FORMAT (*4//42X, 'WAVE REFRACTION ANALYSIS *10A4)
200 FORMAT (*4//49X, 'WAVE REFRACTION PROGRAM--COASTAL*
1* RESEARCH DIVISION*1)
210 FORMAT (/*15, 'MI=14,13X, MJ=14, 13X, LIMNP=*
1 '15X, HX, NPRINT=14, 9X, GRID=1F10.4, 5X, DCON=1F10.4/* DELTAS=
2 F5.3)
220 FORMAT (1H*2A4)
230 FORMAT (/*15, 'WAVE FRONT INCREMENT =F7.3, 6H SEC*'/
1 'H GRINC =F10.4, 14H, TIME STEP =F8.3, 7H SECSS**
1 '24H WAVE FRONT INCREMENT =F7.2, 6H SEC*'/
240 FORMAT (/*15, 'POINT X*5X*Y*2X*4AZIMUTH DEPTH LENGTH SPEED RK*'
1 '5X*SK1*4X, THE HEIGHT UHD=4X, TOTAL=6X, GROUP*'
2 '4X*TOTAL LONGSHORE=4X, UIR*/*1 '7X, ENERGY=4X
3 'VFL0CITY=3X,POWER=5X,POWER='*
4 'I6+F7.1*2F6.1*6X+F7.1*F6.1*4X+F7.2)

11-37
SINH(DUM)=.5*(EXP(DUM)-(1./EXP(DUM)))

C READ TITLE INFORMATION
READ (5,100) ITITLE
READ (5,140) FAC
READ (5,178) DATE, MFAS, W
CALL DATE (IDATE)

C READ GRID INFORMATION AND OTHER BASIC DATA
READ (5,110) MI, MJ, LMNPT, NPRINT, GRID, OCON, DELTAS
IJMAX = MI * MJ
IF (IJMAX.GT.20000) GO TO 290
GO TO 300

290 WRITE (6,250)
STOP

C READ PLOT INFORMATION
300 READ (5,120) HEADER, SCX, XSG, YSG, SCNV, DGXL, DGYL

C READ ALL DEPTH VALUES
SCALE=GR1D/SCX

C SET ORIGIN FOR PLOTS
CALL PLOTS (JBUF+,5000,9)
IF (FAC .EQ. 0.) FAC=1.
CALL FACTOR (FAC)
CALL PLOT (3,92,.3)
CALL BOTTOM
WRITE (6,200)

C SET SOME INITIAL VALUES
RMS=MI
RMS=RMS-2.5
TOP=MJ
TOP=TOP-2.5
XLIMIT=(MI-1)*SCX
RY0=1.*5.70796327

C PRINT TITLE AND GRID DATA
WRITE (6,190) ITITLE
WRITE (6,284) IDATE
WRITE (6,286)
WRITE (6,210) MI, MJ, LMNPT, NPRINT, GRID, OCON, DELTAS
C READ NUMBER OF SETS OF RAYS AND SHORELINE DATA
READ 130,NOSETS
WRITE (6,280) HOUND,SCX,XSG,YSG,SCNV,DGXV,SCYV,SCALE,NOSETS
360 CONTINUE
C PROCESS EACH SET
XSLINE = 0.0
YSLINE = 0.0
DIFF = 0.
380 NO 510 NOSET=1,NOSETS
READ (10,9990,END=415) XSS, YSS, JPFN
9990 FORMAT(3A4)
XSLINE=XSS/GRID
YSLINE=YSS/GRID
C PLOT LOWER LEFT CORNER FOR A SET
CALL PLOT (0.0, 1.0, 3)
CALL PLOT (0.0, 0.0, 2)
CALL PLOT (1.0, 0.0, 2)
CALL PLOT (0.0, 0.0, 2)
CALL PLOT (0.0, 0.0, 3)
XSL = XSLINE*SCX
YSL = YSLINE*SCX-HOUND
CALL PLOT (XSL, YSL, 3)
GO TO 411
C PLOT SHORELINE FOR A SET
410 CONTINUE
READ (10,9990,END=415) XSS, YSS, JPFN
411 LPEN=JPFN
XHOLD = XSLINE
YHOLD = YSLINE
XSLINE=XSS/GRID
YSLINE=YSS/GRID
IF (JPFN = 1) 400, 390, 400
390 LPEN=2
CALL PFFDIA (XSLINE, YSLINE, 2)
CALL PFFDIA (XHOLD, YHOLD, 2)
400 CALL PFFDIA (XSLINE, YSLINE, LPEN)
GO TO 410
415 CONTINUE
REWIND 10
C PLOT LOWER LEFT CORNER OF WINDOW
420 IF (XSG=HHS) 430, 440, 440
430 CALL PFFDIA (XSG, YSG, 3)
CALL PFFDIA (XSG, YSG, 1.0)
CALL PFFDIA (XSG, YSG, 2)
CALL PFFDIA (XSG+1.0, YSG+2)
C PLOT LOWER RIGHT CORNER OF WINDOW
CALL PFFDIA (XSG, YSG, 2)
XSGL=XSG+DGXL/SCX
YSGL=YSG+DGYL/SCX
CALL RFDIA(XSGLYSYSG+3)
CALL RFDIA(XSGLYSYSG+1+2)
CALL RFDIA(XSGLYSYSG+2)
CALL RFDIA(XSGLYSYSG+2)
CALL RFDIA(XSGLYSYSG+2)

READ BASIC WAVE DATA FOR A SET
READ(S,160) LPLLOT, NORAYS, T, HO, SK, SK1, THI, STAZ,
1 UNIT
IF (NORAYS .GE. 400) GO TO 800
SKP=SK
READ (S,170) ISP,LCW,WPIC,CKDEP,DF,FRP,PD,YFA
IF (IFW .EQ. 0) READ (S,171) IRED
IF (IRED .NE. 25) IRED=5
IF (PD .EQ. 0.) PD=DFP(1)*DCON*DF
IF (NOSET .EQ. 1) WRITE (6,282) LPLLOT,NORAYS,T,HO,SK,SK1,THI,
* STAZ,UNIT,ISP,LCW,WPIC,CKDEP,DF,IFP,PU,YFA
IF (NOSET .EQ. 1) WRITE (6,288) DATE,MEAS
IF (NOSET .EQ. 1) GO TO 445
WRITE (6,200)
WRITE(S,190) ITITLE
WRITE (6,284) IDATE
WRITE (6,286)
WRITE (6,210) MI,MJ,LIMNPT,NPRINT,GRID,DCON,DELTAS
WRITE (6,280) HOUNO,SCX,YSG,MCYSG,SCNY,SCYL,SCALE,NOSETS
WRITE(6,282) LPLLOT,NORAYS,T,HO,SK,SK1,THI,
* STAZ,UNIT,ISP,LCW,WPIC,CKDEP,DF,IFP,PU,YFA
WRITE (6,288) DATE,MEAS
445 CONTINUE

C SET INITIAL VALUES FOR THE SET
IF ((NOSET .GE. 2) .AND. (DF .EQ. OFF)) GO TO 340
IF (NOSET .GE. 2) DF=DF-OFF
IF (DF) 310,340,310
310 DO 330 J = 1,IJMAX
DEP (J) = DEP (J) + DF
330 CONTINUE
340 OFF=OFF+DF
KSP=ISP
SIG=6.28318531/T
CO=5.2120406*T
WLO=CO*T
DRC=WLO*0.5
DTG=UNIT/GDGR
GRC=DTGR*CO
WFI=T*WPIC
KPLLOT=WFI/UNIT*0.1
IF (KPLLOT .EQ. 0) GO TO 810
C PROCESS EACH RAY IN SET
DO 500 NORAY=1,NORAYS
HPREV=H0
NS=GRINC
500 CONTINUE

11-60
IF (LCK) 460 * 450 * 460

READ RAY DATA

450 IF (1WR = EQ. 0) READ (TRED, 120, END=501) XC(NORAY), YC(NORAY)
IF (XC(NORAY) .LE. 0.) GO TO 501
X=XC(NORAY)
Y=YC(NORAY)+YFA
AZIMTH=STAZ
RK=1.*0
SK=1.*0
B1=1.*0
H2=1.*0
RKPREV=1.*
SKP=1.*
GO TO 470

460 IF (1WR = EQ. 0) READ (TRED, 120, END=501) XC(NORAY), YC(NORAY),
* AAZ(NORAY), RK1(NORAY), RHK1(NORAY)
IF (XC(NORAY) .LE. 0.) GO TO 501
X=XC(NORAY)
Y=YC(NORAY)+YFA
AZIMTH=AAZ(NORAY)
RK=MRK(NORAY)
H1=1./RK1/RK1
H2=1./RK/RK
SK=5SKPR
SKP=1.*
RKP=1.*

470 AZITH+Z70.0-AZIMTH

C    SET INITIAL VALUES FOR RAY

NPT=1
CXY=0.
WL=WLO

C    PRINT STEP AND TIME INFORMATION
WRITE(6,230) GRINC, UNIT, WFI
RAYNO=NORAY
XNO=X*SCX
YNO=Y*SCA-BOUND
IF (YNO) 490 * 480 * 490

C    IDENTIFY RAY ON PLOT

480 KFIRST=1
CALL NUMBER (XNO, YNO=0.15 * 0.125, RAYNO, RAYNO, 0., 1.)
CALL PDFIA (Y*3)

C    PRINT DEEPWATER WAVE INFORMATION

490 WRITE(6,240) NPT, X, Y, STAZ, WLO, C0, HO

C    CALL RAYCON TO COMPUTE, PRINT, AND PLOT THIS RAY

CALL RAYCON (X*Y*A)
500 CONTINUE
501 CONTINUE
C PRINT TITLE AND WAVE DATA ON PLOT
XLEG=XLIMIT-6.72
CALL SYMBOL (XLEG,-0.5,0.168,TITLE=0.40)
CALL SYMBOL (XLEG,-1.25,HLEG=LEG1(1) * 0.14)
CALL NUMBER (999.999.*0.112,STZ=0.1)
CALL SYMBOL (999.999.*HLEG=LEG1(5) * 0.5)
CALL SYMBOL (XLEG-1.25,HLEG=LEG1(7) * 0.20)
CALL NUMBER (999.999.*0.112,STZ=0.1)
CALL SYMBOL (999.999.*HLEG=LEG2(1) * 0.8)
CALL SYMBOL (XLEG-1.50,HLEG=LEG3(3) * 0.15)
CALL SYMBOL (999.999.*112.IDATE=0.8)
CALL SYMBOL (XLEG+1.25,HLEG=0 CONTOUR AT *0.13)
CALL SYMBOL (999.999.*HLEG=0.4)
CALL SYMBOL (XLEG+1.25,HLEG=RELATIVE WATER LEVEL=0.22)
CALL NUMBER (999.999.*HLEG=DIFF+0.2)
CALL SYMBOL (XLEG+1.25,HLEG=MEAS+0.12)
CALL SYMBOL (XLEG+1.25,HLEG=HAP DATE=0.10)
CALL SYMBOL (999.999.*HLEG=DATE=0.4)
CALL SYMBOL (XLEG-1.75,HLEG=DEEPWATER WAVE HEIGHT=0.23)
CALL NUMBER (999.999.*HLEG=0.2)
CALL SYMBOL (999.999.*HLEG=FEET=0.5)
C DRAW LOWER RIGHT CORNER OF PLOT FOR A SET
CALL PLOT (XLIMIT=0.3)
CALL PLOT (XLIMIT=1.2)
CALL PLOT (XLIMIT=0.2)
CALL PLOT (XLIMIT=-1.0,2)
CALL PLOT (XLIMIT=0.2)
CALL PLOT (XLIMIT=0.3)
IST =1
IST1=0
511 REWIND 11
509 CONTINUE
READ (11,9980,END=790) XS,YS,DEPTH,IPN
XX=XS*SCX/GRID
YY=YS*SCX/GRID
IF (YY.EQ.0.) GO TO 600
IF (YY.GT.0.) GO TO 600
IF (YY+HOUND)
MDEPTH=DEPTH
IPEN=3
GO TO 730
600 READ (11,9980,END=770) XS,YS,DEPTH,IPN
IF (DEPTH.EQ.0.) GO TO 600
IF (IPN.EQ.IPN) GO TO 650
IPH=2
MDEPTH=DEPTH
CALL PLOT (XH+YH+IPFN)
IPEN=3
IST=1

