COMPARISON OF NUMERICAL AND HYDRAULIC OCEANOGRAPHIC PREDICTION MODELS

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THESIS

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OCEANOGRAPHIC PREDICTION MODELS

by

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Comparison of Numerical and Hydraulic

Oceanographic Prediction Models

by

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ABSTRACT

The Hydro-Numerical Prediction Model developed by Hansen is applied to San Diego Bay, and the results compared both with the hydraulic model and the real data obtained by field measurements. This allows one of the few good comparisons between numerical and hydraulic models for the prediction of actual conditions.

The bay was divided into two sections that were run separately in order to obtain the desirable spatial resolution. This division required solving the problems of proper tuning and matching techniques between both portions. The solution involved the addition of an appended pseudo-bay to the first section of the model in order to compensate for the correct tidal prism. The effects of a proposed second open entrance in the southern part of the bay were studied. This resulted in an increase of flushing in the southern portion of the bay but caused the currents in the center of the bay to be small which decreased dispersion in the central portion of the bay. In general, both models produced similar and reliable results, but there was a considerable reduction of cost and time with the numerical model.

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TABLE OF SYMBOLS AND ABBREVIATIONS

C	Phase wave speed
C_m	Velocity in the model
C_p	Velocity in the prototype
d	Total difference
F	Friction force
f	Coriolis parameter
F_r	Froude number
g	Acceleration of gravity
g_m	Gravity in the model
g_p	Gravity in the prototype
H	Total depth $(h + \eta)$
h	Depth of the water at mean sea level
h_m	Depth in the model
h_p	Depth in the prototype
HTU HTV	Depth at U and V grid points
HTZ	Depth at Z grid points
J	Dimensionalless constant
K	Coefficient of horizontal kinematic eddy viscosity
$\vec{k}$	Vertical unit vector
km	Kilometer
L	Characteristic length
L_m	Characteristic length in the model
L_p	Characteristic length in the prototype

ℓ	Length of mesh
M,N	Grid co-ordinates (also m,n)
m	Meter
cm	Centimeter
MEH NEH	Near border grid points
p	Hydrostatic pressure
R	Bottom roughness coefficient
R_g	Gravity ratio. Gravity scale
R_c	Velocity ratio. Velocity scale
R_h	Depth ratio. Vertical scale
R_L	Length ratio. Horizontal scale
R_t	Time ratio. Time scale
R_{vd}	Discharge ratio. Discharge scale
R_v	Volume ratio. Volume scale
r	Coefficient of friction
t	Time
u,v	Components of horizontal velocity
$\vec{V}$	Total velocity vector
V_c	Characteristic velocity
$\overline{V},\overline{U}$	Mean u and v components
$W_{(\ )}$	Wind speed component
X,Y	Space co-ordinates
Z,U,V	Grid points
α	Smoothing parameter
β	$1 - \alpha$

δ	Partial difference
γ	Specific weight
λ	Drag coefficient
η	Sea level anomaly
ρ	Density of the fluid
τ	Wind stress
$\vec{\Omega}$	Earth angular velocity
∇	$\frac{\partial}{\partial x} + \frac{\partial}{\partial y}$
τ^b	Bottom stress
Δ	Difference

ACKNOWLEDGEMENTS

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I. INTRODUCTION

A. REVIEW

The study of bays, estuaries and other semi-restricted areas is difficult because these masses of water are subject to constant movement with short time irregular periodicities. The important mechanism driving the circulation in these areas generally is the tide. The water is partially renewed and mixed during each tidal cycle due to the interchange of water between such areas and the ocean. The shape and depth of the area governs the direction and speed of the currents generated during this interchange. The constant flow of water causes a constant state of non-equilibrium of constituents, temperature and potential energy inside the bays or estuaries.

The study of such areas by field observations is extremely laborious requiring large expenditures of manpower and money. Another approach to the solution of the problem is to reproduce the physical characteristics of these areas by the use of hydraulic models. Hydraulic models have been used for many decades and have proven to be a reliable method for studying an area although space and operating problems make them a relatively expensive tool of investigation.

With the advent of high speed computers, the numerical solution of the differential equations used to describe

flow was made possible. Oceans, seas, gulfs and other water masses have been described by the use of this technique. It transforms a physical model into a program which can be modified to simulate different conditions more easily, can be stored for future uses and alterations, is faster and allows solutions to be obtained at reasonable cost.

The U. S. Army Corps of Engineers made a study of San Diego Bay by means of a hydraulic model based on field measurements made in early 1967. The results have been reported in a Technical Report [10] and published in a paper [1] by the U. S. Corps of Engineers.

The Hydro-Numerical Prediction Model developed by Hansen is applied to San Diego Bay, and the results compared both with the hydraulic model and the data obtained by field measurements. This allows one of the few good comparisons between numerical and hydraulic models for the prediction of actual conditions.

B. OBJECTIVES

The objective of this thesis is to reproduce by means of the Hansen hydrodynamic-numerical model the existing conditions in San Diego Bay and compare them with conditions produced in the hydraulic model operated by the U. S. Corps of Engineers. This comparison will result in a proper evaluation of the merits and limitations of both models.

The division of the bay into two separate models is attempted in order to obtain comparable resolution in the numerical model. This division requires solving problems in the method of running numerical models in series and of transfering boundary conditions from one section to another.

II. HYDRAULIC MODEL OF SAN DIEGO BAY

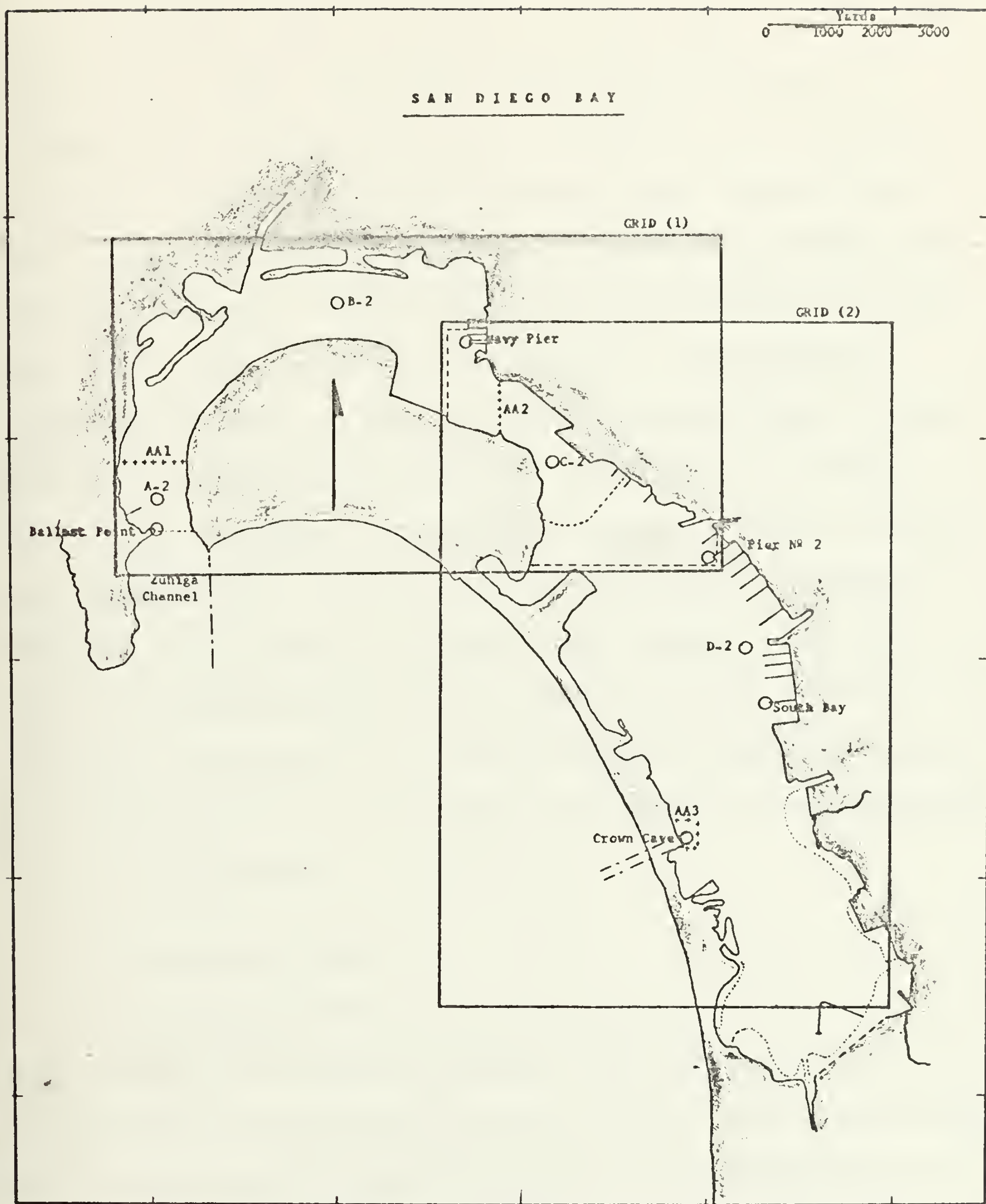
A. DESCRIPTION OF SAN DIEGO BAY

San Diego Bay is located on the southern coast of California, U.S.A. The bay is long, curved, has an area of approximately 90 sq. km. and a maximum width of 3.1 km. [Fig. 1]. It is connected with the ocean by the narrow Zuniga Channel at its northern end.

The inflow of fresh water can be considered negligible except during local heavy rainfall. The circulation of the entire bay is driven by the tide at its unique entrance. The tidal circulation can be perturbed by local wind conditions.

The tide is of the mixed type with a period of 24.83 hours and maximum range of about 1.89 meters. Field measurements indicate that tidal variations become larger in the bay increasing to 1.98 meters at the center portion of the bay and 2.1 meters near the southern end. Currents have a maximum speed of about 0.7 meters/second in Zuiga Channel.

A channel is maintained for navigation starting at Zuniga Channel and continuing throughout San Diego Bay. The channel depth is 12.8 meters below MLLW from the ocean to the vicinity of the South Bay gage. Other channels of minor importance exist in the southern portion of the bay.



Yards
0 1000 2000 3000
SAN DIEGO BAY
GRID (1)
GRID (2)
B-2
Navy Pier
AA2
AA1
A-2
C-2
Ballast Point
Zuniga
Channel
Pier Nº 2
D-2
South Bay
AA3
Crown Cove
44'
42'
32º 40'
38'
36'
14'
12'
117º 10'
08'
06'

FIGURE 1

B. PURPOSE OF THE U.S. CORPS OF ENGINEERS MODEL STUDY

The natural shape of San Diego Bay and its only entrance at the northern end, its use as a Naval Base, and the influence of a large community surrounding the Bay, have brought into consideration the construction of a second navigation entrance somewhere along Silver Strand Beach. This second entrance is expected to cause decreasing ship traffic throughout Zuniga Channel and increasing flushing rate of the Bay, possibly improving the environmental conditions within the bay. A major consideration in evaluating the overall benefits of a second entrance depend heavily on assessing the extent to which it would increase the flushing rate. These effects could not be computed reliably by the available analytical methods [10], so a physical hydraulic model of the bay, in which several suggested locations for a second entrance could be tested, was constructed to investigate the effects of each proposed location, in detail.

C. THE HYDRAULIC MODEL

The dominant forces in rivers, narrow estuaries and some lakes, are pressure gradient forces driving circulations which are opposed by friction [12]. In large scales of circulations, the opposing forces are combinations of friction and Coriolis force, or Coriolis force alone.

Similarity can be considered as being graded from geometrical through kinematic to dynamic in the attempt to

reproduce the existing conditions in a scale model. A model has geometric similarity if the ratios of all homologous dimensions are equal. The model is said to have kinematic similarity if the paths and patterns of motion are geometrically similar to those of homologous occurrences in the prototype, and the ratios of homologous velocities are equal at all times. Dynamic similarity is achieved when the ratios of homologous masses and forces affecting motion are equal at all times. Complete dynamical similarity is difficult to achieve in fluid models and, kinematic similarity, of necessity, involves elements of dynamic similarity.

The general equation of motion can be written in the form:

$$\rho\frac{d\vec{V}}{dt} = -\rho 2\vec{\Omega}x\vec{V} - \nabla p + \rho\vec{k}g + F$$

Where:

$\rho\frac{d\vec{V}}{dt}$ = inertial force

$\rho 2\vec{\Omega}x\vec{V}$ = coriolis force

∇p = pressure gradient force

$\rho\vec{k}g$ = gravity force

F = friction force

Each term of the equations of motion represents the forces present in a prototype and what is to be represented

in a model. Since the totality of forces cannot be easily reproduced in hydrodynamic models, a few important terms are usually singled out.

In scaling a model, each quantity and dimension of those particular terms of the equation of motion used to describe a flow must be reduced to the model scale. Dimensionless ratios of terms are used to achieve correct model scales. The numerical value of the dimensional ratio must be the same for the model as for the prototype for simiarity to prevail.

Several dimensionless ratios of terms are common to oceanographic modeling, and each one is used depending on the characteristics of the flow in the prototype. The Froude number is generally used in models of estuaries because it involve the ratio of inertial to gravity forces. These forces are, with friction, the dominant forces. The direction of flow is primarily down the gradient of pressure.

