CHAPTER 41

COMPUTER EVALUATION OF LITTORAL TRANSPORT

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ABSTRACT

Hindcast deepwater wave statistics and bottom hydrographic data are combined with a water-wave refraction analysis to estimate the littoral transport in a beach zone. The effects of hindcast data station location, of wave ray density in the breaker zone, of changes in the bottom-fitting surface in the depth calculation of the refraction analysis, and of methods of smoothing the contribution of individual rays to the littoral transport computation are explored.

INTRODUCTION

Dobson (1967) at Stanford developed and verified a simple and theoretically sound computer program for water wave refraction. This paper summarizes the evolution of the Stanford refraction program into the area of littoral transport.

There is now a body of rational theory and systematic experiments that show a definite and causal relationship between alongshore power and littoral transport. Most recently these relationships have been documented by Galvin (1972), Komar and Inman (1970) and Longuet-Higgins (1972). In addition, offshore wave energy can be evaluated in terms of hindcast data over the region that covers the source of the waves. When the hindcast data and the relationship between alongshore power and sand transport are brought together with computer programs for wave refraction and a systematic evaluation of alongshore power, the engineer has the tools necessary for the development of design data and rational decision making. Mogel, Street and Perry (1970) provided the first computer based analysis utilizing the above concepts. In the intervening years the empirical relationship between alongshore power and sand transport has been given a rational theoretical basis and the Stanford programs have been refined and improved.

THE COMPUTATION

Figure 1 is a flow chart of the computation process. First a refraction analysis (Mogel et al. 1970) is made of all applicable periods and directions. The refraction is done over two grids of hydrographic data. The OUTER GRID is used to bring waves from deep water where they are not refracting. It is represented by still water depths specified at

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the intersections of two sets of mutually perpendicular, equally spaced lines. The grid spacing is made large to speed computation. The INNER GRID is used to give the detail necessary to accurately represent the coastal zone. The inputs to the OUTER analysis are a grid of hydrographic data, wave ray starting cards and program control parameters. The refraction program uses a least square surface fit on the depth data to compute the depth and derivatives necessary for the computations. The spacing of the wave rays is chosen to give adequate coverage of the beach zone. The OUTER analysis produces a set of wave ray starting cards for the INNER analysis. The INNER GRID computation, like the OUTER has as inputs a grid of hydrographic data, the above mentioned wave ray starting cards and program control parameters. The output of the INNER computation is a set of wave breaking statistics giving the parameters of each of the deep water waves when they break. The criteria used for breaking is when $H/d > 0.78$.

The wave breaking data are used as an input to the alongshore power -- littoral transport computation step. Also used are hindcast data giving month by month deep water statistics on height, direction, period, and average frequency. The hindcast data used were compiled by National Marine Consultants Inc. (1960) using meteorological records and charts along the California coast for the years 1956, 1957, and 1958.

The other inputs needed are the coordinates of the locations in the beach zone where sand transport data are needed. The output is a set of month by month and yearly tables of alongshore energy and littoral transport.

Figure 2 shows a section of the Northern California coast where computations were made. The boxed areas around Trinidad Head show the INNER and OUTER computation grids. The Southeast corner of each grid is used as the origin. All results are presented in terms of grid units. The computations were part of a study to determine the effect of damming the Mad River, located between Trinidad Head and Cape Mendocino, and removing a source of beach material. Station 1 and Station 2 are two of the National Marine Consultants' hindcast stations. The directional histograms show the annual deep water wave energy. As can be seen, Station 1 has considerably more energy from the North and West than Station 2. The interpolated station is derived from Stations 1 and 2 by assuming the waves originate at the intersection of a line connecting the two stations and a line from the computation zone at the heading of the particular wave direction. The energy value used is then computed by interpolation based on the two lengths. For example, point A is considered the origin of waves traveling Northeast.

Figure 3 shows the effect of the three hindcast stations on the annual net littoral transport. The horizontal axis shows the North-South location and the vertical axis the potential sand transport with positive Northern transport. As expected from the energy diagram, Station 1 produces more Northerly transport than Station 2 and the interpolated station produces transport between the two. The interpolated station is used henceforth. These computations were done with a least squares quadratic surface fit over 12 grid points in the refraction program and by fitting a parabola through the contribution of each wave in the four rays nearest the transport computation point. The curves are rather rough with large influences from individual wave rays.