II-62
IST1=0
CALL PLOT (XH,YH,IPEN)
650 XX=XS*SCX/GRID
YY=YS*SCX/GRID
IF (YY .LT. BOUND) GO TO 665
YY=YY=BOUND
IF (IST1 .EQ. 0) GO TO 670
IF (XX .LT. XXH) GO TO 660
IF (XX .GT. XXH+SIZE) GO TO 660
IF (YY .GT. YYH+.06) GO TO 660
IF (YY .LT. YYH-.06) GO TO 660
IPEN=3
GO TO 600
660 CONTINUE
IST =0
GO TO 640
665 IPH=3
GO TO 600
670 IF (IST .EQ. 0) GO TO 640
IST1=1
IST=0
ADPTH=-DEPTH
DEPTH=AHS(DPETH)
SIZF=3.
IF (DPETH .GE. 1.) SIZE=SIZE+1.
IF (DPETH .GE. 10.) SIZE=SIZE+1.
IF (DPETH .GE. 100.) SIZE=SIZE+1.
IF (DPETH .GE. 1000.) SIZE=SIZE+1.
SIZE=SIZE*.09
IF (XX .GE. FLOAT(MI-3)*SCX) GO TO 675
CALL NUMPER (XX+.035,YY-.035,ADPTH,0,1)
XH=XX
YYH=YY
GO TO 600
675 CONTINUE
XXX=XX-SIZE
CALL NUMPER (XXX+YY-.035,10,ADPTH,0,1)
XH=XXX
YYH=YY
GO TO 600
680 CONTINUE
730 CALL PLOT (XX+YY,IPEN)
IPEN=2
XX=XX
YY=YY
GO TO 600
770 CALL PLOT (XX+YY,3)
790 CONTINUE
C SET ORIGIN FOR A NEW PLOT
CALL PLOT (XLIMIT+3.,0.,-3)
510 CONTINUE
   WRITE(H,270) NOSFTS
   GO TO 820
800 WRITE(6,80) NORAYS
   GO TO 820
810 WRITE (6,90)
820 CALL PLOT (0.,0.,994)
   STOP
END
C RAYCUN SUBROUTINE DECK
C CONTROLS COMPUTATIONS, PRINTING, AND PLOTTING OF EACH RAY
SUBROUTINE RAYCUN(X,Y,A)
COMMON DEP(20000), HI, MJ, SCA, SCALF, GRID, PD
COMMON H1, H2, ROUN, CKDEP, CO, CXY, U(12), DCDH, DCON
1DELTA, DRC, UTGR, NXY, F(J), GINC
2 H1, H2, ICN, IGO, IKET, ISP, JGO, KFIRST, KPLOT
3 LIMNPT, LPLUT, NPRINT, NPT, PHX, PHY, RGO, RAUUS, RAYNO
4RCCO, RKS, RSCNV, SIG, SK, SK1, T0, TH1, TOP
5 V1, V1, W10, X1, XSG, XSGL, YP, YSG, YSGL
COMMON HPREV, SKPREV, PKPREV, UEOT, UMID, ET, CGH, POW, PL, NS
COMMON IDIR
DIMENSION R(16)
100 FORMAT(* 15,14*,4F6.1,F7.1,F6.1,2F7.3,F7.2,2F6.2,4F10.2,3X,A1)
110 FORMAT(* 15,14*,F7.1,3F6.1,F7.1,2F7.3,F7.2,2F6.2,4F10.2,3X,A1)
120 FORMAT(2XH CURVATURE AVERAGE AT POINT I4)
130 FORMAT(34H RAY INSIDE UFTAIRED GRID AT POINT I4, 11H UFTAIRED
 1 29H GRID STARTING LOCATION IS X=F7.2,4H Y=F7.2)
140 FORMAT(7H RAY STOPPED, NO CONVERGENCE FOR CURVATURE)
150 FORMAT(7H RAY STOPPED, WAVE BREAKS AT X=F7.2,4H Y=F7.2)
160 FORMAT(7H RAY STOPPED, REACHED ROUNDANY X=F7.2,4H Y=F7.2)
170 FORMAT(7H RAY STOPPED, LIMNPT EXCEEDED X=F7.2,4H Y=F7.2)
180 FORMAT(7H RAY STOPPED, DELTA'S TOO SMALL X=F7.2,4H Y=F7.2)
190 FORMAT(7H RAY NEAR* F6.2,14H FOOT CONTOUR )
C IF THE RAY STARTS IN WATER LESS THAN BREAKER DEPTH GO TO THE NEXT
C
AUX=A*,017*532925
YNEX=COS(A)*GINC*X
YNEX=SIN(A)*GINC*Y
CALL DEPTH(XNEX,YNEX)
IF (*A*)XY-HO) 492*492*494
492 WRITE (*,298)
298 FORMAT ('08,1*RAY STARTS TOO CLOSE TO SHORE*')
HFTUN
494 CONTINUE
END=0
IF (XSI-WKS) 200,210,210
200 LFIRST=0
SIG=XSG+1.5/SCNV
SIG=YSG+1.5/SCNV
SIGX=XSGL+1.5/SCNV
SIGY=YSGL+1.5/SCNV
GO TO 220
210 LFIRST=1
C SET INITIAL VALUES USED TO START A RAY
220 LPRINT=0

11-63
FLAG1=0.0
ANG=TH1*270.0-A
A=A*U+0.174532925
COSA=COS(A)
SINA=SIN(A)
H=HO
IG1=1

C SAVE VALUES OF X AND Y

230 PX=X
PY=Y

C ADVANCE X AND Y (ONE STEP AND FIND NEW DEPTH

X=COSA*G1N+C+X
Y=SINA*61N+C+Y
CALL DEPTH(X,Y)

NWH1F=1

C CHECK TO SEE IF WAVE HEIGHT IS GREATER THAN .8 OF WATER DEPTH
IF (A*61X-H) 380,380,240

C NO, CHECK TO SEE IF RAY IS IN DEEP WATER
240 IF (DXY-NDC) 320,320,250

C YES, ADVANCE STEP COUNT AND CHECK TO SEE IF LIMNPT IS EXCEEDED
250 NPT=NPT+1
CALL FRICTN
IF (LIMNPT-NPT) 400,400,260

C NO, CHECK TO SEE IF RAY IS TOO CLOSE TO HOUNDARY
260 IF (XMS-X) 270,270,240

C YES, SET TO PRINT OUT RAY TOO CLOSE TO HOUNDARY
270 IRET=5
GO TO 350

280 IF (X-1.5) 270,270,290
290 IF (TIP-Y) 270,270,300
300 IF (Y-1.5) 270,270,310

C RAY WITHIN HOUNDARY AND IN DEEP WATER, GO TO
C CHECK PRINTING AND PLOTTING OPTIONS
310 GO TO 480

C RAY WITHIN HOUNDARY BUT NOT IN DEEP WATER
320 X=PX
Y=PY

C COMPUTE CURVATURE OF RAY IN FIRST STEP AFTER DEEP WATER
CALL CURVE(X,Y,A+FK)