The Froude number is defined as:

$$Fr = \frac{\text{inertial term}}{\text{gravitational term}} = \frac{V_c}{(L\gamma/\rho)^{1/2}}$$

Where:

V_c = characteristic velocity

L = characteristic length

γ = specific weight

ρ = fluid density

As a preliminary step in scaling a phenomenon down to model size, it is useful to construct a ratio of units which by convention is:

$$R = \frac{A_m}{A_p}$$

where A_m is a number representing the dimensions of a certain property of the model and A_p the dimensions of the homologous property in the prototype.

The length ratio is fixed first in order to match the available space or equipment. The numerical value of each dimensionless group constant can be held altering the ratios of the other units included in a dimensionless group. By these procedures, time and other unit dimensions of other related properties may have to be altered to permit the fluid motion in the model to be regarded as behaving in the same physical manner as that in the prototype.

The ratio of inertial (velocity and length) and gravity is of concern for the Froude Number. Shallow-water gravity waves, such as tides, propagate at a speed $C = \sqrt{gh.}$ The velocity ratio (R_c) is satisfied using the length ratio (R_L), where

$$R_c = \frac{C_m}{C_p} = \sqrt{\frac{g_m h_m}{g_p h_p}} = \sqrt{R_g R_h} \doteq \sqrt{R_h}$$

which assumes that the gravity ratio (R_g) is one. Therefore, the length ratio and velocity ratio are left as adjustable parameters

$$R_c = \sqrt{R_h} = \frac{R_L}{R_t}$$

It can be seen from this equation that R_t shortens with increasing R_h and lengthens with increasing R_L.

A distinction between the vertical length (h) and the horizontal length (L) is often made. If the Froude model is geometrically similar to its prototype, $R_h = R_L$.

The vertical scale (R_h) generally must be chosen so that the least depth of water in which the flow is to be studied is approximately one cm. to prevent capillary effects from being important. Then, it may be necessary to depart from similarity by distorting vertical dimensions such that $R_h > R_L$. One is led to a choice of scales by a path which touches first the minimum depth requirement and then an adjustment of the R_L and R_t such that either one becomes constant, leaving the others to be adjusted. The R_t (time ratio) is usually the most flexible parameter available and determines the frequencies of the simulated tides.

The effects of wind stress on the circulation in estuaries and bays are often important and sometimes dominate the tide. To scale it in a model requires more knowledge

of the dynamics of momentum transfer across the air-sea interface than is now available. Empirical procedures must be made to suffice.

For the U.S. Corps of Engineers hydraulic model, the following characteristics and scales were used:

Area: 280 sq. km.

Horizontal scale (R_L) = 1:500

Vertical scale (R_h) = 1:100

Velocity scale (R_c) = 1:10

Time scale (R_t) = 1:50

Discharge scale (R_{vd}) = 1:500 000

Volume scale (R_v) = 1:25 000 000

Physical dimensions = 35 x 40 meters

D. RESULTS OF THE HYDRAULIC MODEL

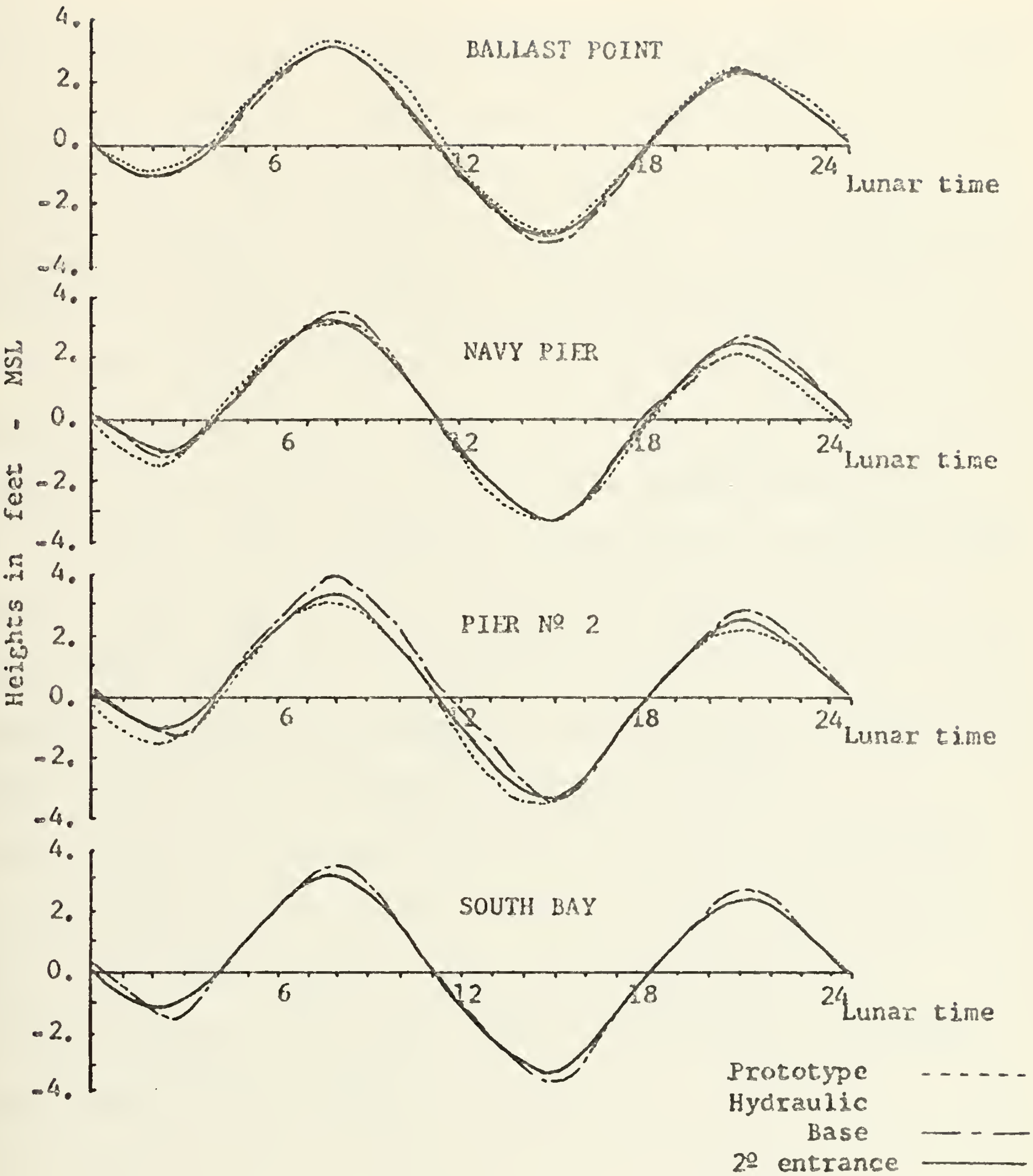
The type of flow being studied determines the predominant forces to consider for dynamic similarity. The San Diego Bay model used a Froude number scaling criteria. After determining the dynamic scaling, a hydraulic model is constructed to match the scaled geometry of the prototype. After reproducing the geometry as closely as possible, kinematic similarity must be obtained. This is accomplished by matching the hydraulic head and flow patterns at various locations in the model over the tidal cycle. This matching is generally accomplished by using roughness elements which can consist of concrete blocks or metal strips. The roughness elements have the effect of increasing turbulence and

changing mean flow patterns. This is a rather laborious and tedious procedure and usually is the most time consuming aspect of hydraulic model building. After the kinematic similarity is satisfactorily accomplished, the model is presumed to be calibrated.

Tests of existing conditions were made under carefully controlled conditions of tides, currents, and simulated pollution input [1]. The results of these calibration tests, called Base Tests, were used to evaluate the effects of navigation openings. Thus, any differences noted during the tests of the proposed second entrances were attributed to influences of the plan being tested and not to errors in the construction of the model.

The wind conditions on the day of observations can introduce large modifications to the normal surface and current characteristics in a bay such as San Diego Bay. Differences from day to day in the values of a mixed tide make a one-day observation a non-periodic function. Therefore, modifications of the field measurements were introduced in order to make them periodic and comparable to a non-wind situation.

The effects of the south entrance on tides throughout the bay are shown by comparative tide curves for measured, base and planned conditions in figure 2-1. The second entrance caused a reduction in the tide range at the southern



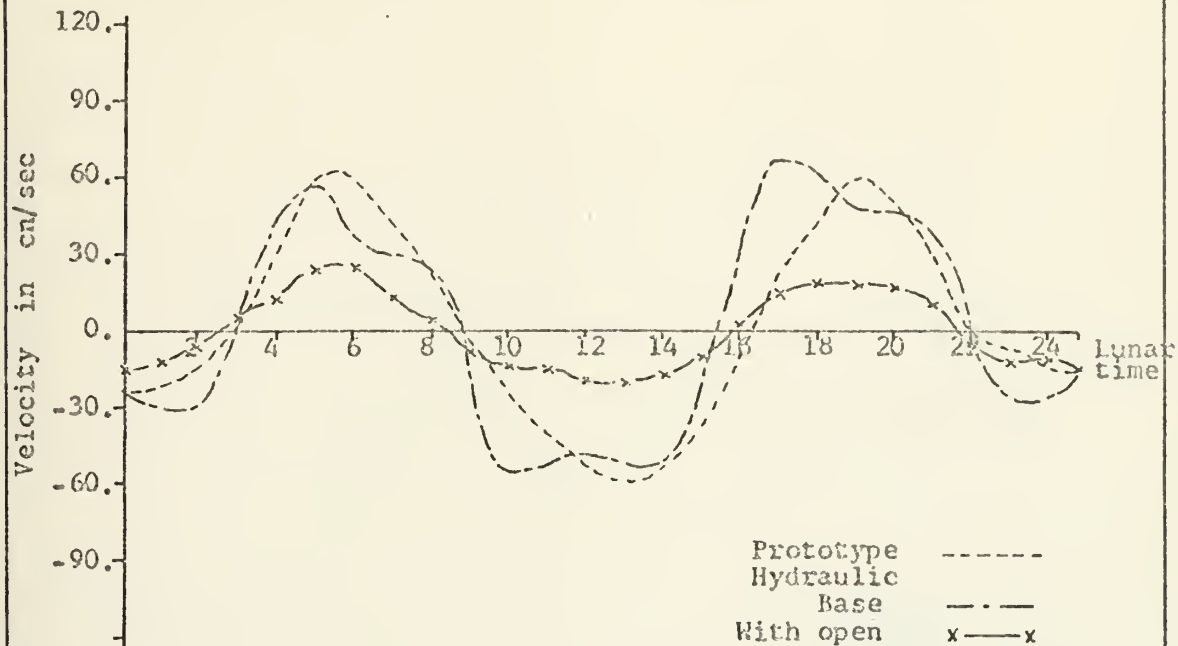
HEIGHTS IN THE PROTOTYPE AND IN
THE HYDRAULIC MODEL

FIGURE 2-1

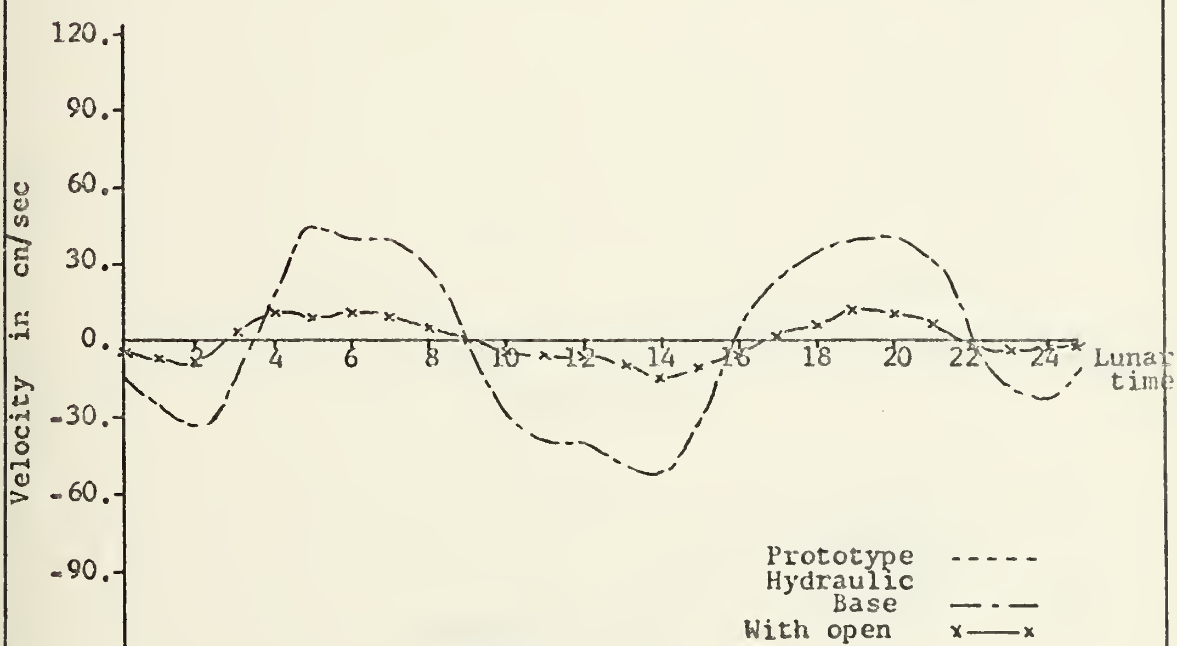
end of the bay by lowering high water and raising low water. At the south bay gage, the reduction in tide range was about 15 cm.