Figure 4 shows transport calculations made using a 24 point least squares, cubic-surface fit in the depth computation and the six nearest rays for the transport calculations. The cubic surface in the depth calculation allows the second derivatives to vary over a computation grid. These are used to compute refraction coefficients. The variable second derivatives lead to a smoother variation of the refraction coefficient with changes in wave ray location.

In Figure 4 the upper curve is the gross transport obtained by summing the absolute value of the individual ray contributions. The solid lower curve is the net transport. The dashed curve is the result of doubling the ray density. The wide variation indicates more refinement may be necessary.

Figure 5 shows a ray by ray computation of the energy factor for West - 11 sec waves with deep water height of 20 ft. The circular points are the rays added when the ray density was doubled. The dashed line shows the energy factor calculated by fitting a parabola to the nearest six rays considering all rays; the dotted line shows the energy factor calculated by fitting a parabola through the nearest six rays considering half of the rays. The large variations of the energy factor here show the reason for the large variations of littoral transport seen in Figure 4. The solid curve is based on the average of the six nearest rays. The fit using the six ray average seems to be more representative. The large variations in the individual rays are a result of the roughness of the depth data used in the refraction analysis. Fitting a parabola through these energy factor values only accentuates the roughness.

Figure 6 shows the gross and net transport using the six ray average. It may be interesting to note that the average transport is about 10% of the gross transport and that the variations are about 5% of the gross.

Figure 7 shows, as an example, the distribution of wave rays along the coast for SW - 11 sec waves. Such a set of rays is required for each period and direction for which significant energy exists in the hindcast data.

CONCLUSIONS

We have developed a tool to help the engineer make decisions on the effects on coastal areas caused by large scale engineering projects. The major weakness in the method is the relationship between alongshore power and littoral transport. However, qualitatively when the alongshore power is Northerly, the sand will move North also. The actual littoral transport could be calibrated for a given area by comparing a sample of measured transports against calculated and adjusting the computations accordingly. We feel that the quality of the hindcast data can have large effects on the quality of the results as well (Mogel and Street, 1974).