C ADVANCE STEP COUNTER AND CHECK TO SEE IF LIMNPT IS EXCEEDED
330 NPT=NPT+1
IF (NPT-LIMNPT) 340,400,400

340 NWH1F=1

C COMPUTE X AND Y COORDINATES AND ANGLE OF RAY FOR NEW STEP
FLAG1=1.0
CALL REFHAC(X,Y,A+FK)
C GO TO CONDITION CONTROLLED BY VALUE OF IRET
350 GO TO (410+30,370,360,340,420), IRET
C SET NWRITE FOR STATUS OF RAY
350 NWRITE=2
GO TO 420
370 NWRITE=3
GO TO 420
380 NWRITE=4
IF (FLAG4.EQ.0.0) GO TO 492
GO TO 420
390 NWRITE=5
GO TO 730
400 NWRITE=6
GO TO 730
410 NWRITE=7
GO TO 730
C COMPUTE REFRACTION AND SLOSHING COEFFICIENTS AND WAVE HEIGHT
420 CALL HIGHT(A)
   IF (DAY-CKDEP) 430,430,460
430 IF (ISP) 450,470,480
440 IF (ISP) 460
450 ISP=0
   NWRITE=9
   GO TO 470
460 IF (ISP) 470,470,740
470 IF (NWRITE-1) 480,480,490
C CHECK PRINT OPTION AND SFT
480 IF (MOD(NFT,NPRINT)) 500,490,500
490 LPRINT=1
C HAS NUMBER BEEN PLACED ON THIS RAY
500 IF (KFIRST) 530,510,530
C IS THIS STEP WITHIN STARTING PLOT BOUNDARY
510 YON=Y*SCX-HOUND
   IF (YON) 700,520,520
C YES, PLOT THE RAY NUMBER, SET TO NO AND PEN UP. AND GO TO PRINT
520 CALL NUMHER(X*SCX,YON-0.15,0.112,PAYNO,0.0,-1)
   KFIRST=1
   CALL HFDIA (X,Y,3)
C CHECK TO SEE IF RAY REACHED DETAILED GRID ON ANY PREVIOUS STEP
530 IF (LFIRST) 590,540,590
C NO, IS RAY WITHIN DETAILED GRID ON THIS STEP
540 IF (A-SGX) 590,550,550
550 IF (X-SGX) 560,560,590
560 IF (Y-SGY) 590,570,570
570 IF (Y-SGY) 590,580,590
C YES, SET NWRITE FOR THIS CONDITION
580 NWRITE=8
   LFIRST=1
   LPRINT=1
C COMPUTE DETAILED GRID STARTING POSITION
   DX=(X-XS)*SCV
   DY=(Y-YS)*SCV
C STFF WITHIN BOUNDARY, IS TIC MARK TO BE PLOTTED ON RAY
590 IF (MOD(NPT,NLOT)) 600,620,600
C NO, IS STEP TO BE PLOTTED
600 IF(MON(NPT,PLPLOT)) 700,610,700
C YES, PLOT STEP AND GO TO PRINT
610 CALL PEFIDIA(X+Y,2)
      GO TO 700
C
C TIC MARK TO RF PLOTTED PERPENDICULAR TO RAY.
C
C COMPUTE ANGLE AND AZIMUTH IN DEGREES
620 AA=A*57.29578
    ANG=THI+270.0-AA
C
C SET TO PLACE ASTERISK ON PRINT OUT BY THIS STEP
LPRINT=-1
C
C FIND QUADRANT THAT RAY IS IN AND COMPUTE TIC MARK COORDINATES
IF(AA-90.) 630,630,640
630 YTIC=-0.05*SIN(90-AA)
    X Tic=0.05*SIN(A)
      GO TO 690
640 IF(AA-180.) 650,650,660
650 YTIC=-0.05*SIN(A-H90)
    X Tic=0.05*SIN(3.141592654-A)
      GO TO 690
660 IF(AA-270.) 670,670,680
670 YTIC=-0.05*SIN(A-3.141592654)
    X Tic=0.05*SIN(4.712388961-A)
      GO TO 690
680 YTIC=-0.05*SIN(A-4.712388961)
    X Tic=0.05*SIN(6.283185307-A)
C
C PLOT TIC MARKS
690 CALL PEFIDIA(X+XTIC+Y-YTIC,2)
    CALL PEFIDIA(X-YTIC,2)
    CALL PEFIDIA(X+Y,2)
C
C CHECK PRINT OPTION
700 IF(LPRINT) 710,740,720
C
C PRINT STEP INFORMATION WITH ASTERISK BY STEP NUMBER TO DENOTE
C THAT A TIC MARK WAS MADE PERPENDICULAR TO RAY ON PLOT
710 CONTINUE
C
C CALL ENERGY (A,END)
    IF (DXY LE. PD)
      & WHITE(6,100) NPT,X,Y,ANG,DXY,WL,CXY,RK,SK,H,UMID,WHAT,FT*
      & CGP,POWER,PL,IDIR
C
C RESET PRINT OPTION TO NO PRINT AND GO TO CHECK STATUS OF RAY
LPRINT=0
      GO TO 740
C
C COMPUTE RAY AZIMUTH IN DEGREES AND PRINT STEP INFORMATION
720 ANG=THI+270.0-A*57.29578
    CALL ENERGY (A,END)
    IF (DXY LE. PD)
      & WHITE(6,110) NPT,X,Y,ANG,DXY,WL,CXY,HK,SK,H,UMID,WHAT,ET*
      & CGP,POWER,PL,IDIR
C
C RESET PRINT OPTION TO NO PRINT AND GO TO CHECK STATUS OF RAY

LAST STEP OF A RAY

COMPUTE RAY AZIMUTH IN DEGREES AND PRINT STEP INFORMATION

ANGLE = THI + 270 * U - A * S / 29579

WRITE (6, 110) NPT, XY, ANG, UX, V

PLOT LAST STEP OF RAY

CALL RFFDIA (X, Y, 2)

GO TO CONDITION CONTROLLED BY VALUE OF NWRITE

GO TO (830, 750, 740, 770, 780, 790, 800, 820, 850).

PRINT PROGRAM MESSAGE AND CONTINUE RAY COMPUTATIONS

WRITE (6, 120) NPT

GO TO M30

PRINT PROGRAM ERROR MESSAGE AND STOP RAY COMPUTATIONS

WRITE (6, 140)

GO TO M10

WRITE (6, 150) X, Y

CALL RFFDIA (X, Y, 2)

END = 1

CALL EFEOF (A, END)

END = 0

GO TO M10

WRITE (6, 160) X, Y

GO TO M10

WRITE (6, 170) X, Y

GO TO M10

WRITE (6, 180) X, Y

IF (U = 3)

GO TO M30

WRITE (6, 130) NPT, DGX, DGY

IWRITE = 7

WRITE (IWRITE, 135) DGX, DGY, ANG, RK, RKPREV

FORMAT (3F10.2, 2F10.4)

CHECK STATUS OF RAY AND BRANCH TO PROPER CONDITION

GO TO (230, 330, 340) * 160

WRITE (6, 190) CKDP

GO TO M30

END
REFRAC SUBROUTINE DECK

COMPUTES CURVATURE OF RAY IN A NEW STEP

CHECKS TO SEE IF RAY HAS REACHED HOUNDAPY

COMMON DEP(20000), HI, B2, BO, HOUN, CKDEP, CO, CXY, U(12), DCON, DCON,
1DELTA, DMC, DTGR, DXY, E(6), 1PINC,
2H, HH, HO, ICN, IGO, IREI, ISP, JGO, KFIHST, KPLT,
3LIMNPT, LPLT, NPRINT, NPT, PHX, PHY, RGO, RADIUS, RAYNO,
4RCCO, WK, RK, SCNV, SIG, SK1, S11, T, TMI, TOP,
5V, WL, WLO, XP, XSG, XSGL, YP, YSG, YSGL

COMMON HPREV, SKPREV, RKPREV, UROT, UMIN, ET, CUR, POW, PL, DS

DIMENSION F(9)

SET INITIAL VALUE FOR NO AVERAGE OF CURVATURE
NCUR=1

GO TO CONDITION CONTROLLED BY VALUE OF IGO
GO TO (100, 110, 350), IGO

FIRST TIME THROUGH SUBROUTINE, SET FOR THIS CONDITION
100 FKM=FK
IGO=2

COMPUTE STEP LENGTH
110 DS=CXY*DTGR

IS STEP LENGTH SMALLER THAN PRESCRIBED MINIMUM VALUE
IF(DS-DELTA) 120, 130, 130

YES, SET IRET FOR THIS CONDITION AND RETURN TO RAYCON
120 IRET=1
RETURN

NO, COMPUTE TEST FOR CONVERGENCE OF CURVATURE
130 RESMAX=0.00005/DS

DO A MAXIMUM OF 20 ITERATIONS TO COMPUTE NEW STEP
140 DO 210 I=1, 20

COMPUTE DELTA ANGLE FOR NEW STEP TRIAL
DELA=FKM*DS

COMPUTE TRIAL ANGLE AND COORDINATES
AA=AA+DELA
AM=DELA*0.5+A
XX=COS(AM)*DS*X
YY=SIN(AM)*DS+Y

COMPUTE CURVATURE OF RAY FOR TRIAL
CALL CURVE(XX, YY, AA, FKM)

WILL WAVE BREAK IN TRIAL STEP
IF(XX*DSY-H) 150, 150, 160

YES, SET IRET FOR THIS CONDITION AND RETURN TO RAYCON
150 IRET=2
RETURN

NO, WAS CURVATURE AVERAGED IN LAST SOLUTION
160 GO TO (170, 240), NCUR

II-70
C NO, COMPUTE AVERAGE CURVATURE OF THIS TRIAL STEP
170 FKM=(FK+FKK)*0.5
C IS THIS FIRST ITERATION
180 IF(1-I) 210*210*180
C NO, IS CONVERGENCE TEST SATISFIED
190 IF(RESMAX-ABS(FKP-FKM)) 190*190*240
C NO, IS THIS THE 18TH ITERATION
190 IF(I-18) 210*200*210
C YES, SET DUMMY VARIABLE TO USE IN AVERAGING RAY CURVATURE
200 FKCK=FKM
C CONVERGENCE TEST NOT SATISFIED
C SAVE CURVATURE FOR THIS TRIAL AND IF NOT 20TH START NEW TRIAL
210 FKP=FKM
C CONVERGENCE TEST NOT SATISFIED AFTER 20 ITERATIONS
C IS CONVERGENCE TEST SATISFIED BETWEEN 18TH AND 20TH ITERATIONS
C NO, SET I RFT FOR NO CONVERGENCE AND RETURN TO RAYCON
220 I RFT=3
RETURN
C YES, SET CURVATURE EQUAL TO AVERAGE OF 18TH AND 20TH
C ITERATION AND SET
230 FKM=(FKM+FKCK)*0.5
C CURVATURE IS COMPUTED, SET VALUES OF NEW STEP TO RETURN
GO TO 140
240 X=XX
Y=YY
A=AA
FK=FKK
IF(NCUR-2) 260*250*260
250 I RFT=4
RETURN
260 IF(RHS-X) 270*270*280
270 I RFT=5
RETURN
280 IF(X-1.5) 240*290*300
290 I RFT=6
RETURN
300 IF(TOP-Y) 310*310*320
310 I RFT=5
RETURN
320 IF(Y-1.5) 330*330*340
330 I RFT=6
RETURN
340 I RFT=6
350 RETURN
END
CURVE SUBROUTINE DECK

SUBROUTINE CURVE(X,Y,A,FK)

COMMON DEP(20000),MI,MJ,SCX,SCALE,GRID,PD

COMMON B1,B2,BOUND,CKDEP,CO,CXY,D(12),DCDH,DCON

IDELTAS,DRC,DTR,DUY,E(6),GRINC

2 H,H1,H2,H3,H4,H5,H6,H7,H8

3 LIMP,LPLUT,LMP1,LMP2,LMP3,LMP4,LMP5,LMP6,LMP7,LMP8

4XCCO,RSN,PK,SCN,V,SIG,SK,SK1,SK2,TH1,TH2,TOP

5 V,W,L,WL,XP,XP1,XSGL,YP,YSGL

COMMON HPREV,SKPREV,PKPREV,UMID,ET,CMP,POW,PL,DS

GO TO (140,100)

100 CALL DEPTH(X,Y)

IF (DXY*200.0<0.0) 110,140,140

110 IF (DXY) 120,120,130

120 RETURN

130 JG0=2

ARG=32.1725*(DXY)

CXY=SORT(ARG)

DCDH=16.06625/CXY

GO TO 170

140 CI=CXY

JG0=1

DO 150 I=1,50

ARG=((DXY)*SIG)/CI

ARG=TANH(ARG)

CXY=CO*ARG

IF (ARG*(CXY-CI)=-0.0001) 160,150,150

150 CI=(CXY+CI)*0.5

160 RCCO=CXY/CO

SCMC=(1.0-RCCO*RCCO)*SIG

V=SCMC*(DXY)+RCCO*CXY

DCDH=CXY*SCMC/V

170 PHX=E(4)*2.0*XP+E(5)*YP+E(2)

PHY=E(6)*2.0*YP+E(5)*XP+E(3)