The effects of the second entrance on mid-depth current velocity are shown in figures 2 and 3. The opening reduced the maximum mid-depth current velocities at all stations on gauges "A" through "D" by 15 to 75 cm./sec. The flushing of the southern portion of the bay became governed by the new entrance and there seemed to be little interchange of water between the northern and southern portion of the bay with the area in the vicinity of Pier No. 2 gauge having very small currents. Under those new conditions, the entire bay appears to have two completely different circulation systems driven by tides at Zuniga Channel and at the second entrance. The flushing appears to be increased in the southern portion by including a second entrance.

The pictorial representations of the flow in the bay under both conditions [1] are shown in figures 29, 30, 36 and 37. In these figures, the flow is represented at different stages of the tide, and its intensity is scaled by the length of the lines.

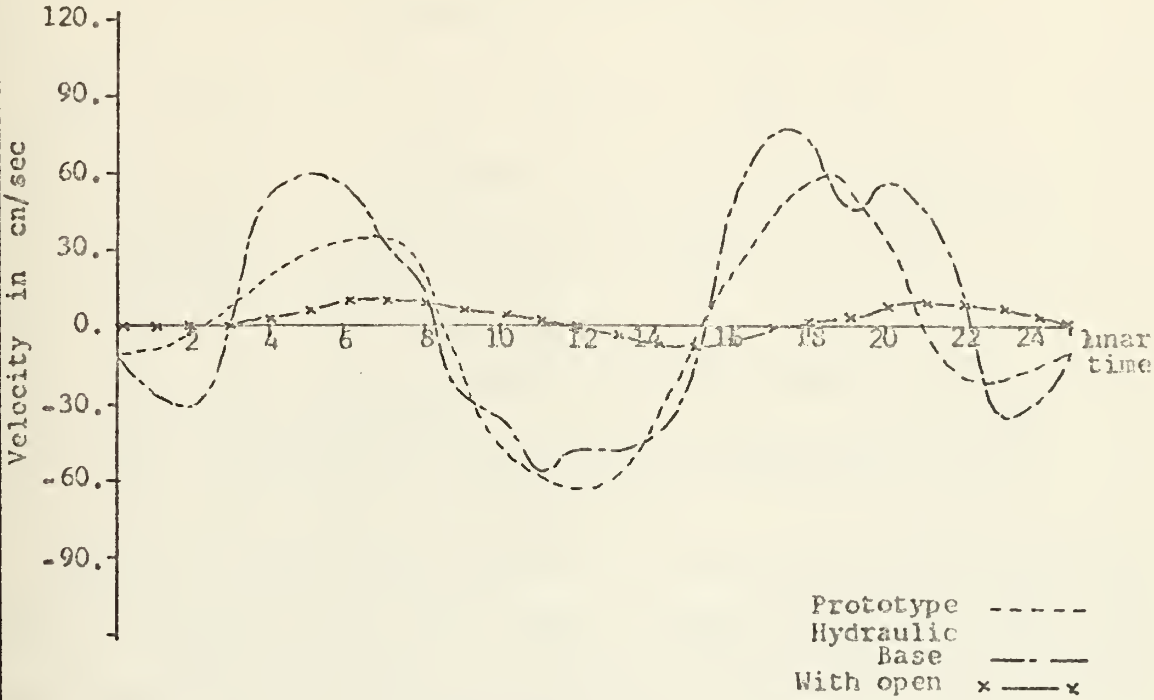


CURRENT AT A-2

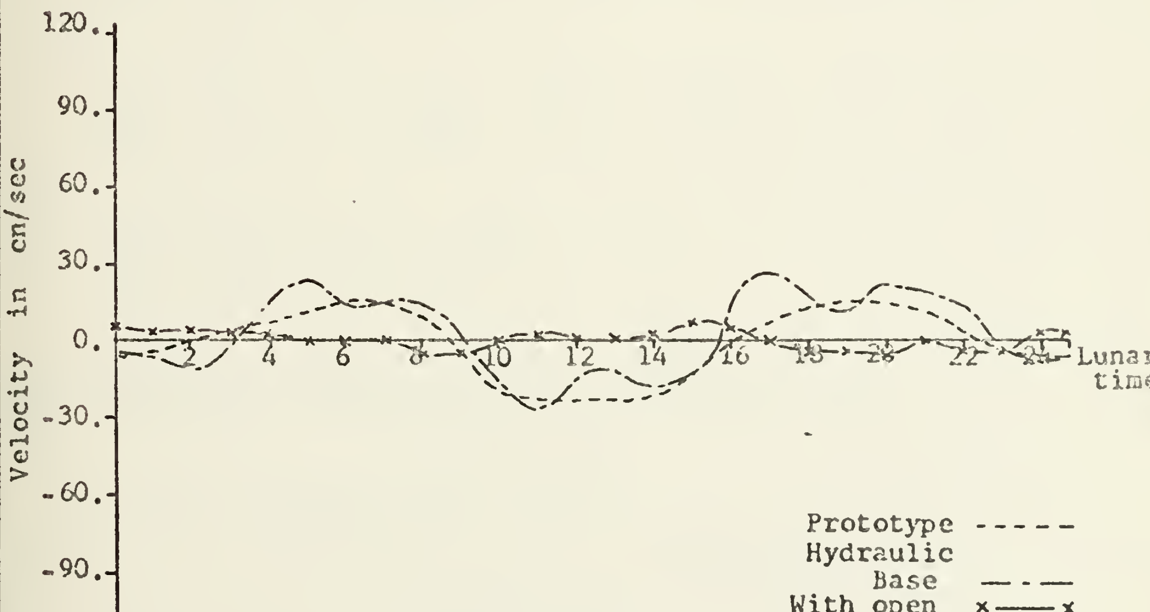


CURRENT AT B-2

FIGURE 2



CURRENT AT C-2



CURRENT AT D-2

FIGURE 3

III. THE HANSEN HYDRODYNAMICAL MODEL

The assumptions of the numerical model are:

1. The fluid is homogeneous and incompressible.
2. Pressure is hydrostatic and thus, the changes in pressure are due solely to changes in water surface elevation.
3. Advection terms are ignored.
4. The fluid is in hydrostatic equilibrium in the vertical direction.
5. The geographical and vertical variations of the Coriolis force are neglected.

Applying these assumptions to the equations of conservation of momentum and mass, basic equations are obtained for the single-layer model developed by Hansen [6]. Horizontal momentum equations are integrated over depth to give

$$\frac{\partial u}{\partial t} - fv = -g\frac{\partial \eta}{\partial x} + K\nabla^2 u - \tau^b(x) + \tau(x)$$

$$\frac{\partial v}{\partial t} + fu = -g\frac{\partial \eta}{\partial y} + K\nabla^2 v - \tau^b(y) + \tau(y)$$

$$\frac{\partial \eta}{\partial t} + \frac{\partial}{\partial x}(Hu) + \frac{\partial}{\partial y}(Hv) = 0.$$

The wind stress components are represented by

$$\tau(x) = \frac{\lambda}{H} W_x \sqrt{W_x^2 + W_y^2} ,$$

$$\tau(y) = \frac{\lambda}{H} W_y \sqrt{W_x^2 + W_y^2}$$

and the bottom stress components are represented by

$$\tau^b(x) = \frac{r}{H} u \sqrt{u^2 + v^2} \quad \text{and}$$

$$\tau^b(y) = \frac{r}{H} v \sqrt{u^2 + v^2} \quad .$$

The various terms of the equations are defined as:

K = coefficient of horizontal kinematic eddy viscosity

λ = drag coefficient

$W_{(\ )}$ = wind speed component

η = surface elevation

H = total depth = $h + \eta$

x,y = space coordinates

u,v = velocity components

g = acceleration of gravity

f = coriolis parameter

$\nabla = \frac{\partial}{\partial x} + \frac{\partial}{\partial y}$

Both the wind stress and bottom stress equations are empirically developed. The wind stress terms, as used in the model, are assumed to be a quadratic expression in wind speed, where λ is the wind drag coefficient with a typical value of 0.65. The bottom stress is assumed to be non-linearly dependent on u and v, and its formulation, like the wind stress, have been derived by empirical means. It was originally formulated for shallow water application. Over deep water, its value becomes small and its applicability is questionable.

An implicit central difference scheme is used for achieving time dependent solutions of the equations. At the boundaries, the values of η, u and v are taken at the actual points rather than from the surrounding points as shown in Figure 4.

The driving forces are tides input at the open boundaries, and wind at the surface over the entire grid. The tide values are computed at each time step and introduced as new values of η at each point of the boundaries.

The finite approximations are given below. The water surface elevations are first calculated using the conservation of mass equation.

$$\eta^{t+\frac{\Delta t}{2}}(n,m) = \eta^{t-\frac{\Delta t}{2}}(n,m) - \frac{\frac{\Delta t}{2}}{\Delta \rho}\{H_u{}^t(n,m)U^t(n,m) - H_u{}^t(n,m-1)U^t(n,m-1) + H_v{}^t(n-1,m)V^t(n-1,m) - H_v{}^t(n,m)V^t(n,m)\}$$

The horizontal and vertical velocity components are then determined from respective horizontal and vertical momentum equations.

$$U^{t+\Delta t}(n,m) = \{1 - [\Delta t\ r/Hu^{t+\Delta t}(n,m)]\sqrt{\overline{U}^t(n,m)^2+V^{*t}(n,m)}\}\overline{U}^t(n,m)$$

$$+ \Delta t\ f\ V^{*t}(n,m) - \frac{\Delta t/2g}{\Delta \ell}\{\eta^{t+\frac{\Delta t}{2}}(n,m+1)$$

$$- \eta^{t+\frac{\Delta t}{2}}(n,m)\} + \Delta t\ X^{t+\Delta t}(n,m)$$

$$V^{t+\Delta t}(n,m) = \{1 - [\Delta t\ r/Hv^{t+\frac{\Delta t}{2}}(n,m)]\sqrt{\overline{V}^t(n,m)^2+U^{(t)}(n,m)}\}\overline{V}^t(n,m)$$

$$- \Delta t\ f\ U^{*t}(n,m) - \frac{\Delta t/2g}{\Delta \ell}\{\eta^{t+\frac{\Delta t}{2}}(n,m)$$

$$- \eta^{t+\frac{\Delta t}{2}}(n+1,m)\} + \Delta t\ Y^{t+\Delta t}(n,m)$$

where

$$\overline{U}^t(n,m) = \alpha U^t(n,m) + \frac{1-\alpha}{4}\{U^t(n-1,m)+U^t(n+1,m)+U^t(n,m+1)$$
$$+U^t(n,m-1)\},$$

$$\overline{V}^t(n,m) = \alpha V^t(n,m) + \frac{1-\alpha}{4}\{V^t(n-1,m)+V^t(n+1,m)+V^t(n,m+1)$$
$$+V^t(n,m-1)\},$$

$$U^{*t}(n,m) = \frac{1}{4}\{U^t(n,m-1)+U^t(n+1,m-1)+U^t(n,m)+U^t(n+1,m)\},\ \text{and}$$

$$V^{*t}(n,m) = \frac{1}{4}\{V^t(n,m-1)+V^t(n+1,m-1)+V^t(n,m)+V^t(n+1,m)\}.$$

The factor α can be interpreted as related to the horizontal kinematic viscosity parameter. In the program it is treated as a tuning parameter and is related to the eddy viscosity coefficient by:

$$\frac{K\Delta t}{\Delta \ell^2} = \frac{1-\alpha}{4} = \frac{\beta}{4}$$

The total depth of water is calculated by:

$$Hu^{t+\Delta t}(n,m) = hu(n,m) + \frac{1}{2}\{\eta^{t+\frac{\Delta t}{2}}(n,m) + \eta^{t+\frac{\Delta t}{2}}(n,m+1)\}$$

$$Hv^{t+\Delta t}(n,m) = hv(n,m) + \frac{1}{2}\{\eta^{t+\frac{\Delta t}{2}}(n,m) + \eta^{t+\frac{\Delta t}{2}}(n,m+1)\}$$

The effects of wind are computed by:

$$X^t = \frac{\lambda\, W_x^{\,t} \sqrt{(W_x^{\,t})^2 + (W_y^{\,t})^2}}{H} - \frac{1}{\rho}\,\frac{\partial P_o}{\partial x} \qquad \text{and}$$

$$Y^t = \frac{\lambda\, W_y^{\,t} \sqrt{(W_x^{\,t})^2 + (W_y^{\,t})^2}}{H} - \frac{1}{\rho}\,\frac{\partial P_o}{\partial y} \quad .$$

where P_o is the barometric pressure. Its gradient is assumed to be zero for small areas and normal conditions.