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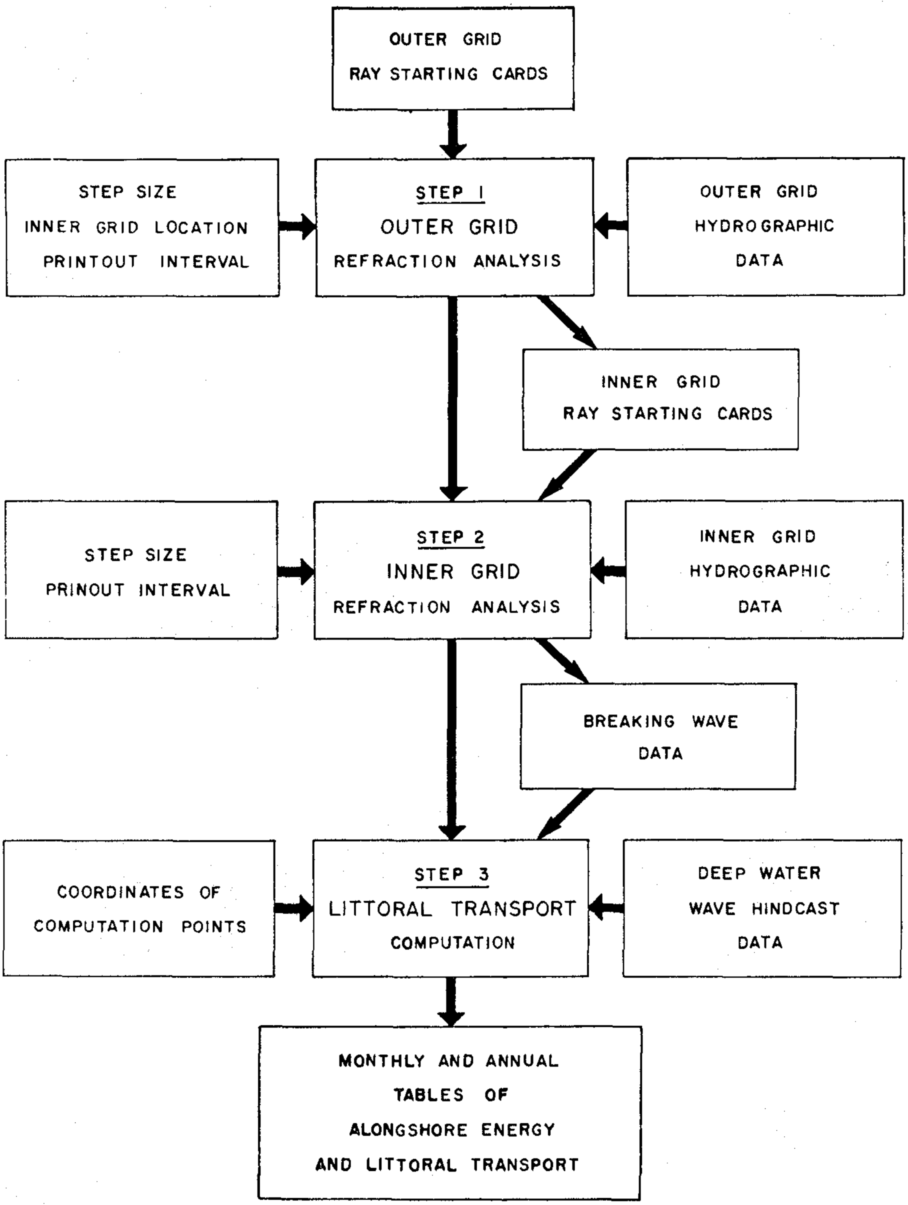
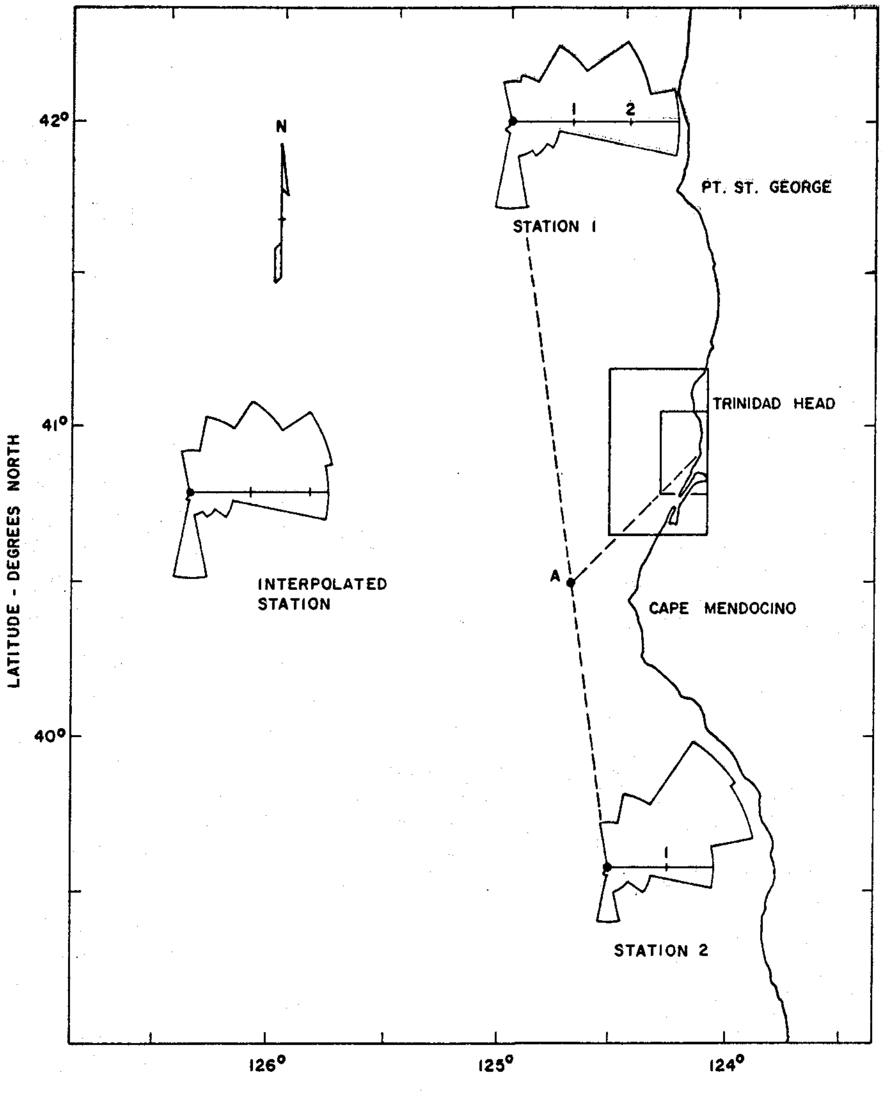