FK=(STN(A)*PHX-COS(A)*PHY)*DCDH*DCON/CXY

RETURN

END
DEPTI SUBROUTINE DECK

SUBROUTINE DEPTI (X, Y)

COMMON DEP(20000), MJ, MJ, SCX, SCALE, SK I, PD
COMMON H1, R2, HOUND, CKREP, CO, CXY, D(12), DCON, DCON1
IDELTA1, DRC, DTR, DXY, 1.0, GMRNC
2 H, HH, HO, ICH, IGR, IRT, ISP, JGR, KFIRST, KPLUT
3 LIMPT, LPLUT, NPRINT, NPT, PHX, PHY, R90, RADIUS, RAYNO,
4RCCO, PHS, PK, SCNV, SIG, SK, SKI, T, THI, TOP,
5 V, WL, WLO, XP, XSG, XSGL, YP, YSG, YSGL

COMMON HREP, SKPPEV, RKPREV, UHOT, UMID, FT, CGR, POW, PL, DS

DIMENSION S(12, 3)

S(1, 1) = 0.30831241
S(2, 1) = 0.23644207
S(3, 1) = 0.21770331
S(4, 1) = 0.23644207
S(5, 1) = -0.08492423
S(6, 1) = 0.05143541
S(7, 1) = 0.05143541
S(8, 1) = 0.08492823
S(9, 1) = 0.00548046
S(10, 1) = 0.13038277
S(11, 1) = 0.13038277
S(12, 1) = 0.05548026
S(1, 2) = 0.05322964
S(2, 2) = 0.19677030
S(3, 2) = 0.14413872
S(4, 2) = 0.10546122
S(5, 2) = 0.09033100
S(6, 2) = -0.06759374
S(7, 2) = 0.03349283
S(8, 2) = 0.03349283
S(9, 2) = -0.18241626
S(10, 2) = -0.34031099
S(11, 2) = -0.12440190
S(12, 2) = -0.12440190
S(1, 3) = 0.05322964
S(2, 3) = 0.10546122
S(3, 3) = 0.14413872
S(4, 3) = 0.19677030
S(5, 3) = 0.03349283
S(6, 3) = -0.03349283
S(7, 3) = -0.06759374
S(8, 3) = 0.09033109
S(9, 3) = -0.12440190
S(10, 3) = -0.12440191
S(11, 3) = 0.34031099
S(12, 3) = 0.13038277

11-73
\[
\begin{align*}
S(1.4) &= -0.1249998 \\
S(2.4) &= -0.1249999 \\
S(3.4) &= -0.1249998 \\
S(4.4) &= -0.1249998 \\
S(5.4) &= 0.125 \\
S(6.4) &= 0.125 \\
S(7.4) &= 0.0 \\
S(8.4) &= 0.0 \\
S(9.4) &= 0.1249999 \\
S(10.4) &= 0.1249999 \\
S(11.4) &= 0.0 \\
S(12.4) &= 0.0 \\
S(1.5) &= 0.05263157 \\
S(2.5) &= 0.05263157 \\
S(3.5) &= 0.05263158 \\
S(4.5) &= 0.05263157 \\
S(5.5) &= 0.15789473 \\
S(6.5) &= 0.15789474 \\
S(7.5) &= 0.15789474 \\
S(8.5) &= -0.15789473 \\
S(9.5) &= 0.15789473 \\
S(10.5) &= 0.15789473 \\
S(11.5) &= 0.15789473 \\
S(12.5) &= 0.15789473 \\
S(1.6) &= 0.1249998 \\
S(2.6) &= 0.1249998 \\
S(3.6) &= 0.1249998 \\
S(4.6) &= 0.1249998 \\
S(5.6) &= 0.0 \\
S(6.6) &= 0.0 \\
S(7.6) &= 0.125 \\
S(8.6) &= 0.125 \\
S(9.6) &= 0.0 \\
S(10.6) &= 0.0 \\
S(11.6) &= 0.1249999 \\
S(12.6) &= 0.1249999 \\
\end{align*}
\]

\[
\begin{align*}
I &= X + 1, \\
J &= Y + 1, \\
XP &= \text{AMOD}(X + 1, ) \\
YP &= \text{AMOD}(Y + 1, ) \\
IF(NPT - 1) &= 120 * 120 * 100 \\
100 &= IF ([P - 1] ) = 120 * 110 * 120 \\
110 &= IF ([J - J]) = 120 * 150 * 120 \\
120 &= IF = I \\
JP &= J \\
I &= JP \\
J &= JP \\
II ÄX &= (I - 1) * MI \\
D(1) &= \text{DEP}(II ÄX + J) \\
D(2) &= \text{DEP}(II ÄX + J + 1) \\
\end{align*}
\]
D(3) = DEP (IIAX + MI + J + 1)
D(4) = DEP (IIAX + MI + J)
D(5) = DEP (IIAX + J + 2)
D(6) = DEP (IIAX + MI + J + 2)
D(7) = DEP (IIAX + 2 * MI + J + 1)
D(8) = DEP (IIAX + 2 * MI + J)
D(9) = DEP (IIAX + MI + J - 1)
D(10) = DEP (IIAX + J - 1)
D(11) = DEP (IIAX - MI + J)
D(12) = DEP (IIAX - MI + J + 1)
DO 140 K=1,6
   SUM=0
   DO 130 L=1,12
      SUM=SUM+D(L)*S(L,K)
130 CONTINUE
   F(K)=SUM
140 CONTINUE
150 DXY=(F(1)*E(2)*XP+E(3)*YP+E(4)*XP*XP+
      F(5)*XP*YP+E(6)*YP*YP)*UCON
RETURN
END
C

REFRACTION COEFF SUBROUTINE DECK

SUBROUTINE HEIGHT(A)
COMMON UE(20000),MI,MJ,SCX,SCALE,GRID,PD
COMMON BI, B2, BOUND, CKDIEP, CO, CXY, U(12), DCDH, DCON,
1DELTA, DRC, DTGR, DXY, E(6), GRINC,
2H, HH, HO, ICN, IGO, IRET, ISP,, JGO, KFIKST, KPLOT,
3LIMNPT, LPlot, NPRINT, NP7, PHX, PHY, R90, RADIUS, RAYNO,
4RCCO, RBS, RK, SCNv, SIG, SK, SK1, T, THI, TOP,
5V, WL, WLO, XP, XSG, XSGL, YP, YSG, YSGL
COMMON HPREV, SKPREV, RKPREV, UROT, UMIN, ET, CGR, H0, PL, NS
SKPREV=SK
RKPREV=RK
WL=WLO*RCCO
GN=12.566370614*DXY/WL
HS1=EXP(GN)
HS2=2.0/HS1
CG=(1.0*GN/(HS1-HS2)*2.0)*CXY
IF (CG) 100, 110, 110
100 P=RETURN
110 CONTINUE
WK=ABS(1.0/B2)
SK=SQRT(C0/CU)
RK=SQRT(HK)
H=(HO*SK*RK)/SK1
GO TO (120, 130), JGO
120 U=-2.0*SIG*RCC0*CXY/(V*V)
GO TO 140
130 U=-0.5*DXY
140 U=U*DCON
DCO=DCDH*DCON
COSA=COS(A)
SINA=SIN(A)
P=-(COSA*PHX*SINA*PHY)*DCDH*DTGR*2.0
Q=((E(4)*2.0*U*PHX*PHX)*SINA*SINA-(E(5)+
1U*PHX*PHY)*2.0*SINA*COSA+(E(6)*2.0*U*
2PHY*PHY)*COSA*COSA)*DCDH*CXY*DTGR*DTGH*
32.0
B3=((P-2.0)*B1+(4.0-0)*B2/(P+2.0)
A1=B2
A2=B3
CALL FRICTION
RETURN
ENDD
SUBROUTINE TO PLOT WAVE RAYS