The stability of the model is governed by the Courant-Friedrichs-Levy criterion which says that the maximum length of the time step is determined by the grid size and maximum depth in the area,

$$\Delta t \leq \frac{\ell}{\sqrt{2gH_{max}}} \quad .$$

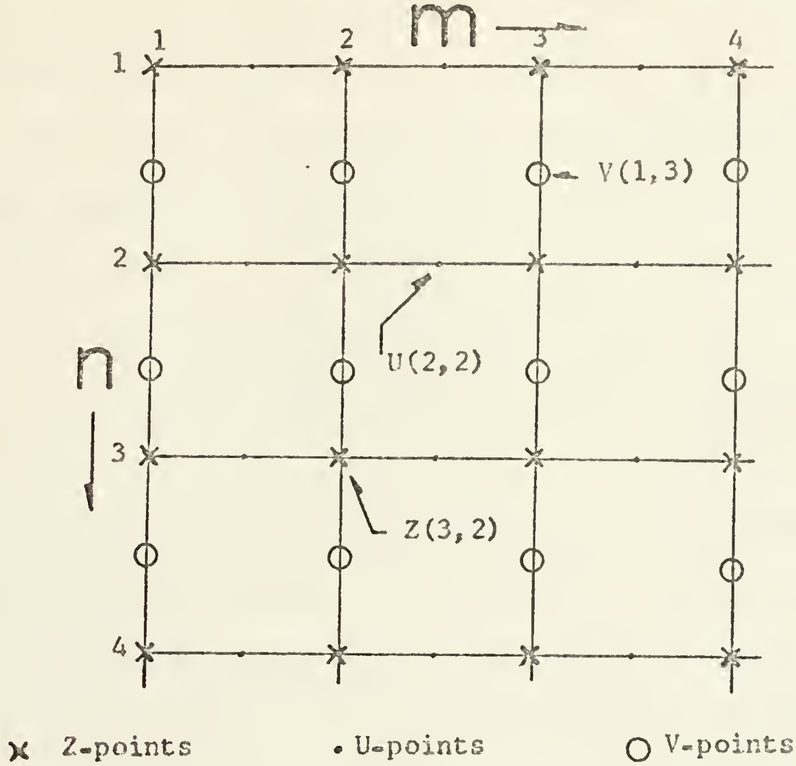
For this particular grid, a Δt (half-time step) of 5 seconds was adopted.

If the computational area contains small sections of greater depths [4], a "false bottom" can sometimes be assumed in these areas. (E.g., areas deeper than 500 meters can be assumed to be 500 meters deep.) This will often result in a considerable increase in the time step, or a decrease of the grid length if total computation time is a critical factor. Experiments have shown that the error introduced with the above procedure is acceptable in some cases for practical applications of the model.

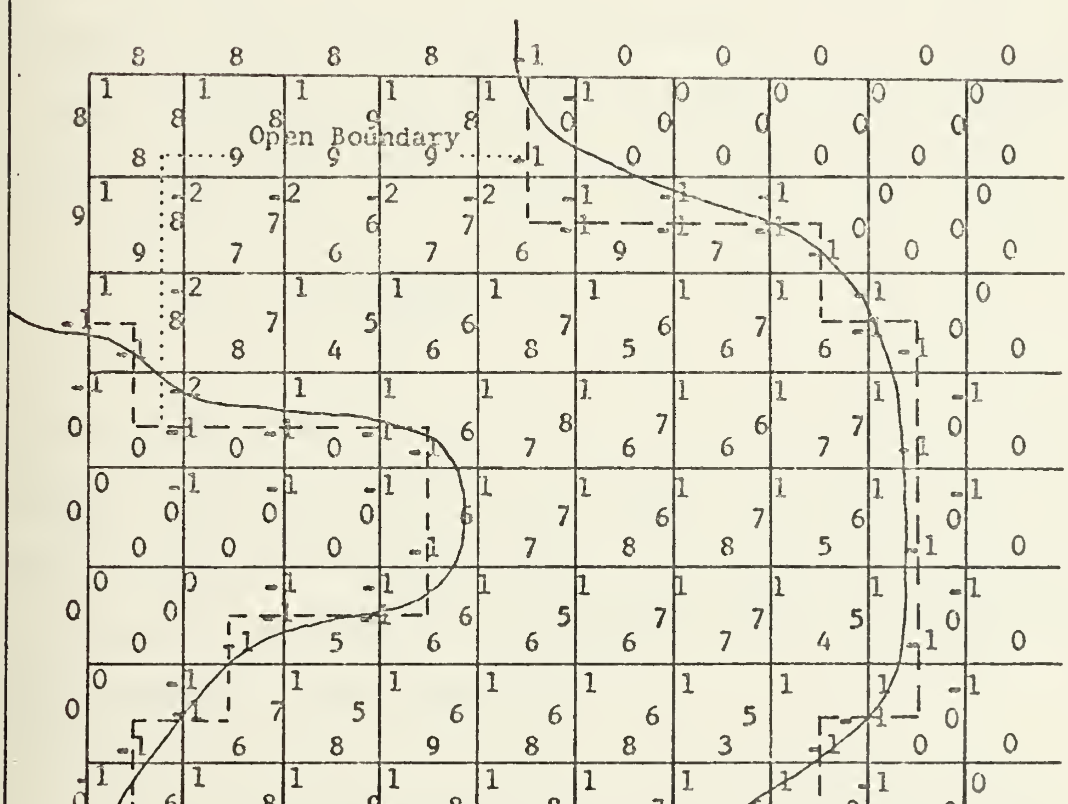
The grid net consists of three different sets of grid points shown in Figure 4-a; the water elevation (z), the u-velocity component and the v-velocity component. Each of these three points have the same coordinate designation (n,m). The coastline must pass through u and v points and not through z points and the values of depths at any of these particular points are read in the program as HTU and HTV.

The HTZ points act as water-coast-land designators having values of 1, -1, and 0 respectively. The HTU and HTV show the depth values (in cm.), the coastline as -1, and land as 0, depending on their location in the grid [Figure 4-b].

At the input open boundaries, HTZ points have values of -2 (and -3) for the first and second open boundaries (if applicable). Outside of the input boundaries, values of zero for HTZ are prescribed.



SCHEME OF THE GRID NET



COMPUTATION GRID

FIGURE 4

The coefficient of horizontal kinematic eddy viscosity is interpreted as related to the values of the u and v current components. Hansen states that the computations are always stable for values of Beta $(1-\alpha)$ larger than zero and the normal value used is 0.01. However, this coefficient can also be used as a tuning factor. If a higher value is used, the current speed is generally decreased.

In areas where the depth distribution is irregular, accelerations and surface irregularities appear in the model. This abnormality can be solved by means of a proper smoothing of the bottom or the sea surface. This is accomplished in this model by the smoothing of the sea surface elevation which is a numerical artifact of the model. This is done to insure numerical convergence.

The coefficient of horizontal kinematic eddy viscosity in the finite solution, is represented by the relation

$$K = \frac{\Delta\ell^2(1-\alpha)}{4\Delta t}$$

For the values of $\Delta\ell$(100 m), Δt(5 sec.) of this specific model, and alpha (0.992) recommended by Laevastu for estuaries (personal communication), K becomes 0.9×10^5 cm^2/sec.

Bowden [2] suggests for estuaries with a tidal current amplitude of V and a depth of h,

$$K = 0.15\ Vh$$

This relation gives a value of $K = 0.25 \times 10^5$ cm^2/sec. for the northern portion of San Diego Bay. This corresponds to an α value of 0.995. For the southern part, this equation gives a value of $K = 0.3 \times 10^4$ with a corresponding value of $\alpha = 0.999$.

The use of these high values for α must be done with caution because the low smoothing can allow undesirable oscillations in the model. If a too low value of α is used in order to obtain good smoothing, the resolution of current could be affected.

As was pointed out in the assumptions of the Hansen Model, the advection terms, $u_j \frac{\partial u_i}{\partial x_j}$ have been neglected. If a value of 50 cm/sec. (about one knot) is assumed for both u_j and u_i, and if the distance between grid points is 200 m, then, the advection terms are of the order of 10^{-2} cm/sec. A representative value of the local velocity change $\frac{\partial u_i}{\partial t}$, is calculated using a Δt of a quarter tidal cycle of 3 hours during which time the velocity changes from a maximum represented by 50 cm/sec. to zero. This term then is of the same order of magnitude as the advection terms. The coefficient of horizontal eddy viscosity (K) is deduced from the horizontal advection terms; then, in the model, what is partially done by the tuning process is accounted in K for the values of the neglected advection terms.

A. SELECTION OF THE GRID

The selection of the grid size is usually based on requirements of details and accuracy, and availability

of computer core memory and time. For open areas and round shaped smooth bays, where the expected velocities and direction fields are smooth, it is not necessary to use a fine mesh. In areas where topography is of primary importance a fine mesh is necessary for reliable results.

The flow in San Diego Bay is governed by the topography of the area; therefore, a small grid size must be introduced. To cover the entire area, a large array would be necessary which would require a large amount of core and computation time.

On the other hand, due to deficiencies in the boundary conditions of the model, inaccuracies of the computations are found near land grid points; therefore, if acceptable results are desirable in narrow channels, the grid must provide enough grid points across these areas.

A small grid of 100 x 100 array was lain over San Diego Bay. Because of the difficulty of handling by the computer, the area was divided in two regions with sufficient overlap to insure proper calibration.

The way the boundary conditions are set at the open boundaries produce errors which propagate throughout the adjacent grid points; therefore, the overlap area must be of considerable size in order that the match section be distant enough from both open boundaries that these influences are negligible. For this specific model, a long

and narrow portion of the bay in front of Coronado was chosen, assuming that in this area flow is parallel to the coastline and free of big eddies.

This division gives two grids: a northern grid of 53 x 30 designated as grid (1), and a second southern grid of 58 x 40 and designated as grid (2) [Figure 1].

The second portion of the bay was run under two different conditions: first under existing conditions (model (2)) and, secondly, with a second open boundary at Crown Cove (model (3)). The division of the bay into two different models will not allow for computation of velocity at the northern entrance for the case of the model (3), but it will give a good indication of what the future conditions will be in the northern channel as the point C-2 (see Fig. 1) will be computed in the second and third models.

B. TIDE INPUT IN THE MODEL (1)

In the northern model referred to as model (1) (the one with two open boundaries), tidal values at both openings was first introduced. The time inaccuracies of the prototype measurements forced water in and out of the bay at the two ends simultaneously. This procedure causes a non-equilibrium state in the bay with corresponding erroneous answers.

A new procedure was tried by leaving the second boundary open without a driving force, letting the water flow in and out according to the propagation of the tidal wave

from the first boundary. Continuation of the surface of the water and currents for each point in the free open boundary was prescribed to insure the flow of water throughout this end. For the values of height, this continuation was obtained by leveling the edges using the concept of a "lubricated wall",

$$Z(NEH,M) = Z(NEH-1,M)$$

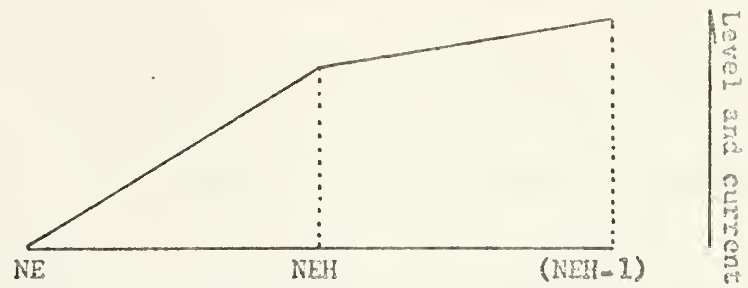
Attempts to continue the surface slope resulted in disturbances being generated in the model,

$$Z(NEH,M) = Z(NEH-1,M)+[Z(NEH-1,M)-Z(NEH-2,M)].$$

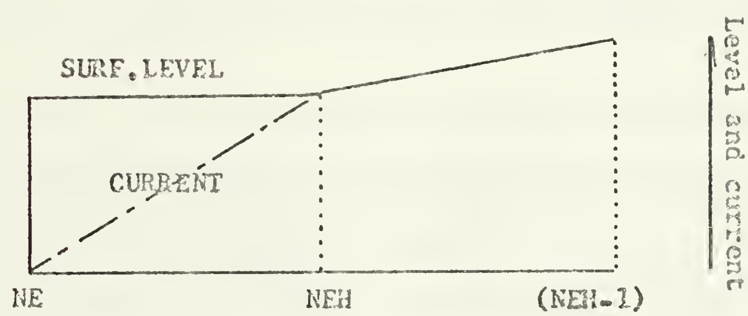
Leveling the edges and letting the model compute the values of currents itself resulted in too severe a decay of the values of velocity at the second boundary; this resulted in no flow through the free open boundary.

To obtain the correct flow of water throughout the free open boundary, a continuation of current (u and v) was prescribed with the assumption that calibration of the model could be obtained modifying the values of this slope by means of applying a smoothing constant (J) to its value [Figure 5],

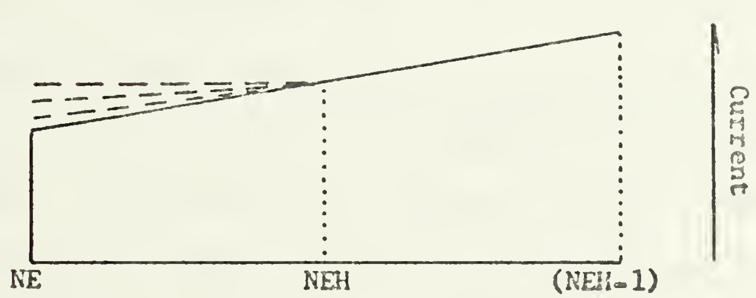
$$V(NEH,M) = V(NEH-1,M)+J[V(NEH-1,M)-V(NEH-2,M)].$$



IMPUT BOUNDARY AND FREE BOUNDARY WITHOUT CONTINUATION



LEVELING OF THE EDGES(LUBRICATED WALL)AT BOUNDARIES



CONTINUATION OF CURRENT AT THE FREE OPEN BOUNDARY
WITH THE GRADIENT CORRECTED
BY A CONSTANT

FIGURE 5

Variations of the values of the currents in the entire model were obtained, but great disturbances in the water surface were introduced up to a point that back-flux was obtained. Figures 6 and 7 show different results obtained for different values of J in the continuation of current used at the free open boundary.