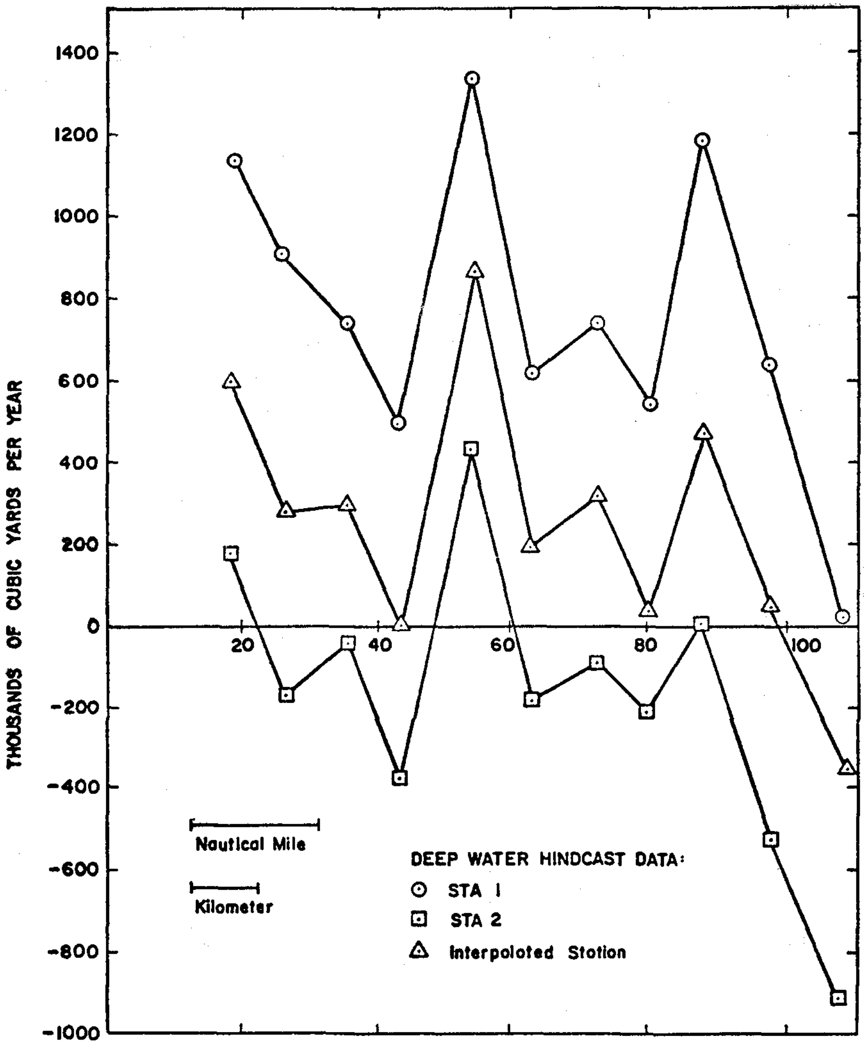
COMPUTATION FLOW CHART

FIGURE 1



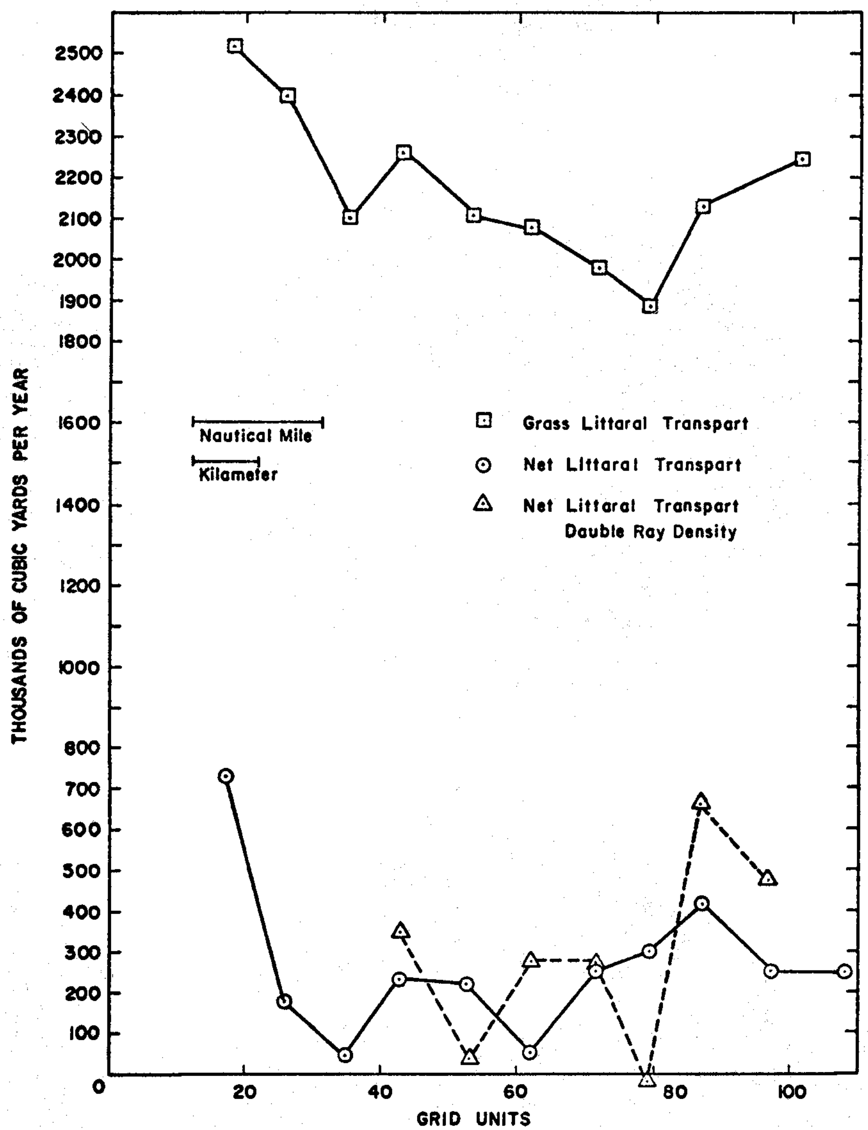
POLAR HISTOGRAMS OF ANNUAL DEEP WATER WAVE ENERGY IN 10^7 FT-LBS PER YEAR