SUBROUTINE PEFU0IA(XR,YR,IPEN)
COMMON DEP(20000),M1,MJ,SCX,SCALE,GRID,PD
COMMON R1, R2, ROUND, CKUEP, CO, CXY, U(12), DCDH, DCON,
IDELTA, ORC, DTGR, DXY, E(b), URINC,
COMMON H, M, R, M, ICN, L60, J4FT, IPS, JGO, KFIPST, KPLOT,
LIMNPT, LPLUT, NPRINT, NPT, PHX, PHY, P90, RADIUS, RAYNO,
POCCO, WHS, RK, SCNV, SIG, SK, SK1, T, IMI, TOP,
V, W, WI, WLO, XG, XSG, XSGL, YP, YSG, YSGL,
COMMON HPPEV, SKPREV, RKPEV, UHOT, UMID, ET, C6, POW, PL, OS
RX=XR*SCX
RY=YR*SCX-ROUND
IF (RY*LT.0.) GO TO 100
CALL PLOT(RX, RY, IPEN)
100 RETURN
END
SUBROUTINE FRICTN
COMMON DEP(20000), MI, MJ, SCX, SCALE, GRID, PD
COMMON BI, A2, BOUND, CKDEP, CO, CXY, U(12), UCDM, DCON,
1DFLTAS, DHC, DTGR, DXY, E(6), GRINC
2H, M, MS, ICN, IGO, IRET, ISP, JGO, KFIRST, KPLT,
3LIMNPT, LPLT, NPRINT, NPT, PHX, PHY, H90, RADIUS, RAYNO,
4RCKO, RMS, RK, SCNV, SIG, SK, SKI, T, THI, TOP,
5V, WL, WL0, XP, XSL, XSG, YP, YSG, YSGL
COMMON HPREV, SKPREV, RKPREV, UB0T, UMID, ET, CGR, POW, PL, DS
DX=DS*GRID
OH=HPREV*(SK/SPREV)*(RK/HPREV)
PI=3.14159265
G=32.17
ARG=2.*PI*DXY/WL
PHI=.6391*(SK/SINH(ARG))*3
HNEW=OH/((.02*OH*PHI*DX)/(SK*T**4)+1.)
HPREV=HNEW
C
H=HNEW
C
THE ABOVE CARD SHOULD BE USED IF THE FRICTIONAL AFFECT
ON WAVE HEIGHT IS DESIRED
C
UROT=H*G/(2.*CXY*COSH(ARG))
UMID=UB01*COSH(ARG*.5)
RETURN
END
II-78
SUBROUTINE ENERGY(A,END)
COMMON DEP(2000),MI,MJ,SCX,SCALF,GRID,P0
COMMON HI,HZ,ROUNH,CKDEP,CO,CXY,D(12),DCNH,DCON,
IDELTA, HNC, DTGR, DXY, E(5), GPDNC,
2H, HH, HO, ICN, IGO, ISRF, ISP, JGO, KFIRST, KPLT,
3LHMX, LPLT, NPHINT, NPT, PHX, PHY, M90, RADIUS, RAYNO,
ACCCO, KHS, R, SCNV, SIG, SK, SK1, T, TH1, TOP,
SV, WL, WL0, AP, XSG, XSL, YP, YSG, YSL
COMMON HPREV,SKPREV,RKPREV,UMOS,UM10,E1,CMR,POW,PLDS
COMMON IDIR
DATA LEFT/*1*/RIGHT/*1*/
PI=3.14159265
IF (PHY .LE. 0.) GO TO 20
AA=A
IF (AA .GT. 6.2831852) AA=A-6.2831852
THETA=ATAN(PHX/PHY)*PI/2,
THETA=PI-THETA
10 DTHETA=THETA-AA
IF (DTHETA .LT. 0.) IDIR=1
IF (DTHETA .GT. 0.) IDIR=LEFT
DX=DOS*GRID
PT=B.*HI*HWL
ATHETA=AHS(DTHETA)
DTHETA=ATHETA
DLR=4.*PI*DXY/WL
SDLH=SINH(DLR)
IF (SDLH .LT. 1.E-10) SDLH=1.E-10
CMR=A*CXY*(1.+DLR/SDLH)
POW=B.*HI*CMR
PL=POW*SIN(A1HTETA)*COS(A1HTETA)
IF (END .NE. 1.) RETURN
H=H
ALPHA=DTHETA
C    PLS IS AN ESTIMATE OF THE LONGSHORE COMPONENT OF ENERGY FLUX IN
C    SURF ZONE. BECAUSE IN THE CALCULATION OF PLS THE SIGNIFICANT WAVE
C    HEIGHT IS USED INSTEAD OF THE ROOT-MEAN-SQUARE THE VALUE OF PLS
C    APPROXIMATELY TWICE THE VALUE OF THE EXACT ENERGY FLUX. THEREFORE
C    YUMY(20)00)
C    PLS IS MORE APPROPRIATELY REFERRED TO AS THE LONGSHORE ENERGY
C    FLUX FACTOR.
C    PLS=3P.1*(HH**2.5)*SIN(2*ALPHA)
C
C
PLS=3P.1*(HH**2.5)*SIN(2*ALPHA)
HHM=HH/3.28
PLSM=(2.60*10**10)*(HHM**2.5)*SIN(2*ALPHA)
WRITE (6,220) PLS
220 FORMAT ('LONGSHORE ENERGY FLUX FACTOR: PLS=*,F14.7,
* FT-FLS/SEC/FT OF BEACH FRONT*)
C C APPROXIMATION OF LONGSHORE TRANSPORT RATE: (1) BASED ON PLS
C (2) BASED ON GALVIN (1972) - ESTIMATE OF THE GROSS LONGSHORE TRANSPORT RATE.
C
Q1=7500*PLS
Q2=200000*MB*MB
QM=.000128*PLSM
WRITE (6,230) Q1,QDIR,Q2
230 FORMAT ('LONGSHORE TRANSPORT RATES: */ */ */'),11X,
1 'FUNCTION OF PLS: Q=*,E14.7,' CURIC YARDS/YR*5X,'FACING OCEAN:',
2 TRANSPORT TO */ */ */12X,
3 'FUNCTION OF HR: Q=*,E14.7,' CURIC YARDS/YR*5X,'GALVIN (1972) -
4 GROSS TRANSPORT RATE:',
WRITE (6,250) PLSTM,QM
250 FORMAT ('METRIC CONVERSIONS: */ */ */ */ */'),11X,
1 'ERGS/MTER*SEC*/ */ */ *,E14.7,' CURIC METERS/YEAR*/
RETURN
C
20 THETA=PI
GO TO 10
END
SUBROUTINE BOTTOM

C THIS PROGRAM CREATES A MAP WITH DEPTHS AT EQUALLY SPACED
C DISTANCES FROM A DIGITIZED HYPOTHETICAL MAP USING THE
C CONTOURS
C THIS PART OF THE PROGRAM READS THE TAPE AND CONVERTS THE
C MENU TO CORRECT FORM FOR PROCESSING.

COMMON DEPTH(20000),IXAX, IYAX, SCX, SCALE, GHID, PD
COMMON H1, H2, HOUND
DIMENSION A(4096)
DIMENSION IPX(5), IPY(5)
DIMENSION IDEP(100)
DIMENSION PP(1000)
DIMENSION IAX(20000),IY(20000)
DATA A0,A1,A2,A3,A4, A5,A6,A7,A8,A9/10,1,2,3,4,5,6,1,
  7,8,9/10
DATA A00, A10, A20, A30, A40, A50, A60, A70, A80, A90
DATA AL/"L"/
DATA ALsh/Aplus,Aminus/"+-+-+"/
DATA A0, A1, A2, A3, A4, A5, A6, A7, A8, A9, A10

TIPSW=0
IPEN=0
ILL = 0
IXSW = 0
IP = 0
IX(1) = 0.0
IY(1) = 0.0
DIV = 10.0
IPSW = 0
ISHR = 0
IEND = 0
ISSW = 0
ICT = 0
ISTOP = 1
FORMAT (3A4)

R000 FORMAT (3A4)

IS = 0
IXY = 1
II = 1
IN = 0
IPT = -1
IN = 5
IOUT = 6
ITAPE = 17
INDSK = 17
ISLH = 0
INUMH = 0
ISIGN = 0
IEND = 0
III = 0

C
C READ INPUT TAPE FROM DIGITIZER
C
200 READ (ITAPE+9000) (A(I),I=1,4096)
9000 FORMAT (64(64A1))
GO 2000 I = 1,4096
IF (A(I),EQ,A0) GO TO 500
IF (A(I),EQ,A1) GO TO 520
IF (A(I),EQ,A2) GO TO 540
IF (A(I),EQ,A3) GO TO 560
IF (A(I),EQ,A4) GO TO 580
IF (A(I),EQ,A5) GO TO 600
IF (A(I),EQ,A6) GO TO 620
IF (A(I),EQ,A7) GO TO 640
IF (A(I),EQ,A8) GO TO 660
IF (A(I),EQ,A9) GO TO 680
IF (A(I),EQ,ASLH) GO TO 940
IF (A(I),EQ,APLUS) GO TO 980
IF (A(I),EQ,AMINUS) GO TO 1010
IF (A(I),EQ,A0) GO TO 1040
IF (A(I),EQ,AF) GO TO 1080
IF (A(I),EQ,A5) GO TO 1120
IF (A(I),EQ,A6) GO TO 1140
IF (A(I),EQ,AL) GO TO 1150
IF (A(I),EQ,AM) GO TO 1180
IF (A(I),EQ,AN) GO TO 1200
IF (A(I),EQ,AST) GO TO 1230
GO TO 2000
500 INUM = INUMH * 10
GO TO 690
520 INUM = INUMH * 10 + 1
GO TO 690
540 INUM = INUMH * 10 + 2
GO TO 690
560 INUM = INUMH * 10 + 3
GO TO 690
580 INUM = INUMH * 10 + 4
GO TO 690
600 INUM = INUMH * 10 + 5
GO TO 690
620 INUM = INUMH * 10 + 6
GO TO 690
640 INUM = INUMH * 10 + 7
GO TO 690

II-82
660 INUMH = INUMH * 10 + 8
680 INUMH = INUMH * 10 + 9
690 ICT = ICT + 1
   IF (IPPSW *EQ. 1) GO TO 2000
   IF (IS+TO.1) GO TO 2000
   IF (ICT GT 5) GO TO 1230
   IF (ICT LT 5) GO TO 2000
   GO TO (730, 740), IXY
730 IXY = 2
   XSS = FLOAT (INUMH) * SCALE / 1000.0
   IF (ISIGN. NE. 2) GO TO 760
   XSS = - XSS
   GO TO 140
790 IXY = 1
   YSS = FLOAT (INUMH) * SCALE / 1000.0
   IF (ISIGN. NE. 2) GO TO 930
   YSS = - YSS
830 IX (II) = XSS + 0.5
   IY (II) = YSS + 0.5
   IF (ISTOP * EQ. 1) GO TO 960
   II = II + 1
   IF (II GT 28000) GO TO 1310
850 CONTINUE
   IF (II LE. 2) GO TO 851
   THX = IAWS (IX (II - 1) - IX (II - 2))
   XH1 = FLOAT (THX)
   IF (XH1 LT. AHS(6, IILL) + 5)) GO TO 851
   IX (II) = IX (II - 1)
   IY (II) = IY (II - 1)
   IX (II-1) = (IX (II) + IX (II-2)) / 2
   IY (II-1) = (IY (II) + IY (II-2)) / 2
   II = II + 1
851 CONTINUE
   IF (IP LE. 5) GO TO 860
   DPTH = DEPTH (ILL) / 10.0
   WRITE (11, 9980) XSS, YSS, DPTH, IPEN
9980 FORMAT (4A4)
   IF (ISHP * EQ. 1) GO TO 4400
   IPEN = 2
860 ISIGN = 0
   ICT = 0
   INUMH = 0
   GO TO 2000
940 IF (ISLH*EQ. 1) GO TO 1330
   IF (ICT LT 5) GO TO 1220
   ISLH = 1
   ILL = ILL + 1
   IF (ILL GT 100) GO TO 1340
   IF (ISIGN * EQ. 2) INUMH = -INUMH
In C0 ('TO Hq60
IF (ISIGN,NE.,0) GO TO 1350
ISIGN = 1
GO TO 2000
1010 IF (ISIGN,NE.,0) GO TO 1350
ISIGN = 2
GO TO 2000
1040 IF (I1).EQ.1) GO TO 1370
ISLM = 0
I$ = 1
IPEN = 3
IP = 1
ISTOP = 0
GO TO 460
1040 ISTOP = 1
ISMP = 0
IF (IP.IE.15) GO TO 4100
IF (IPSW,NE.,0) GO TO 1040
IF (IP1,GE.1) GO TO 1170
1090 IXY = 1
II = II + 1
ISLSM = 0
IPSW = 0
GO TO 460
1135 ILL = ILL + 1
IDEPTH (ILL) = IDEPTH
IX (II) = 0.0
IY (II) = 0.0
1140 IPSW = 1
1150 JPT = IPT + 1
IP = IP + 1
IPX(IP) = IX(II)
IPY(IP) = IY(II)
GO TO 460
1170 IF (IPT,GT,1) GO TO 2010
C X = AXI ! HOMOTOM
C
C IDEPTH = IDEPTH (1)
NRM = 0
IX0IS = IX(II) = IX(1)
IY0IS = IY(II) = IY(1)
X0IS = FLAT (IX0IS)
Y0IS = FLAT (IY0IS)
X0IS = X0IS(X0IS)
Y0IS = Y0IS(Y0IS)
* (X0IS..I..0..0) X0IS = 0.000]
```plaintext
THETA1 = ATAN(YDIS/XDIS)
DIS = SQRT(XDIS**2 + YDIS**2)
DIS1 = DIS
ALEFT = 0.0

C CALCULATE LENGTH OF INCREMENTS ALONG X - BOTTOM

AX = DIS / FLOAT (IXAX - 1)
II = II - 1
DO 3000 LM = 1+II
IXX = IAXS(IX(LM) - IX(LM+1))
IYY = IAXS(IY(LM) - IY(LM+1))
XX = IXX
YY = IYY

C CALCULATE DISTANCE TO NEXT POINT

DD = SQRT((XX**2 + YY**2))
IDC = IDPHT(LM+1) - IDPHT(LM)
ADC = FLOAT (IDC) / DDIV
DPH = FLOAT (IDPHT(LM)) / DDIV
DPH2 = FLOAT (IDPHT(LM+1)) / DDIV
IF (ALEFT.GT.0.0) GO TO 2990
IF (ALEFT.LE.0.0) GO TO 2400
NNN = NNN + 1
IDPHT(NNN) = DPH + ALEFT * ADC / DD
DD = DD - ALEFT

2900 AN = DD AX)
AIDC = (DPH2 - DPH) / AN
NN = AN
IF (NN.EQ.0) GO TO 2950

C CALCULATE DEPTH INCREMENTS

DO 2450 LN = 1,AN
NNN = NNN + 1
IDPHT(NNN) = DPH + FLOAT (LN) * AIDC
2950 CONTINUE

2960 CONTINUE
ALEFT = DO - FLOAT(NN) * AAD
ALEFT = AAD - ALEFT
GO TO 3000

2990 ALEFT = ALEFT - DD
3000 CONTINUE
II = II + 1
IF (IY(1).LT.IY(II)) GO TO 3003
IY(1) = IY(II)
GO TO 3004

3003 IY(II) = IY(1)