These disturbances in the surface can be reduced by applying an inverse correction to the slope of the surface at the edge

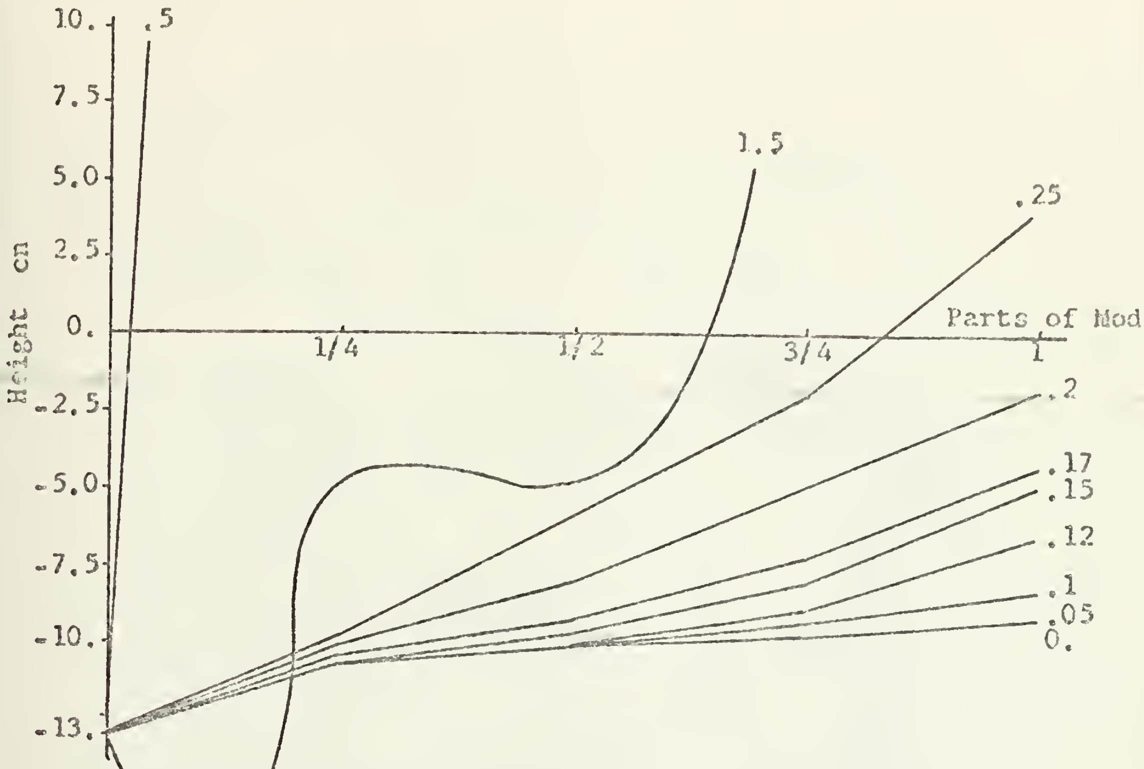
$$Z(NEH,M) = Z(NEH-1,M)-C(Z(NEH-1,M)-Z(NEH-2,M)).$$

No further calibration was attempted because this procedure is not realistic, but a proper calibration may give a good result with savings in computation time.

Because no satisfactory answer was obtained from a free open boundary, the idea was abandoned and the addition of an appended pseudo-bay was tried.

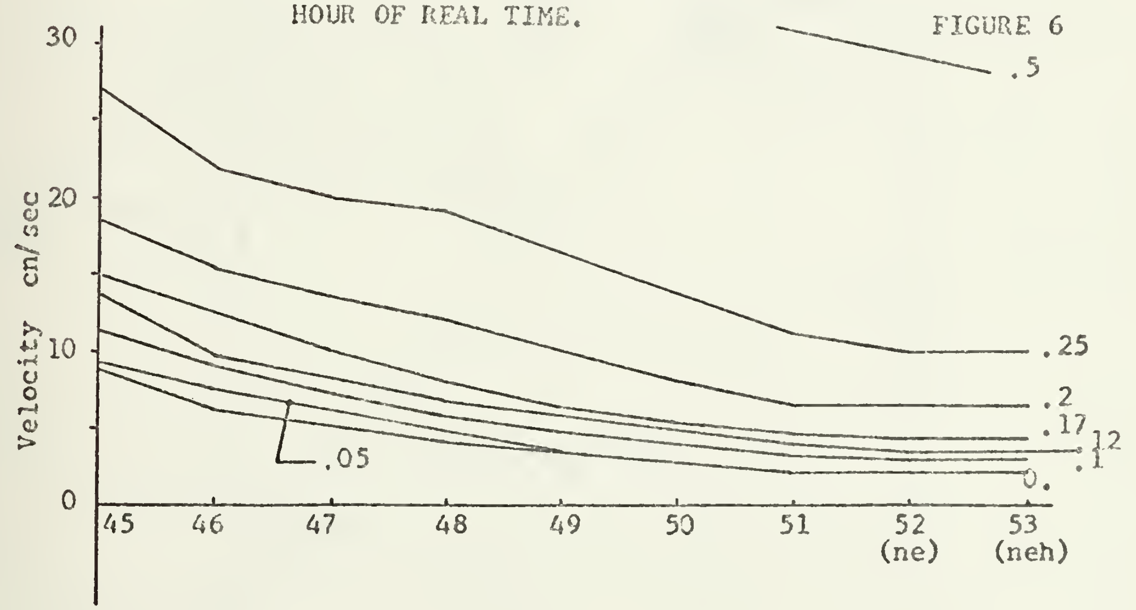
C. ADDITION OF AN APPENDED PSEUDO-BAY

The addition of an appended area at the end of the model (1) creates an additional tidal prism which will force the volume of water passing throughout the first model to increase. This new area, Figures 8 and 9, was obtained by filling the empty spaces of the grid and connecting them to the end of the model. This procedure does not increase the core in the program, but increases the time of computation by about 30% for this specific case.



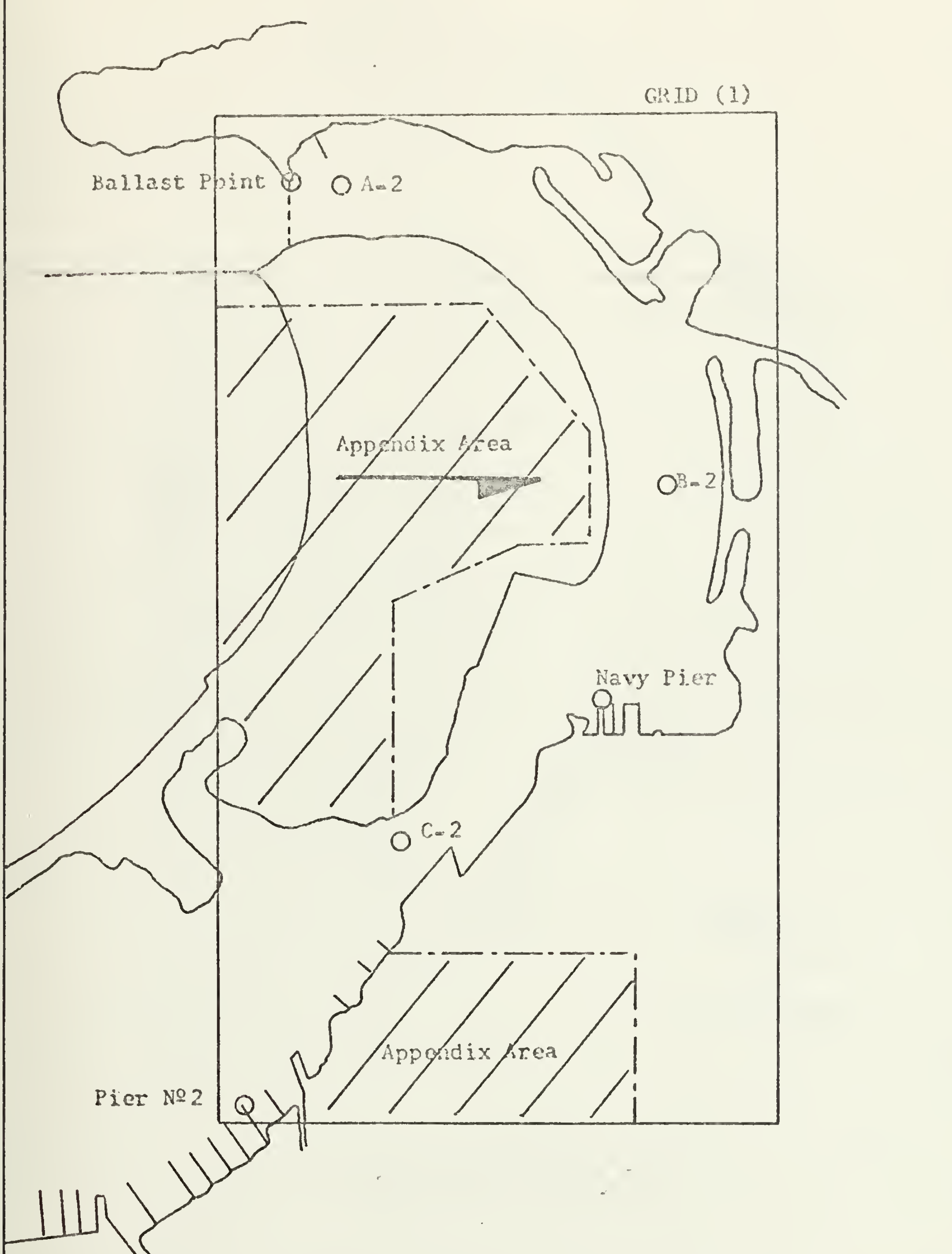
VALUES OF Z ALONG THE MODEL (1) FOR DIFFERENT CONSTANTS IN THE CONTINUATION OF THE FREE BOUNDARY AFTER 1 HOUR OF REAL TIME.

FIGURE 6



VALUES OF VELOCITY AT M= 3 AND N= 45 to 53 IN THE FREE OPEN BOUNDARY FOR DIFFERENT CONSTANTS IN THE CONTINUATION AFTER 1 HOUR OF REAL TIME.

FIGURE 7



APPENDED AREAS IN MODEL (1)