FIGURE 2



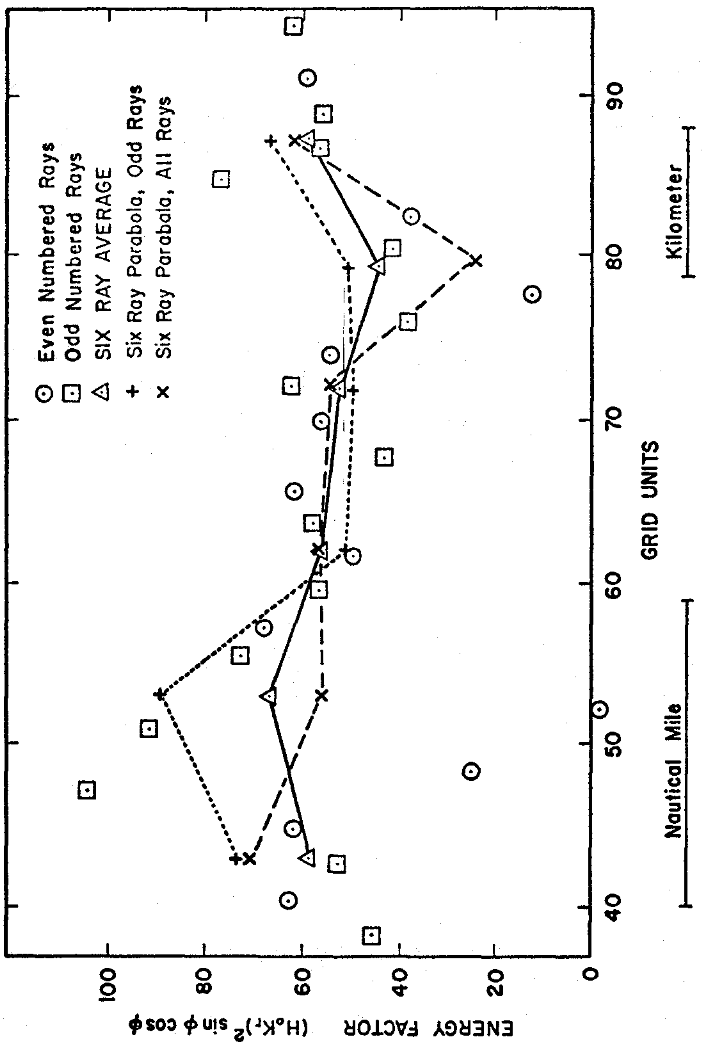
Littoral Transport Using 12 Point Quadratic Surface in Refraction Program, Parabola through 4 Nearest Rays.