```

3004 CONTINUE
IB = IXAX - 1
DO 3005 J = 1, IB
PPD (J+1) = DEPTH(J)
3005 CONTINUE
MMM = IH + 1
IX(1) = IX(IH)
IY(1) = IY(IH)
II = 1
IDEPTH (1) = DEPTH (I Lil)
II = 1
GO TO 1040
3010 IF (IPI.GT.2) GO TO 3410
ALEFT = 0.0
C Y-AXIS - FAR SIDE
C
NNN = 0
IXDIS = IX(IH) - IX(1)
IYDIS = IY(IH) - IY(1)
XDIS = FLOAT (IXDIS)
YDIS = FLOAT (IYDIS)
XDIS = ABS (XDIS)
YDIS = ABS (YDIS)
IF (XDIS.FQ.0.0) XDIS = 0.0001
THETA = ATAN (YDIS/XDIS)
DIS = SQRT (XDIS ** 2 + YDIS ** 2)
DIS2 = DIS
C CALCULATE LENGTH OF INCREMENTS ALONG Y - RIGHT SIDE
C
AYD = DIS / FLOAT (IYAX - 1)
II = II - 1
DO 3360 LM = 1, II
IXX = IAHS (IX(LM) - IX(LM+1))
IYY = IAHS (IY(LM) - IY(LM+1))
XX = IXX
YY = IYY
DD = SQRT (XX ** 2 + YY ** 2)
IDC = DEPTH(LM + 1) - DEPTH(LM)
ADC = FLOAT (IDC) / DDIV
DPH = FLOAT (IDEPHTH (LM)) / DDIV
DPH2 = FLOAT (IDEPHTH (LM+1)) / DDIV
IF (ALEFT.GT.0.0) DDIV 3350
IF (ALEFT.LE.0.0) DDIV 3270
NNN = NNN + 1
DEPH (NNN) = DPH + ALEFT * ADC / DD
DPH = DEPTH (NNN)
DD = DD - ALEFT
IF (DD = DD / AYD)
AIOC = (0 * M2 - IFPH) / AN
NN = AN
IF (NN < 0.0) GO TO 3330
DO 3320 LN = 1 * NN
NNN = NNN + 1
DEPTH (NNN) = DPH + FLOAT (LN) * AIOC
3320 CONTINUE
3330 CONTINUE
ALEFT = DO - FLOAT (NN) * AYO
ALEFT = AYO - ALFFT
GO TO 3360
3350 ALEFT = ALEFT - DO
3360 CONTINUE
II = II + 1
IF (IX(1) > IX(II)) GO TO 3365
IX(1) = IX(II)
GO TO 3367
3365 IX(II) = IX(1)
3370 CONTINUE
MM = MMM + 1
DO 3370 J = MMM, MMM
JJJ = J - MMM + 1
PPR (J + 1) = DEPTH (JJJ)
3370 CONTINUE
MM = MMM + 1
IX(1) = IX(II)
IY(1) = IY(II)
II = 1
IDEPF (1) = DEPTH (ILL)
ILL = 1
GO TO 1040
3410 IF (IPT.GT.3) GO TO 3700
C C X-AXIS = RACK C
C
NNN = 0
IXDIS = IAHS (IX(II) - IX(1))
IYDIS = IAHS (IY(II) - IY(1))
ALEFT = 0.0
XDIS = FLOAT (IXDIS)
YDIS = FLOAT (IYDIS)
IF (XDIS < 0.0) XDIS = 0.0001
THETA3 = ATAN (YDIS/XDIS)
DIS = SQRT (XDIS ** 2 + YDIS ** 2)
DIS3 = DIS
C C CALCULATE LENGTH OF INCREMENTS ALONG X - TOP C
C
AXO = DIS / FLOAT (IXAX - 1)
II = II - 1
DO 3730 LM = 1,II
IXX = IABS (IX(LM) - [IX(LM+1)])
IYY = IABS (IY(LM) - [IY(LM+1)])
XX = IXX
YY = IYY
DD = SQRT (XX ** 2 + YY ** 2)
IDC = IDEP (LM) - IDEP (LM+1)
ADC = FLOAT (IDC) / DDIV
DPH = FLOAT (IDEP (LM)) / DDIV
DPH? = FLOAT (IDEP (LM+1)) / DDIV
IF (ALEF.T GT. DD) GO TO 3720
IF (ALEF.T LE. 0.0) GO TO 3650
NNN = NNN + 1
DEPH (NNN) = DPH + ALEFT * AUC / DD
DPH = DEPH (NNN)
DD = DD / ALEX
AIDC = (DPH? - DPH) / AN
NN = AN
IF (NN EQ. 0) GO TO 3710
DO 3700 LN = 1,NN
NNN = NNN + 1
DEPH (NNN) = DPH + FLOAT (LN) * AIDC
3700 CONTINUE
3710 CONTINUE
ALEF = LN - FLOAT (NN) * AXD
ALEF = AXD - ALEFT
GO TO 3730
3720 ALEFT = ALEFT - DD
3730 CONTINUE
II = II + 1
IF (IY(II).GT.IY(I)) GO TO 3735
IY(II) = IY(I)
GO TO 3737
3735 IY(II) = IY(I)
3737 CONTINUE
MMMM = MAM * IXAX - 2
DO 3740 J = MMM, MMMM
JJJ = J - MMM + 1
PPD (J+1) = DEPH (JJJ)
3740 CONTINUE
MM = MMMM + 1
IX(I) = IX(I)
IY(I) = IY(I)
II = 1
IDEP (1) = IDEP (ILL)
ILL = 1
GO TO 1090
3740 IF (IP1 LE. 4) GO TO 4020
Y-AXIS DOWN

NNN = 0
IXDIS = IAWS(IX(II) - IX(I))
IYDIS = IAWS(IY(II) - IY(I))
XDIS = FLOAT (IXDIS)
YDIS = FLOAT (IYDIS)
IF (XDIS+E1.0.0) XDIS = 0.0001
THETA4 = ATAN (YDIS/XDIS)
DIS = SQRT (XDIS ** 2 + YDIS ** 2)
DIS4 = IXDIS
AYD = DIS / FLOAT (IYAX - 1)
II = IX - 1
ALEFT = 0.0
DO 3940 LM = 1*II
IXX = IAWS (IX(LM) - IX(LM+1))
IYY = IAWS (IY(LM) - IY(LM+1))
XX = IXX
YY = IYY
D0 = SQRT (XX ** 2 + YY ** 2)
IND = IDEPHT(LM+1) - IDEPHT(LM)
ADC = FLOAT (II(C) / DDIV
DPH = FLOAT (IDEPHT (LM)) / DDIV
DPH2 = FLOAT (IDEPHT (LM+1)) / DDIV
IF (ALEFT *GI* D0) GO TO 3940
IF (ALEFT*LE*0.0) GO TO 3910
NNN = NNN + 1
DEPH (NNN) = DPH * ALEFT * ADC / D
DPH = DPH / DPH2
D) = DD = ALEFT
3910 AN = DD / AYD
AIC = (DPH2 - DPH) / AN
NN = AN
IF (NN*FG*0) GO TO 3970
DO 3960 LN = 1*NN
NNN = NNN + 1
DEPH (NNN) = DPH * FLOAT (LN) * AIDC
3960 CONTINUE
3970 CONTINUE
ALEFT = D0 - FLOAT (NN) * AYD
ALEFT = AYD - ALFFT
GO TO 3940
3940 CONTINUE
IP=6
IX(1) = 0
IX(II) = 0
MMM = MMM + IYAX - 3
DO 4000 J = MMM,MMM
JJJ = J - 4MMM + 1
PPU (J+1) = IFPTH (JJJ)
PI = 3.141593

4000 CONTINUE
PPD (1) = DEPTH (MMMH - MMM + 2)
II = 0
THETA1 = THETA1 * PI / 180.0
THETA2 = THETA2 * PI / 180.0
THETA3 = THETA3 * PI / 180.0
THETA4 = THETA4 * PI / 180.0

C FIND INCREMENTS ON X-AXIS - BOTTOM
C ANCI = DIST / FLOAT (IXAX - 1)
C
C FIND INCREMENTS ON X-AXIS - TOP
C ANCT = DIST / FLOAT (IXAX - 1)
ANCAV = (DIST1 + DIST3) / 2.0
ANCAV = ANCAV / FLOAT (IXAX - 1)
ILL = 0
GO TO 1040

4020 WRITE (6, 6030)
6030 FORMAT ('1 L ENTREI EARLY')
STOP

4100 II = II - 1
IF (II EQ 1) GO TO 1090
IXD = 694499994
DPHTH = 0.0
IYH = 0
IXH = 0
IISW = 0
MMM = 0
XVAL = FLOAT (IX (1)) / ANCAV
IXVAL = IFIX (XVAL + 0.5)
XLEN = FLOAT (IXVAL) * ANCAV
IXH = XLEN
IYH = IY (1)
DPHTH = 10*DPHTH (ILL) / 10.0
WHITE (JDISK, 9000) IXH, IYH, DPHTH
GO 4100 J = 2, II