FIGURE 8

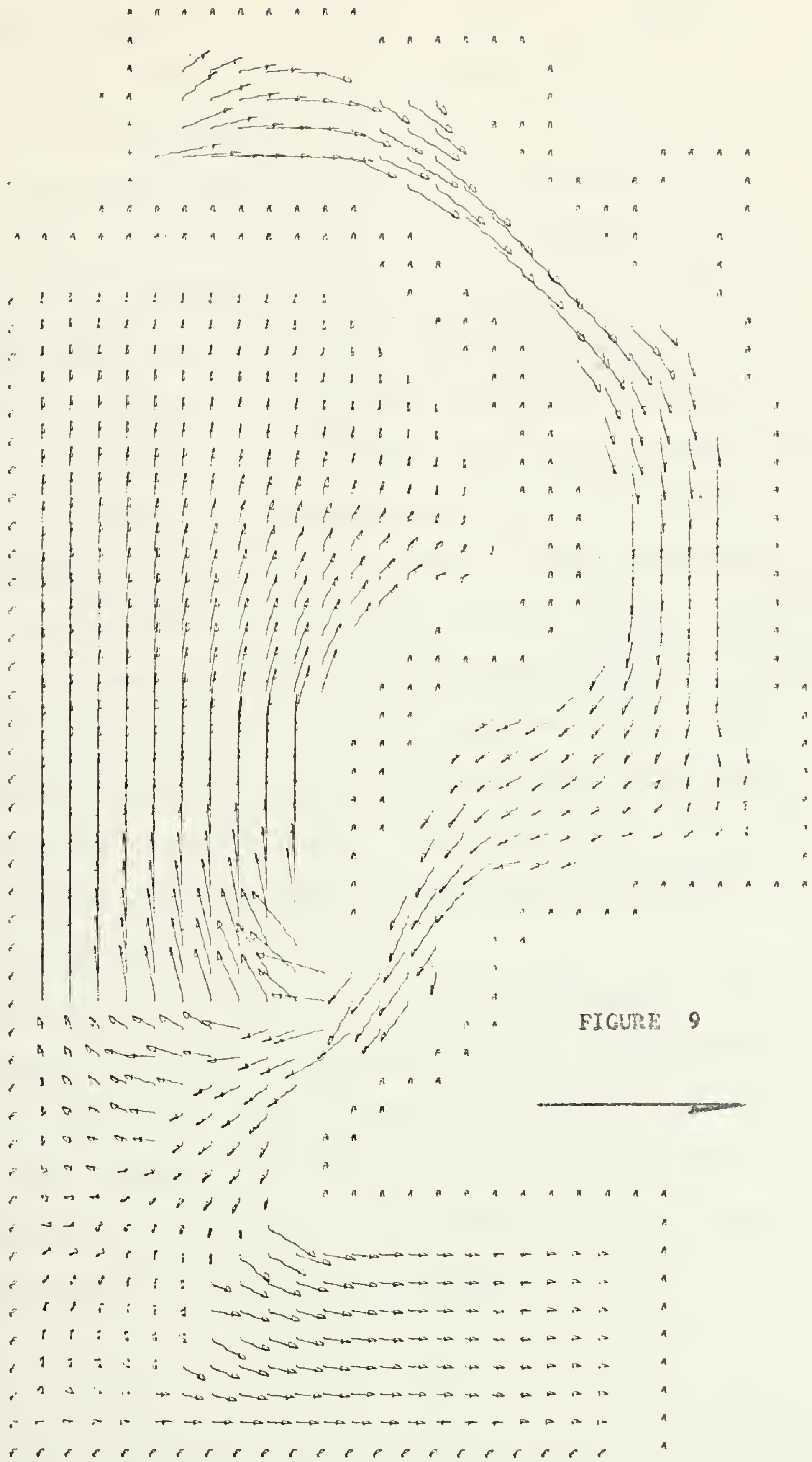


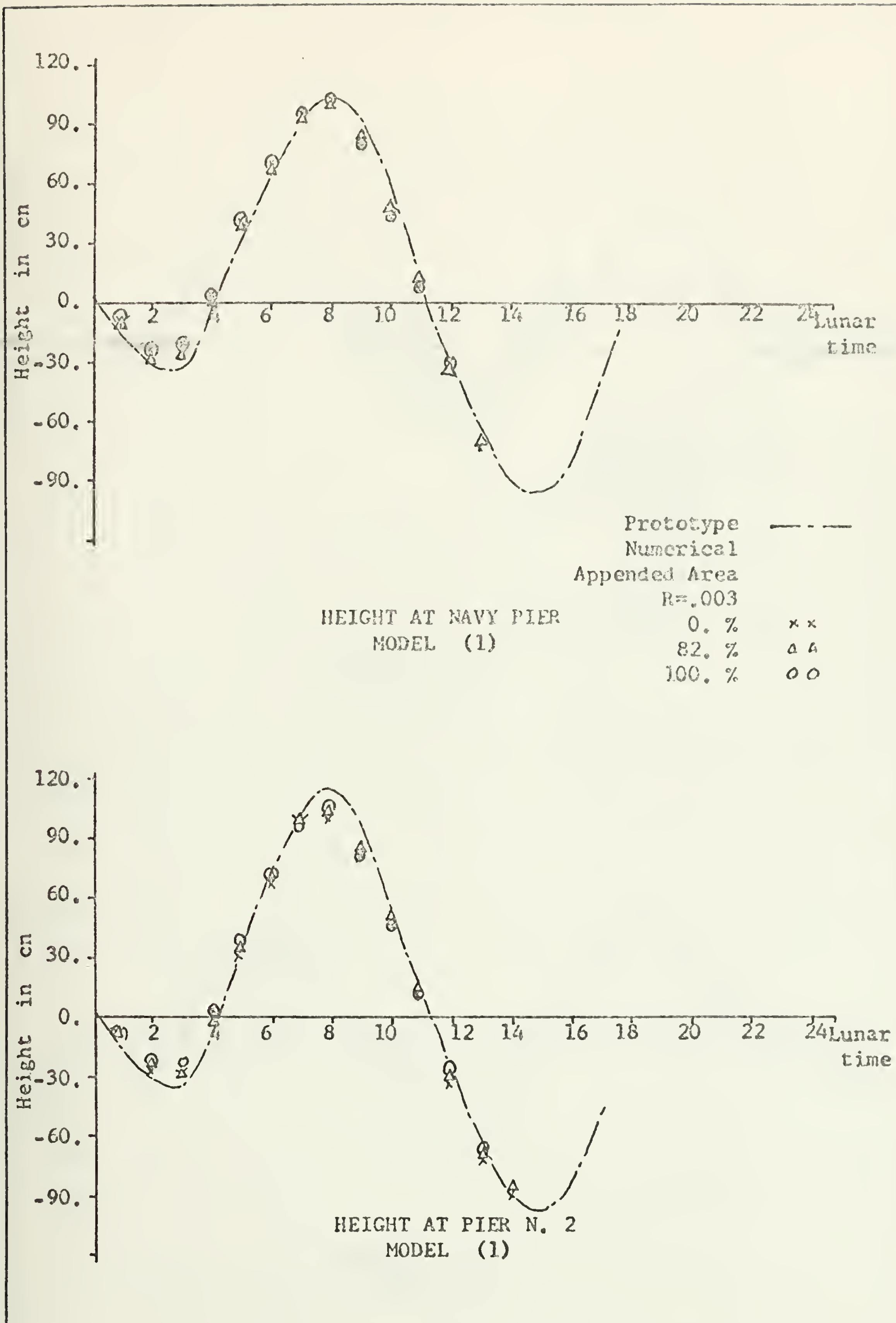
FIGURE 9

CIRCULATION IN MODEL (1) WITH APPENDED AREAS

Areas corresponding to 82% and 100% of the remaining area of the bay were tried. The results, Figures 10, 11, and 12 show an increase of water transport and current values with no appreciable modifications to the values of the water surface. The increase in volume transport and currents were proportional to the increased areas. The values of height remain stable for the different cases.

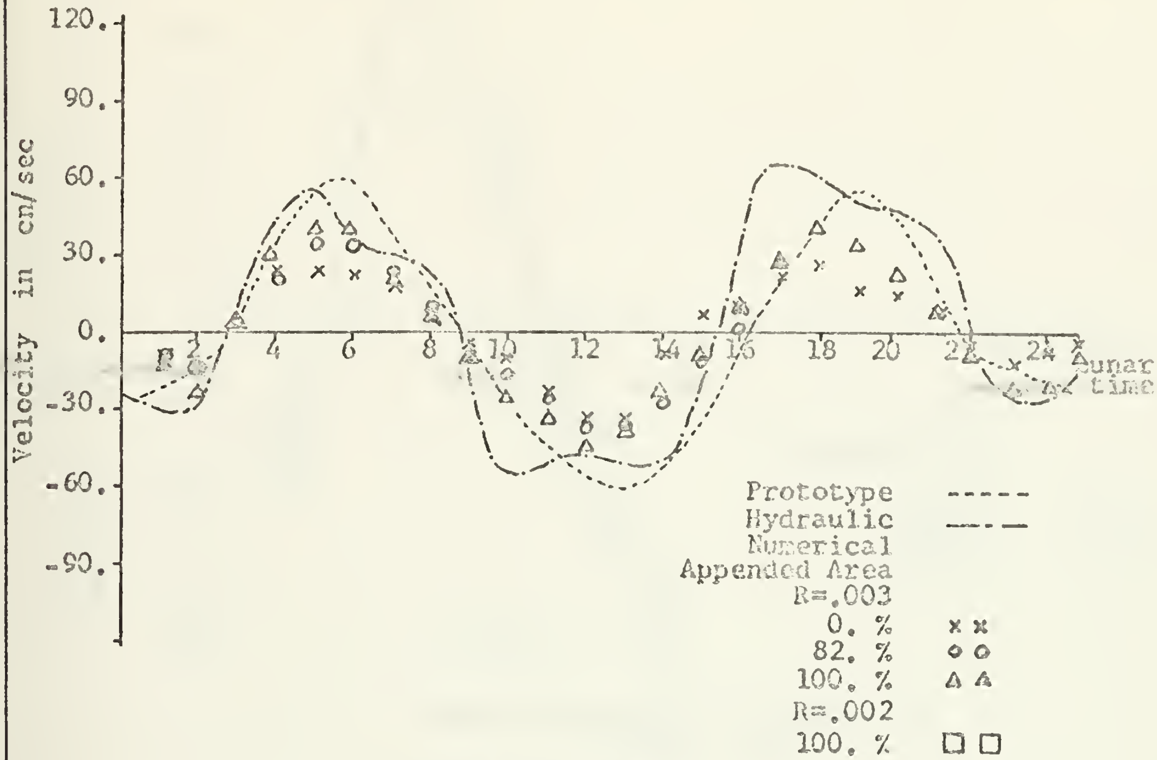
Different values of R (0.003, 0.0028 and 0.002) were applied to the model. The results show that the model is not very sensitive to the variations of this parameter. After comparing the results obtained at the points A-2, B-2 and C-2 for each of the values of R, 0.003 was adopted because it seemed to better fit the measurements at these points in the prototype. The discrepancies at A-2 were attributed to the inaccuracies of the Hansen numerical model near the open boundaries. The results of the model (1) in current, water height and net volume transport are shown in figs. 13, 14, 15.

A pictorial description of the flow throughout the entire model (1), with the appended areas, is shown in Figure 9. The real part of this model and the times of 0., 3., and 9 hours are shown in Figures 16, 17 and 18. The direction of the flow is indicated by the arrows, and its magnitude is scaled by the length.

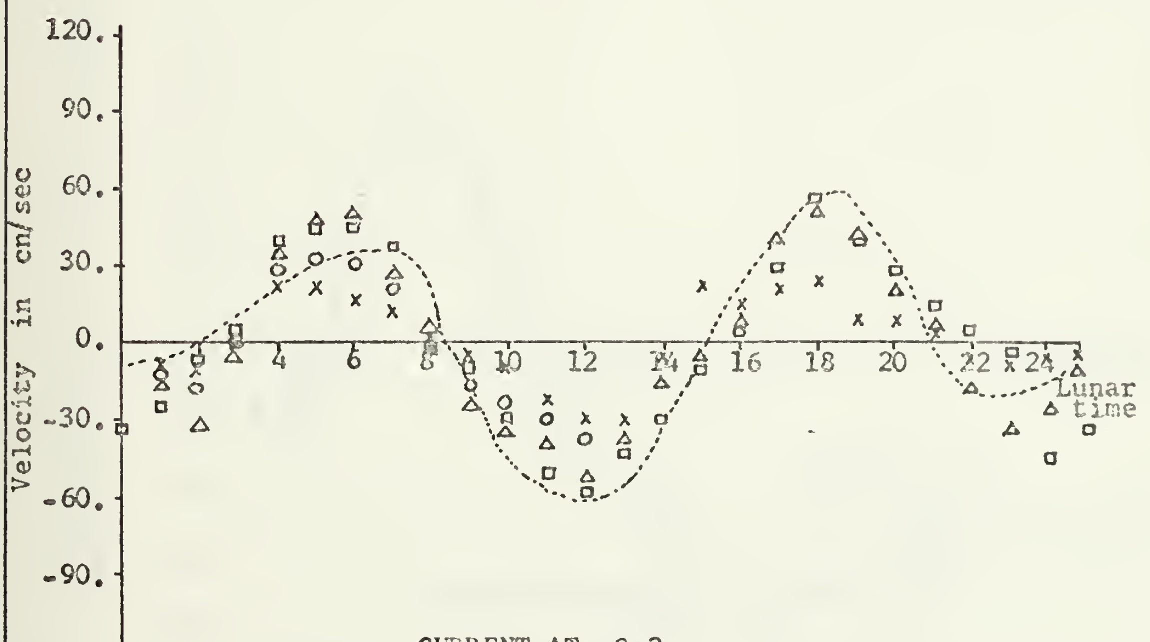


120.
90.
60.
30.
0.
-30.
-60.
-90.
Height in cm
2 4 6 8 10 12 14 16 18 20 22 24
Lunar time
Prototype
Numerical
Appended Area
R=.003
0. %
82. %
100. %
HEIGHT AT NAVY PIER
MODEL (1)
120.
90.
60.
30.
0.
-30.
-60.
-90.
Height in cm
2 4 6 8 10 12 14 16 18 20 22 24
Lunar time
HEIGHT AT PIER N. 2
MODEL (1)

FIGURE 10

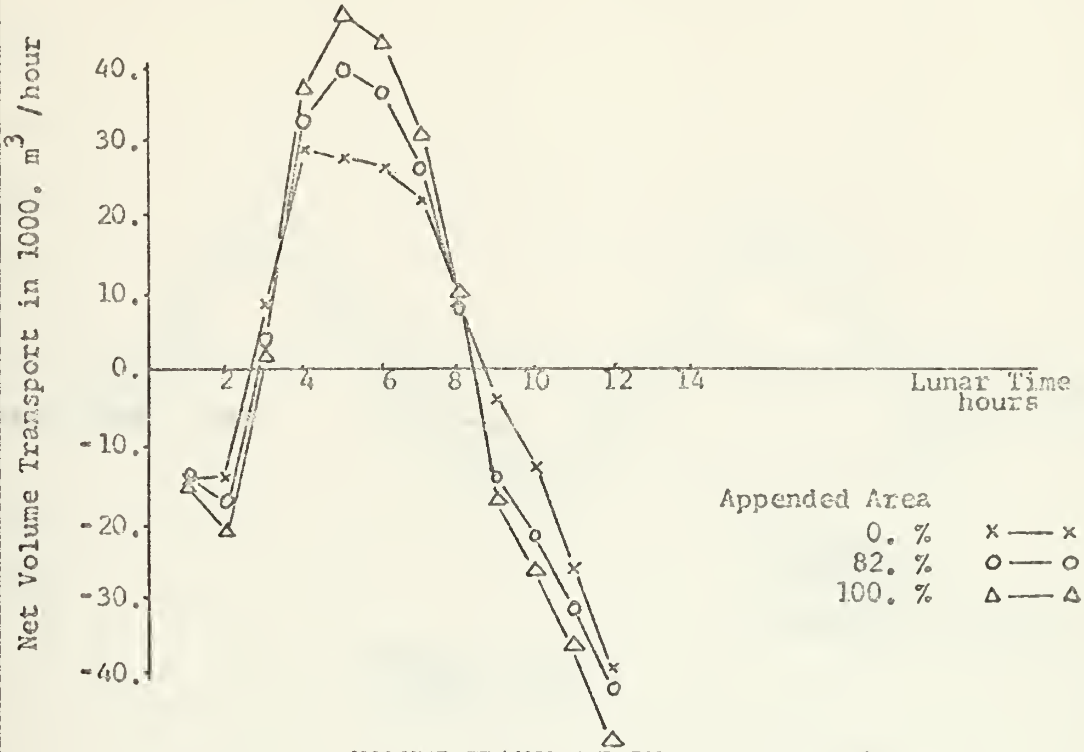


CURRENT AT A-2
MODEL (1)