FIGURE 3



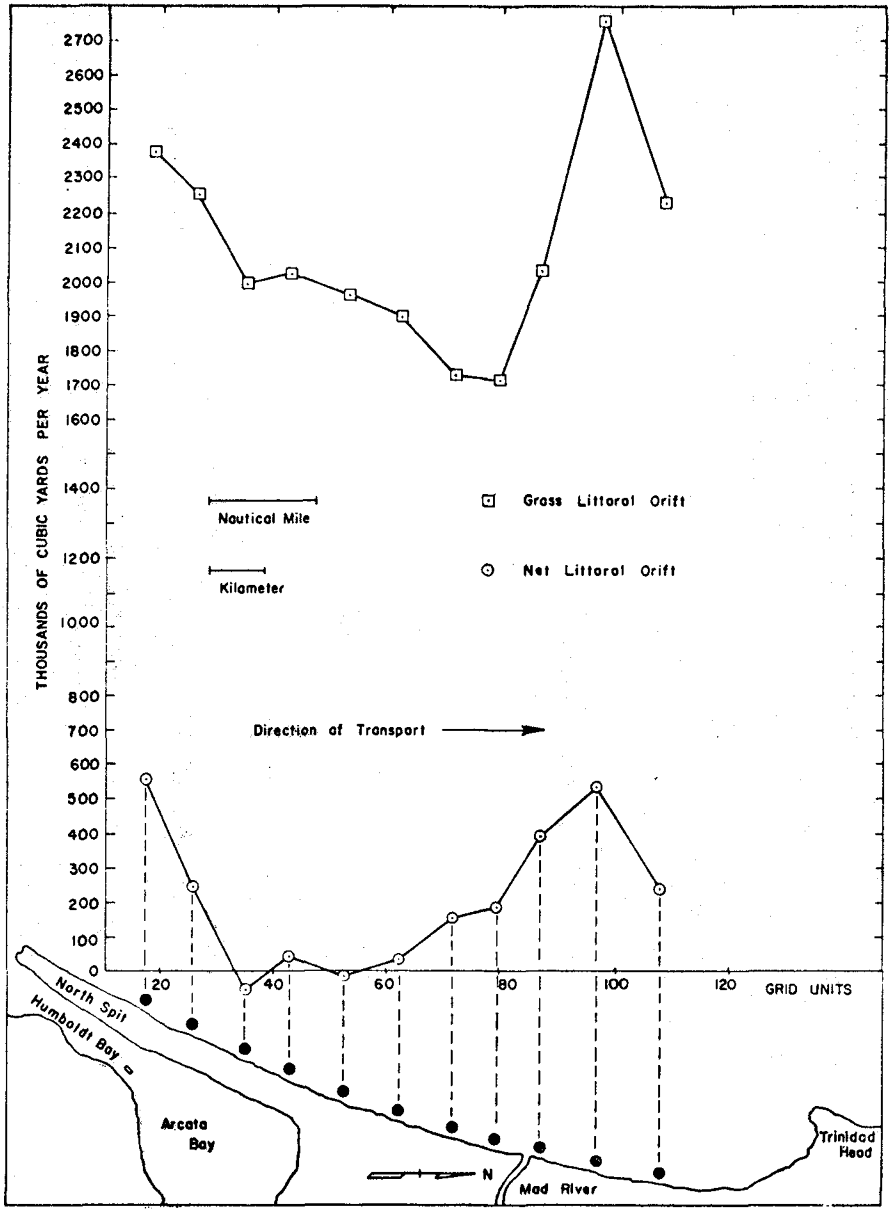
Littoral Transport Using 24 Point Cubic Surface In Refraction Program, Parabola through 6 Nearest Rays.