4110 JL = J - 1
IF (((IX(J) .EQ. IX(JL))) .AND. (IY(J) .EQ. IY(JL))) GO TO 4190
C CALCULATE THE RANGE
XVAL = FLOAT (IX (J)) / ANCAV
IXVAL = IFIX (XVAL + 0.5)
XLEN = FLOAT (IXVAL) * ANCAV
IF (IISW .GE. 1) GO TO 4150

4120 IXH = IFIX (XLEN + 0.5 * ANCAV + 0.5)
IXH2 = IFIX (XLEN - 0.5 * ANCAV + 0.5)  
IXXAV = XLEN  
4150 IF ((IX(J) .GT. IXH1) .OR. (IX(J) .LT. IXH2)) GO TO 4180  
IIAD = IAH (IXXAV - IX(J))  
IF (IIAD .GE. IXD) GO TO 4190  
IXD = IIXD  
IXH = IXXAV  
IYH = IY(J)  
IIw = 1  
DEPTH = IDEPTH (ILL) / 10.0  
GO TO 4190  
4180 IF (IIw .EQ. 0.0) GO TO 4190  
IIw = 0  
WRITE (IDISK*8000) IXH, IYH, DEPTH  
IXD = 999999999  
GO TO 4120  
4190 CONTINUE  
ILL = 0  
II = 0  
GO TO 1090  
C  
SET PFN SWITCH  
C  
4200 IPPSw = 1  
GO TO 4400  
4230 IPPSw = 0  
IPEN = INUMH  
IF (INUMH .LT. 1) GO TO 4240  
IF (INUMH .GT. 3) GO TO 4240  
GO TO 4600  
4240 WRITE (ICUT*8020) INUMH  
9020 FORMAT (*1 PFN VALUE LT 1 OR GT 3 (**13**))  
STOP  
4300 ISHP = 1  
GO TO 1040  
4400 WRITE (10*9990) XSS, YSS, IPEN  
4990 FORMAT (3A4)  
IPEN = 2  
GO TO 4600  
4500 RFwind 12  
RFwind 10  
RFwind 17  
CALL SORT11  
C  
NOW PUT PERIMETER ON  
C  
III = IXAX * IYAX  
DO 4220 K = 1, III  
DEPTH (K) = 99999.9  
4220 CONTINUE
DO 4250 K = 1, IXAX
DEPTF (K) = 1PD (K)

4250 CONTINUE
IN1 = IXAX + 1
IN = IYAX - 2
IP = IXAX + 1
IP1 = 2 * IXAX + 2 * IYAX - 4
DO 4320 K = 1, IN
IN2 = IN1 + IXAX - 1
DEPTF (IN1) = 1PD (IP1)
DEPTF (IN2) = 1PD (IP)
IN1 = IN1 + IXAX
IP = IP + 1
IP1 = IP1 - 1

4320 CONTINUE
IN1 = (IYAX - 1) * IXAX + 1
IP = 2 * IXAX + IYAX - 2
DO 4390 K = 1, IXAX
DEPTF (IN1) = 1PD (IP)
IP = IP - 1
IN1 = IN1 + 1

4390 CONTINUE
C
C NOW START FILLING IN THE POINTS
C
IPIS = 0
NSEG = 0
IP = ?
IPT = 2
ISP = IXAX

4550 CONTINUE
READ (13,8000) IXH, IYH, DPTH
IF (IXH .EQ. 0) GO TO 4550

4560 CONTINUE
ALEFT = 0.0
DPTH = DEPTF (IPT)
AYDIS = (DIS2 + DIS4) / 2.0
AYNC = AYDIS / FLOAT (IYAX - 1)
ISTY = 0
IXSW = 0

4580 CONTINUE
C
C CALCULATE # OF SEGMENTS
C
INC = IAH5 (IYH - ISTY)
DO = FLOAT (INC)
CHGD = DPTH - ODPH
IF (ALEFT .LE. 0.0) GO TO 4565
DO = DO - ALEFT
IF (IN .LT. 0.0) GO TO 4570

II-92
NFWPT = IPT * ISP
DEPTH (NFWPT) = ODPPTH * ALEFT * CHGD / FLOAT(INC)
ODPPTH = DEPTH (NFWPT)
TWT = IPT + IXAX

4585 CONTINUE
IF (DD.EQ.0.0) GO TO 4615
AN = DD / AYNC
NSEG = AN
AIDC = (DEPTH - ODPPTH) / AN
IF (NSEG.LE.0) GO TO 4601
DO 4600 LMN = 1*NSEG
NEWPT = IPT + ISP
DEPTH (NEWPT) = ODPPTH + AIDC * FLOAT(LMN)
IPT = IPT + IXAX
4600 CONTINUE

4601 CONTINUE
ALEFT = DD - FLOAT(NSEG) * AYNC
ALEFT = AYNC - ALEFT

4602 CONTINUE
ODPPTH = DEPTH
READ (13,H000,END=4570) IXA, IYA, DPTH
IF (IXA.EQ. IP (2) .OR. IXA .GE. IP (3)) GO TO 4570
IF (IXA.EQ.IXH) GO TO 4660
4605 ISTY = AYDIS + 0.5
IPPT = IXAX + (IXAX - 1) + IP
CHGD = DEPTH (IPPT) - ODPPTH
INC = IAMS (IYM - ISTY)
DD = FLOAT (INC)
IF (ALEFT.LE.0.0) GO TO 4606
DD = DD - ALEFT
IF (DD.LT.0.0) GO TO 4590
NEWPT = IPT + ISP
DEPTH (NEWPT) = ODPPTH + ALEFT * CHGD / FLOAT (INC)
ODPPTH = DEPTH (NEWPT)
CHGD = DEPTH (IPPT) - ODPPTH
IPT = IPT + IXAX

4606 CONTINUE
IF (DD.EQ.0.0) GO TO 4590
AN = DD / AYNC
AIDC = CHGD / AN
NSEG = AN - 1.0 + 0.5
IF (NSEG.LE.0) GO TO 4590
DO 4650 LMN = 1*NSEG
NEWPT = IPT + ISP
DEPTH (NEWPT) = ODPPTH + AIDC * FLOAT (LMN)
IPT = IPT + IXAX

4650 CONTINUE

4590 CONTINUE
IF (IEND.EQ.1) GO TO 4690
IP = IP + 1

II-93
IPT = IP  
IXH = IXA  
IYH = IYA  
GO TO 4560  
4570 IEND = 1  
GO TO 4605  
4660 IXH = IXA  
ISTY = IYH  
IYH = IYA  
GO TO 4580  
4670 ALEFT =AH$=0)  
GO TO 4602  
4675 ALEFT = 0,0  
GO TO 4602  
4690 IIAX = 1  
IIIAX = IXAX  
ITOT=IXAX*IIXAX  
DO 100 K=1,ITOT  
IF (DEPTH(K) .GT. 9999.0) DEPTH(K)=DEPTH(K-1)  
100 CONTINUE  
DO 4695 K = 1,IIAX  
WRITE (F*6040) K,DEPTEH(I)),I1=IIAX,IIIAX)  
IIAX = IIAX + IXAX  
IIIAX = IIIAX + IXAX  
6040 FORMAT (*(T+F10.2),/)  
4695 CONTINUE  
RETURN  
  
C  NOW WRITE AXIS VALUE TO ISK FILE  
  
1220 WRITE(1OUT*6001)  
6001 FORMAT(*5 NUMBER TOO SHORT*//)  
1230 WRITE (1OUT*6000)  
6000 FORMAT (*1 NUMBER TOO LONG*//)  
1240 J = 1 - 20  
IF (J.LT.1) J = 1  
J2 = J + 40  
IF (J2.LE.4096) GO TO 1290  
J = J2 - 40  
1290 WRITE (IOUT*6005) (A(KK),KK=J,J2)  
6005 FORMAT (**41A1)  
STOP  
1310 WRITE (1OUT*6010)  
6010 FORMAT (**1 EXCEEDED 20000 POINTS ON ONE CONTOUR*//)  
STOP  
1330 WRITE (1OUT*6015)  
6015 FORMAT (**1 NO FFPTH BETWEEN SLASHES*//)  
STOP  
1350 WRITE (IOUT*6020)  
6020 FORMAT (**1 TWO SIGNS WITH ONE NUMBER*//)

II-94
GO TO 1240
1370 WRITE (IOUT*6025)
6025 FORMAT (*1 NO SLASH BETWEEN DEPTHS*)
IOFF = 0
STOP
1380 WRITE (IOUT*6035)
6035 FORMAT (*1 MORE THAN 100 DEPTHS ALONG AN AXIS*)
STOP
2000 CONTINUE
GO TO 200
END
* EXEC ASMGCL,PARMLINKED='LET.LIST,EXEC,CALL'
//ASM.SYSLIN DD UNIT=*,SPACE=
//ASM.SYSP DD *
SORT1 CSECT
BEGIN SAVE (14,12)
  HALR 11:0
  USING 1:11
  LP 12:13
  LA 13:SAVF
  ST 13:1(12)
  ST 12:4(13)
  H HERE
SAVEA DS 1AF
HERE LA 1:PARLIST
  LINK EP=SORT,MP=(E+1)
  L 13:SAVEA+4
  RETURN (14,12)
CNOP 0:H
PARLIST DC X*RU
DC X*0000
ADLIST DC X*0024
DC A(SORTCD)
DC A(STCOED)
DC A(RCOCED)
DC A(RUCOED)
DC F*0
DC F*0
DC X*0000
DC X*6500
DC C*HALT
DC X*FF00
DC C*AC
SORTCD DC C* SORT FIELDS=(1:4+A:5+4+A),FORMAT=FI
STCOED DC C* *
RCOCED DC C* RECORD LENGTH=12,TYPE=F *
RUCOED DC C* *
END
*
//LINKED.SYSLMOD DD DSN=N310013.WORK(REFERCASE),DISP=(NEW,CATLG)
// SPACE=(THK(10,2,28),WHLSE)(DCB=LOADMOD)
// UNIT=3330*MSVGP=USCQ
//LINKED.SYSLIH DD DSN=SYSIL.FOPTIH,DISP=SHR
// DSN=SYSIL.LINKLH,DISP=SHR
// DSN=ACAO.SYSLIH.G5005,DISP=SHR,UNIT=,VOL=SRK

II-96
TAPE TO DISK (TTD)

The program TTD is an Assembler routine that copies the digitized depth data from magnetic tape to disk. A listing of the JCL and source deck follows this brief description of how to use the program.

The //GO.INTAPE card specifies the tape volume to be stored. The ????? in the VOL=SER=????? parameter is replaced by the number on the tape reel. For example, if the number were CRD26, the parameter will be VOLUME=SER=CRD26.