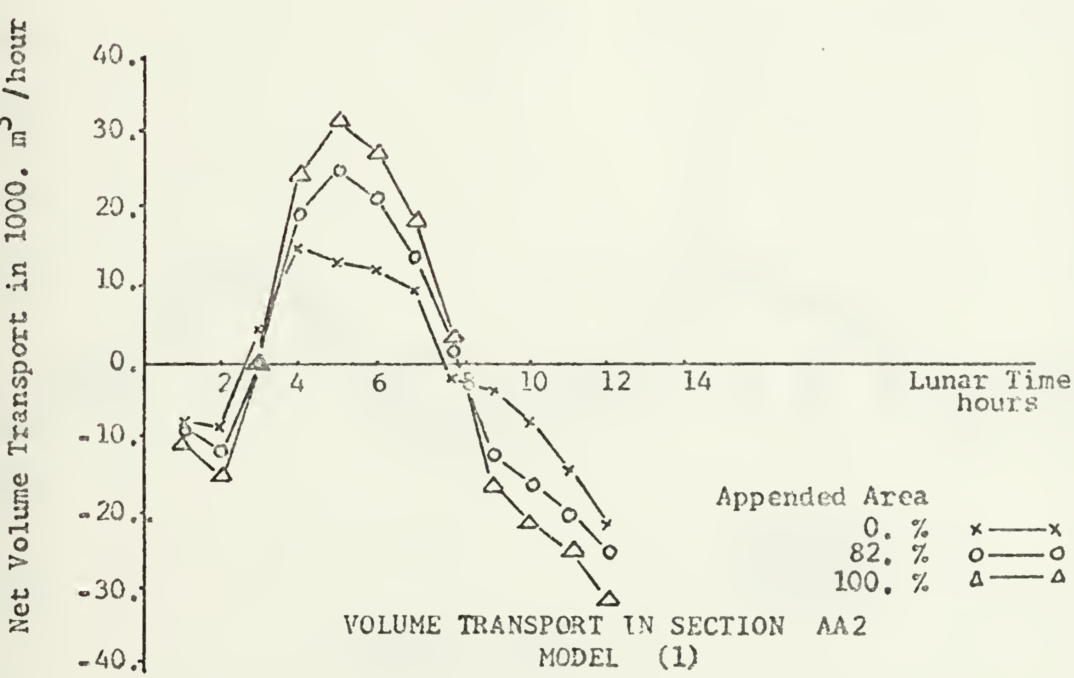


CURRENT AT C-2
MODEL (1)

FIGURE 11

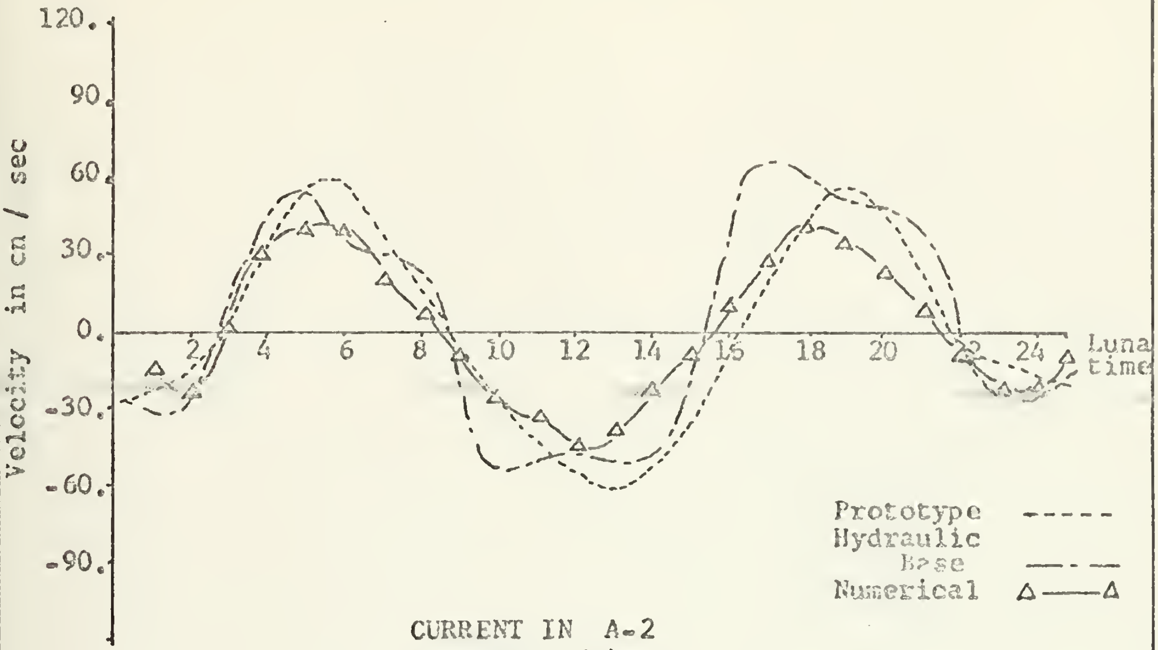


VOLUME TRANSPORT IN SECTION AA1
MODEL (1)

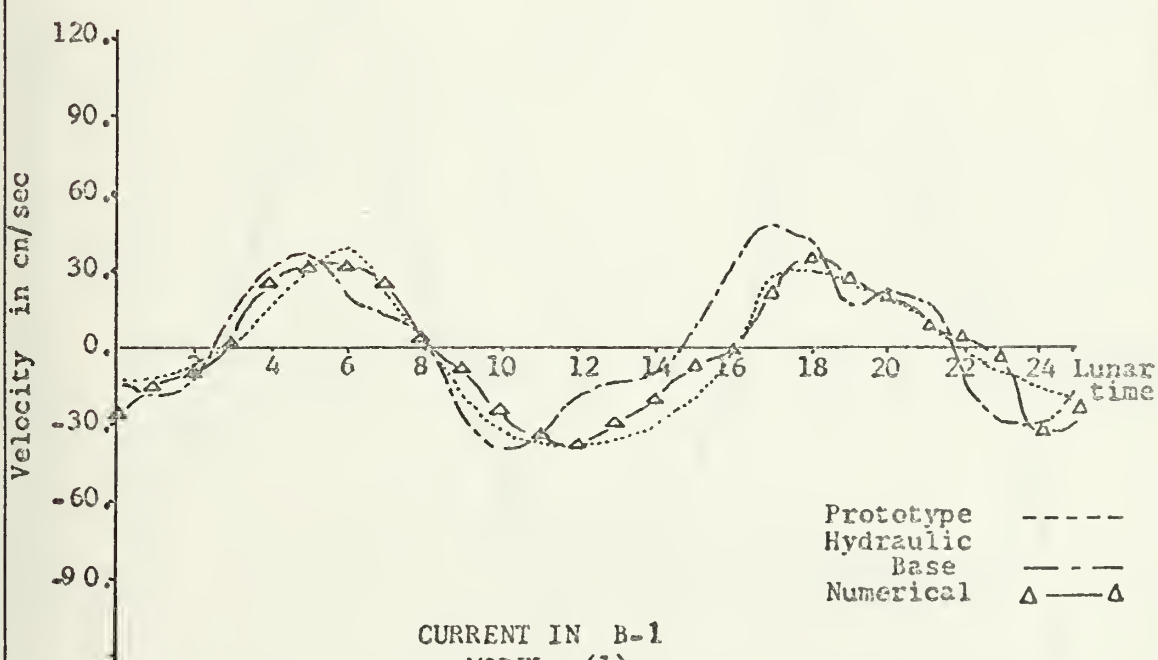


VOLUME TRANSPORT IN SECTION AA2
MODEL (1)

FIGURE 12

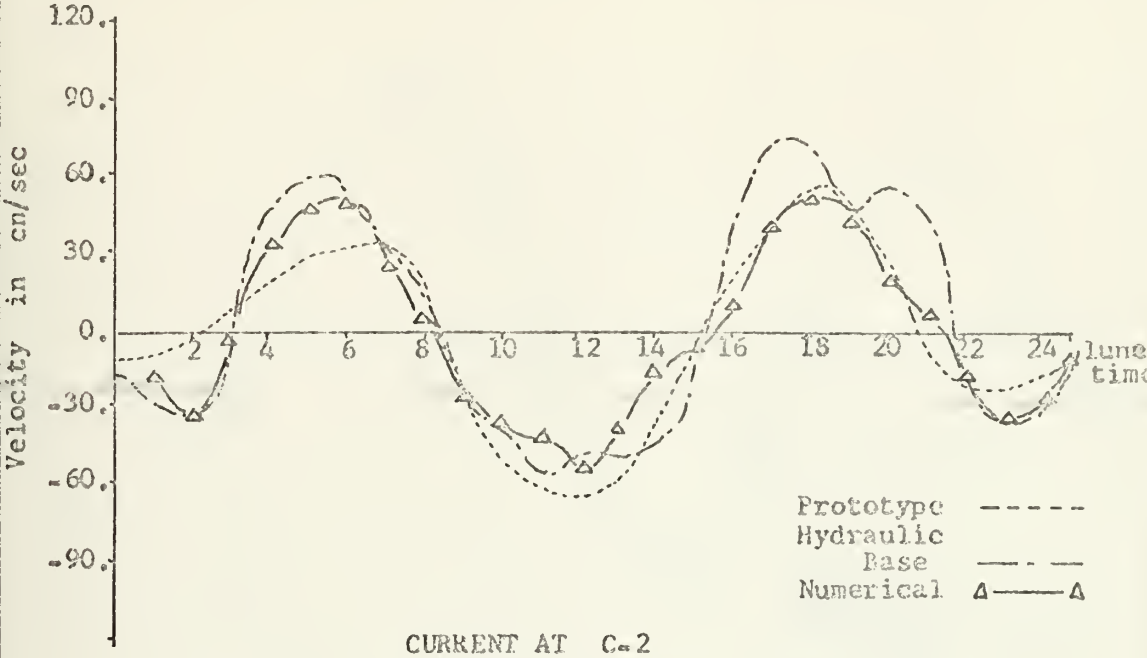


CURRENT IN A-2
MODEL (1)

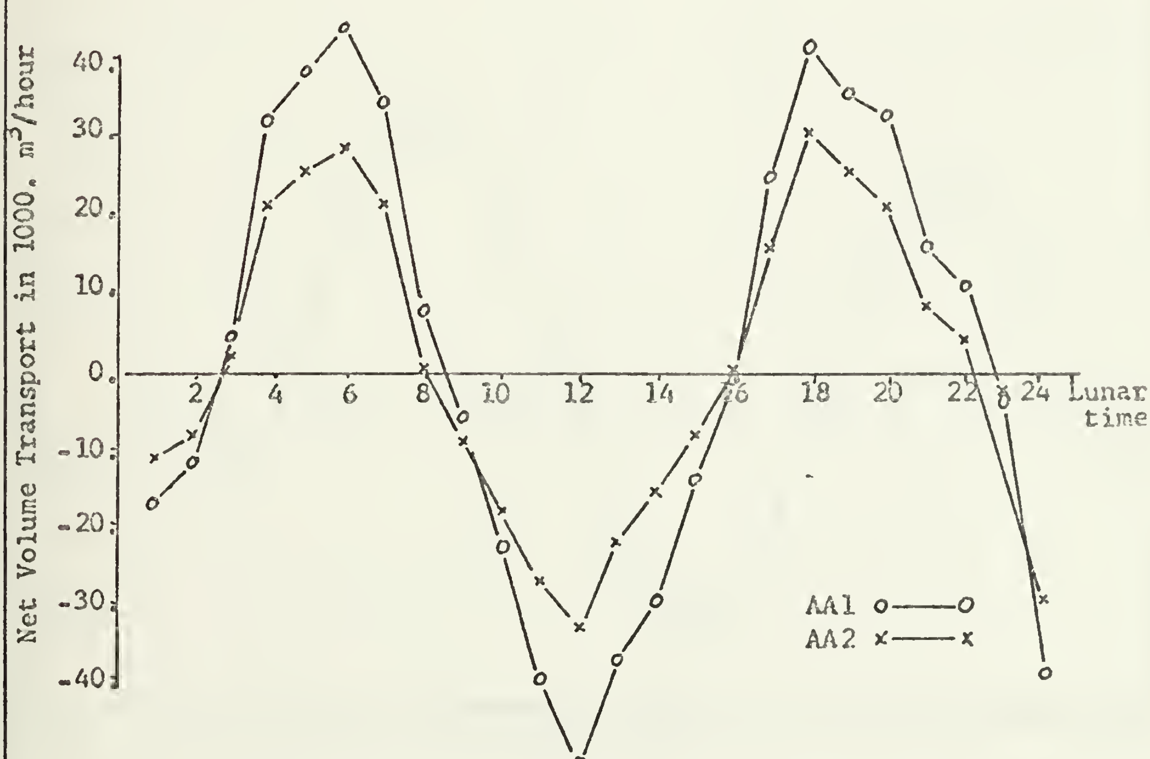


CURRENT IN B-1
MODEL (1)