FIGURE 4



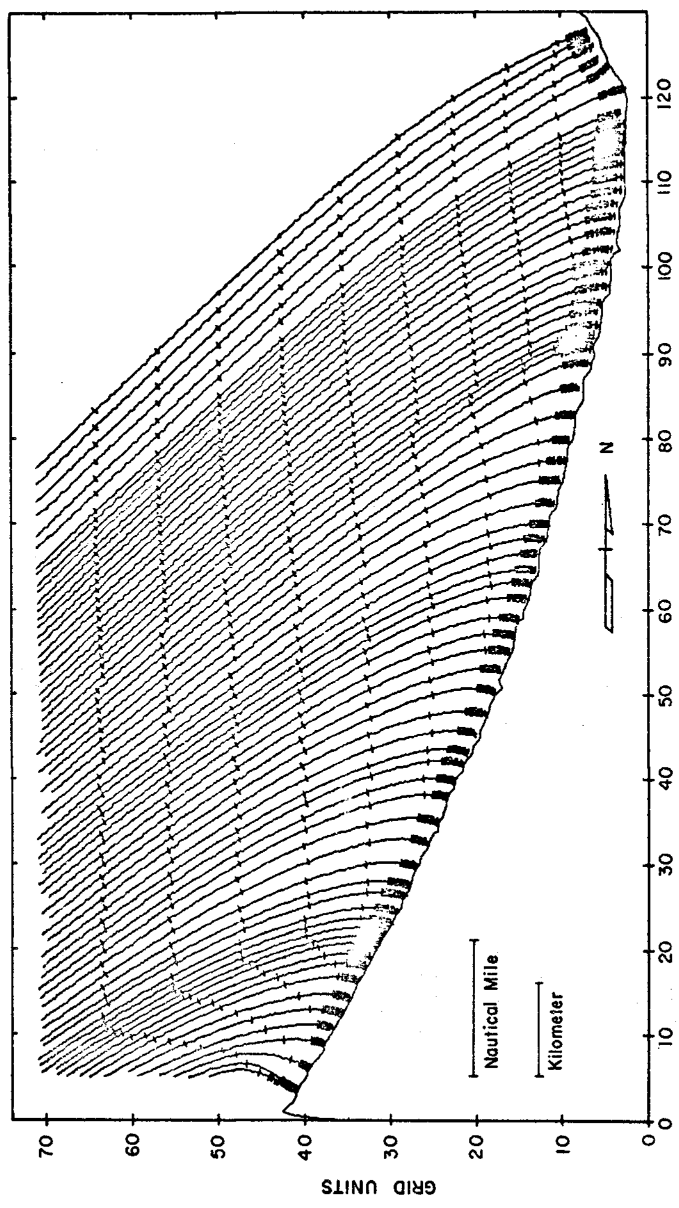
ENERGY FACTOR FOR WEST - 11 SEC
Breaking Waves with H_o = 20 feet.

FIGURE 5



Littoral Transport Using 24 Point Cubic Surface In Refraction Program, Average of 6 Nearest Rays.

FIGURE 6



GRID UNITS
INNER GRID REFRACTION DIAGRAM, SW - 11 SEC

FIGURE 7