The //GO.OUTTAPE specifies the output data set name, under which the depth data is to be stored. See JCL Considerations for rules on coding the data set names (DSN).
LISTING OF TTD (TAPE TO DISK)

//TTD JOB N3100138,TTD,TIME=(9,9),  
// USER=N310013,PASSWORD=CRD  
//STP1 EXEC ASMFCLG  
//ASM.SYSIN DD *  
COPY START 0  
R15 EQU 15  
R14 EQU 14  
R13 EQU 13  
R12 EQU 12  
R11 EQU 11  
R10 EQU 10  
R9 EQU 9  
R8 EQU 8  
R7 EQU 7  
BEGIN STM R14,R12,12(R13)  
LR R12,R15  
USING BEGIN,R12  
B ARD  
SAVEA DS 18F  
ARD LA R11,SAVEA  
ST R11,8(R13)  
ST R13,4(R11)  
LR R13,R11  
L R11,=A(TAPEIN-1024)  
USING TAPEIN-1024,R11  
OPEN (TAPEIN,INPUT,TAPEOUT,OUTPUT)  
LOOP EQU *  
GET TAPEIN,RECORD  
PUT TAPEOUT,RECORD  
L R3s=F*4096*  
LA R4*RECORD  
LOOP1 EQU *  
CLI 0(R4),C*F*  
BE EOF  
LA R4+1(R4)  
BCT R3,LOOP1  
B LOOP  
EOF EQU *  
PUT TAPEOUT,RECORD  
CLOSE (TAPEIN,TAPEOUT)  
L R13,4(R13)  
LM R14,R12,12(R13)  
RR R14  
LTORG  
RECORD DS 4096C  
TAPEIN DCR DSORG=PS,MACHF=GM,DDNAME=INTAPE,LRECL=4096,BLKSIZ=4096,X  
RECFM=F,EODAD=EOF,BUFNO=1  
TAPEOUT DCR DSORG=PS,MACHF=PM,DDNAME=OUTTAPE,LRECL=4096,
BLKSIZE=4096,RECFM=F

END BEGIN

//GO.SYSDUMP DD SYSOUT=A
//GO.INTAPE DD DSN=SJC,UNIT=TAPE,DISP=OLD,VOLUME=SER=?????,
// DCB=(BLKSIZE=4096,RECFM=F,EROPT=ACC,BUFNO=1),LABEL=(1,RLP)
//GO.OUTTAPE DD DSN=N310013.EXAMPLE,DISP=(NEW,CATLG,DELETE),
// UNIT=3330V,MSVGP=USCP,SPACE=(THK,(5,2),HLSL),
// DCB=(BLKSIZE=4096,RECFM=F)
LISTING DIGITIZED DATA (DIGCOPY)

A listing of the digitized depth information can be printed from disk by the Assembler program DIGCOPY. This is an easy means of verifying the digitized data by comparing the printed X,Y coordinates and the corresponding depths with the depths on the hydrographic chart.

The data set name referred to in the //GO.TAPE card (third from the last card) is the same data set name used in the //GO.OUTTAPE card in the TTD program previously described. (This program, DIGCOPY, and TTD were written by Jim Crabtree to aid in transferring data and in error checking.)
LISTING OF DIGCOPY (DIGITIZED TAPE)

//DIGCOPY JOB (N310013R,9),DIGCOPY,TIME=(9),MSGLEVEL=(1,1),
// USER=N310013, PASSWORD=CRO
//STEP1 EXEC ASMFCGL6
//ASM.SYSIN DD *
PRINT NOGEN
DISPLAY START 0
R0 EQU 0
R1 EQU 1
R2 EQU 2
R3 EQU 3
R4 EQU 4
R5 EQU 5
R6 EQU 6
R7 EQU 7
R8 EQU 8
R9 EQU 9
R10 EQU 10
R11 EQU 11
R12 EQU 12
R13 EQU 13
R14 EQU 14
R15 EQU 15
BEGIN STM R14,R12+12(R13)
LR R12,R15
USING BEGIN,R12,R11
L R11,BASE2
B ARD
ASAVE DS 18F
BASE2 DC A(BEGIN+4096)
ARD EQU *
LA R10,ASAVE
ST R10+8(R13)
ST R13,ASAVE+4
LR R13+R10
LA R7+1
OPEN (TAPEIN,INPUT,PRINTER,OUTPUT)
SR R3,R3
LA R5+LINE+10
BAL R10+HEADER
LOOP EQU *
* * GET TAPE RECORD
* * GET TAPEIN+TAPE
* LA R9+TAPE
START SCAN

LA R8, 4095
LA R8, 1(R8)

ALOOP EQU *
CLI 0(R9), C'0'
BL NOTNUM
CLI 0(R9), C'9'
BH NOTNUM

TM EX, X'FF'
BO ARD2
B ARD1

* TEST FOR ALPHA

NOTNUM EQU *
CLI 0(R9), C'Z'
BH SPECERR
CLI 0(R9), C'S'
BL SPEC
B ALPHA

SPEC EQU *
CLI 0(R9), C'H'
BH SPECERR
CLI 0(R9), C'J'
BL SPEC1
B ALPHA

SPEC1 EQU *
CLI 0(R9), C'A'
BL SPEC2
CLI 0(R9), C'I'
BH SPECERR
B ALPHA

* TEST FOR SPECIAL CHARACTERS

SPEC2 EQU *
CLI 0(R9), C'/'
BE ALPHA
CLI 0(R9), C'-'^
BE MOVEXY
CLI 0(R9), C'*'
BE ALPHA
CLI 0(R9), C'*'
BE MOVEXY
CLI 0(R9), C'.'
BE ARD2

* SLASH
* MINUS
* ASTERICK
* PLUS
MOVEXY EQU *
    MVI EX*X*00
    TM ALP*X*FF
    BZ MOVEXY1
    C R5=A(LINE+10)
    BE MOVEXY1
    LA R3,1(R3)
    BAL R6,WRITER

MOVEXY1 EQU *
    MVI ALP*X*00
    CLI XY*C*X
    BNE Y
    LA R3,1(R3)
    MVI XY*C*Y
    LA R4+LINE+130
    SR R4+R5
    C R4=F*12
    BH ARD2
    BCTR R3+0
    BAL R6,WRITER
    LA R3,1(R3)
    B ARD2

ARD1 EQU *
    TM ALP*X*FF
    BZ ARD2
    LA R3,1(R3)
    MVI EX*X*FF

ARD2 EQU *
    MVC 0(R5)+0(R9)
    LA R5,1(R5)
    LA R9,1(R9)
    R TEST

Y EQU *
    MVI XY*C*X
    B ARD2

ALPHA EQU *
    MVI EX*X*00
    MVI ALP*X*FF
    C R5=A(LINE+10)
    BE ALPHA1
    BAL R6,WRITER

ALPHA1 EQU *
    LA R3,1(R3)
    MVC 0(R5)+0(R9)
    BAL R6,WRITER
    CLI 0(R9)+C*X
    BE CLOSE
    LA R9,1(R9)
    MVI XY*C*X

END TEST

CLOSE

11-103
TEST EQU *
C R5=A(LINE+130) * LINE EXCEEDED
BL TEST1 * NO
BAL R6=WRITER * YES

TEST1 EQU *
BCT R8=ALOOP
MVI XY=C'X'
B LOOP

HEADER EQU *
MVI PLINE,C'1'
MVI LINE,C'0'
MVC LINE+1(131)*LINE
MVC LINE+10(26)*=CL26*CHARACTER DISPLAY OF TAPE
MVC LINE+100(4)*=CL4*PAGE
MVC LINE+104(4)*=XL4*40202120
ED LINE+104(4)*PAGECT
AP PAGECT,*P*1'
PUT PRINTER,PLINE
MVI PLINE,C'0'
MVC LINE(132)*PLINE
MVC LINE(116)*HEAD
PUT PRINTER,PLINE
ZAP LINECT,*P*3'
MVI PLINE,C'0'
MVI LINE,C'0'
MVC LINE+1(131)*LINE
BR R10

SPECERR EQU * * UNSPECIFIED CHARACTER
CLI O(R4)*X'00'
BE TEST1 * BLOCK FILLER
BAL R6=WRITER
MVC LINE(5)*=CL5****
BAL R6=WRITER
TRT 0(1,R9)*TAB1
BZ ALPHA
MVC BYTES(2)*=XL2'0000'
MVZ BYTE1=0(R9)
MVN BYTE2=0(R9)
PACK BYTE1-BYTE1
TR BYTES(2)*TAB2
MVC LINE+10(2)*BYTES
MVC LINE+14(31)*=CL31'(UNIDENTIFIED CHARACTER IN HEX)
BAL R6=WRITER
LA R9=1(R9)
B TEST1

WRITER EQU *
CLC LINE(5)*=CL5****
BE W1
MVC LINE(8)*=XL8*40202020202120
CVD R7=0000B
ED  LINE(8)*DOUB*4
AR  R7,R3
W1  EQU *
PUT  PRINTER,PLINE
MVI  PLINE,C
MVC  LINE(132)*,PLINE
AP  LINECT=*P'1
CP  LINECT=*P*60
BL  WRITER1
BAL  R10*HEADER
WRITER1 EQU *
LA  R5,LINE+10
SR  R3,R3
BR  R6
CLOSE  EQU *
      CLOSE (TAPEIN,,PRINTER)
      L  R13,ASAVE+4
      LM  R14,R12,12(R13)
      BR  R14
LTORG
DOUB  DS  D
TAPE  DS  4096C
XY  DC  C'X'
PLINE  DS  C
LINE  DS  CL132
HEAD  DC  CL49*RECORD # X Y X Y X Y X Y
      DC  CL48*X Y X Y X Y X Y
      DC  CL19*X Y X Y
PAGECT  DC  PL2*1
LINECT  DC  PL2*0
BYTES  DS  OCL2
BYTEE1  DC  X*00
BYTEE2  DC  X*00
EX  DC  X*00
ALP  DC  X*00
TAB2  DC  CL16*0123456789ABCDEF
TAB1  DC  256X*FF
      ORG  TAB1*74
      DC  XL7*000000000000000
      ORG  TAB1*90
      DC  XL8*000000000000000
      ORG  TAB1*107
      DC  XL5*0000000000
      ORG  TAB1*122
      DC  XL6*00000000000000
      ORG  TAB1*193
      DC  XL9*000000000000000
      ORG  TAB1*209
      DC  XL9*000000000000000
      ORG  TAB1*226
DC XL8'00000000000000000*
ORG TAB1+240
DC XL10'0000000000000000000*
ORG TAB1+256
PRINTER DCR DSORG=PS, DDNAME=LINES, LRECL=133, BLKSIZE=133, RECFM=FA,
MACRF=PM
TAPEIN DCR DSORG=PS, DDNAME=TAPE, LRECL=4096, BLKSIZE=4096, RECFM=F,
EODAD=CLOSE, MACRF=GM
END BEGIN

GO.LINES DD SYSOUT=A
GO.SYSUDUMP DD SYSOUT=A
GO.TAPE DD DSN=N310013.EXAMPLE, DISP=SHR

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