FIGURE 13

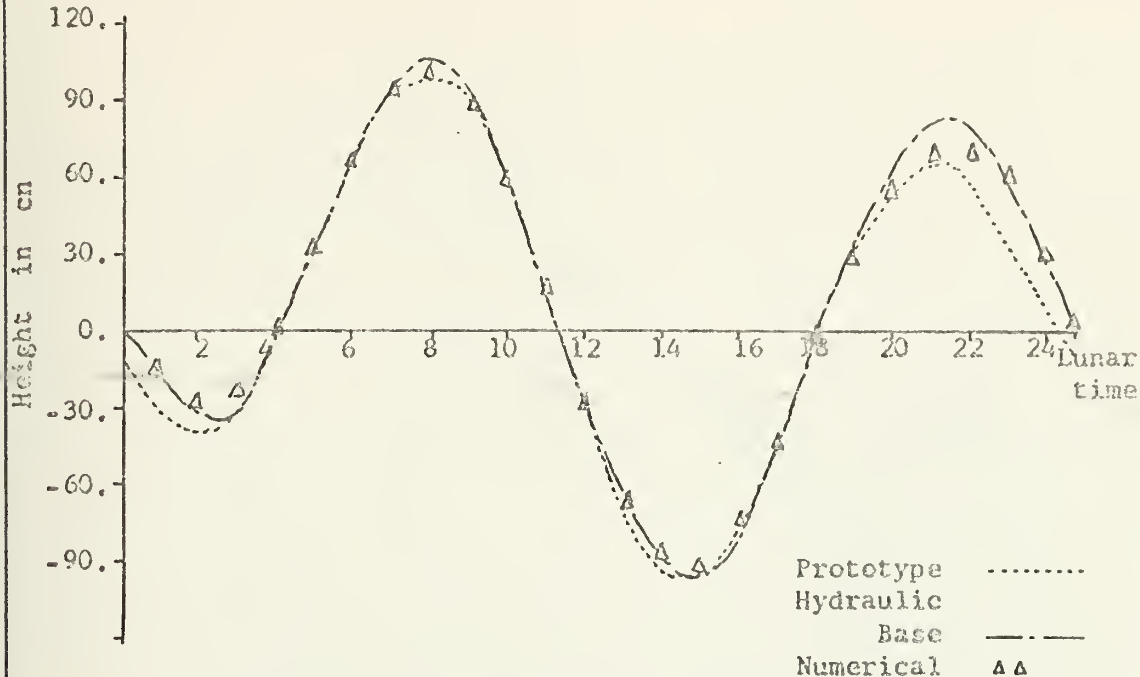


CURRENT AT C-2
MODEL (1)

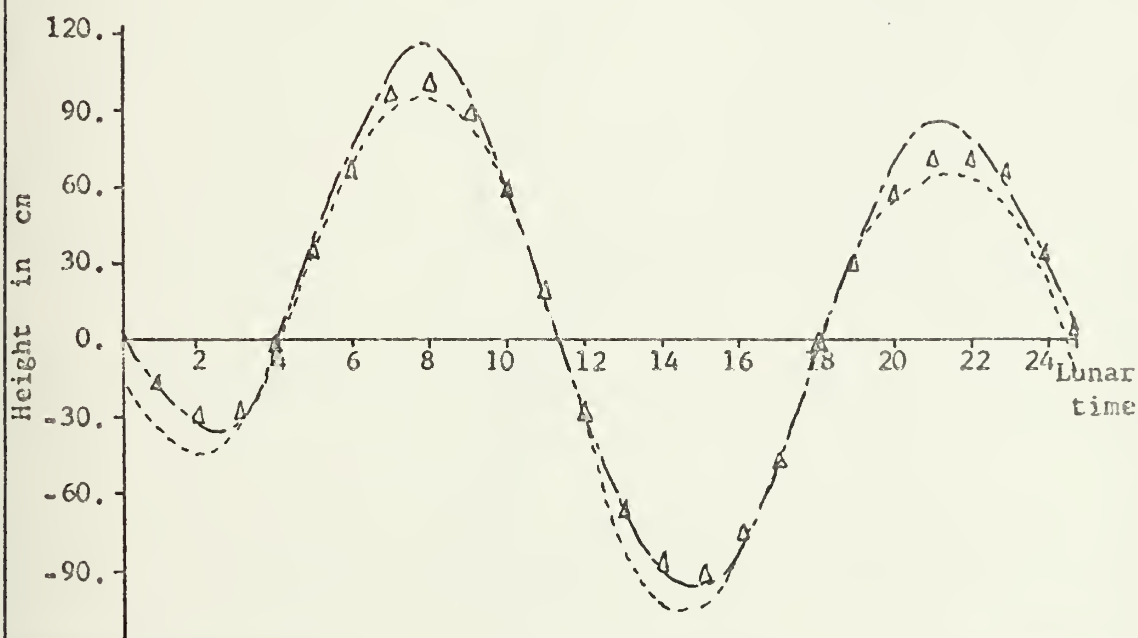


NET VOLUME TRANSPORT MODEL (1)

FIGURE 14



HEIGHT AT NAVY PIER
MODEL (1)

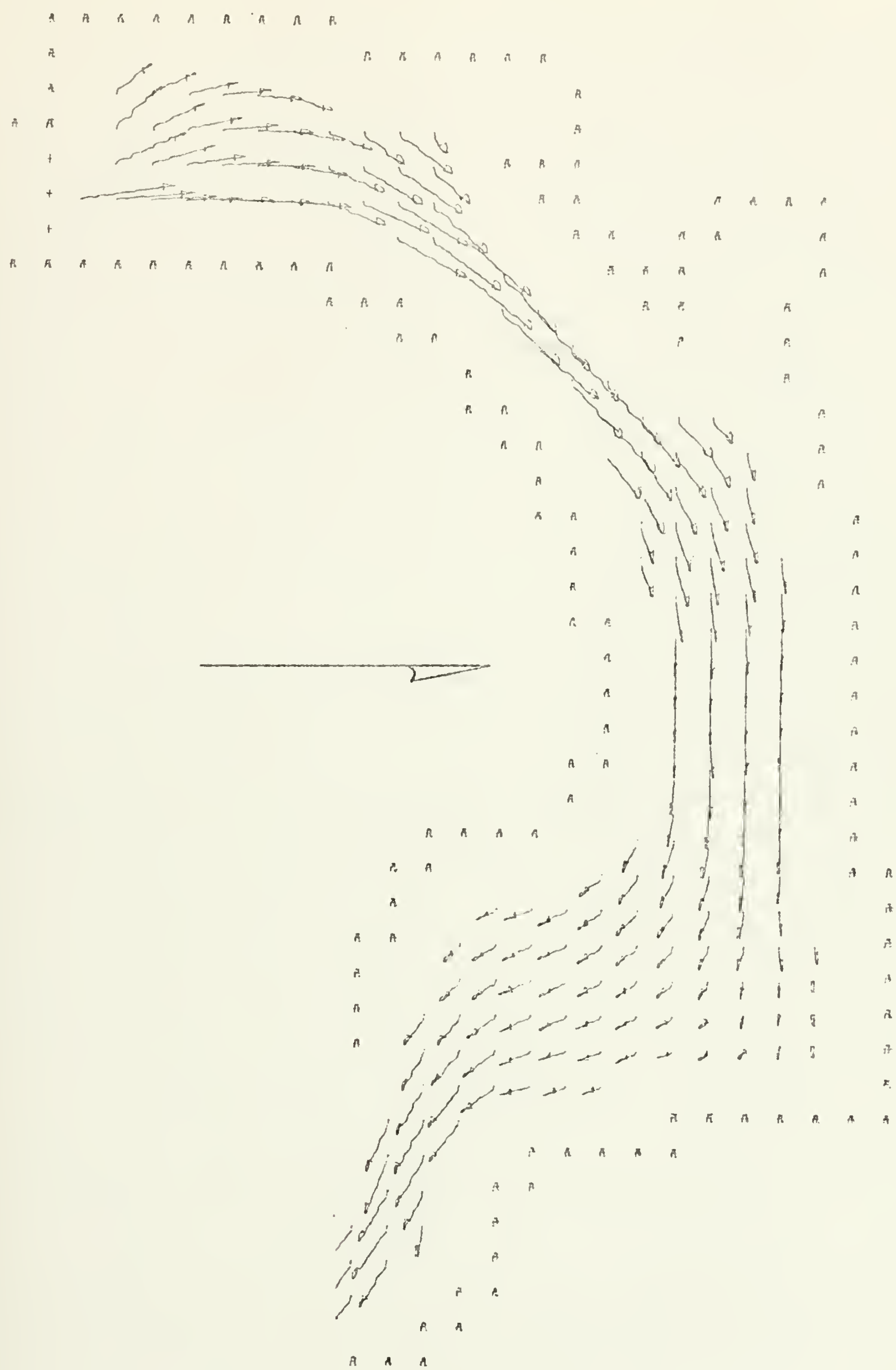


HEIGHT AT PIER N. 2
MODEL (1)

FIGURE 15

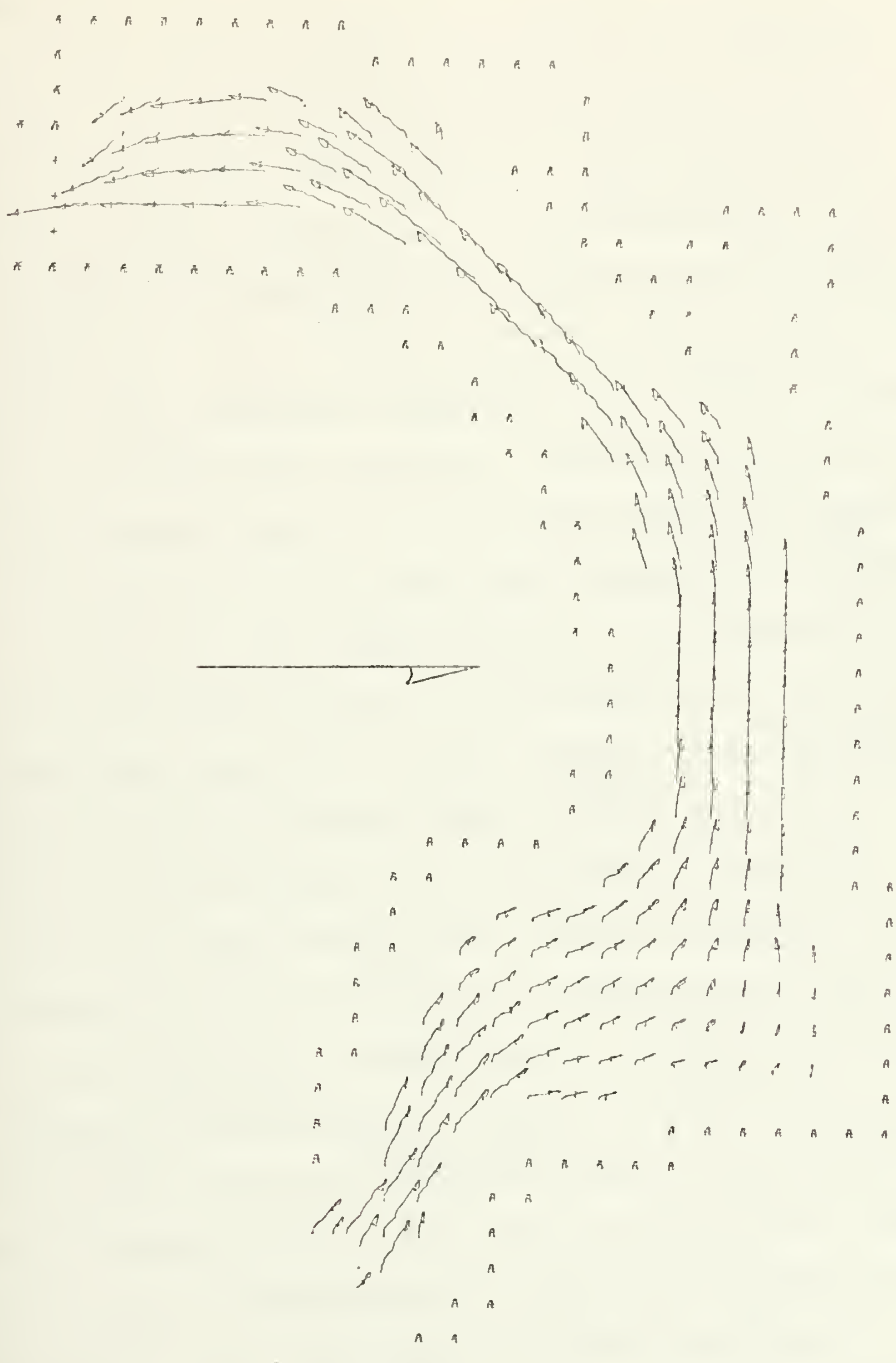
CURRENT DISTRIBUTION IN MODEL (1)
TIME = 0. hr.

FIGURE 16



CURRENT DISTRIBUTION IN MODEL (1)
TIME = 3 hr.

FIGURE 17



CURRENT DISTRIBUTION IN MODEL (1)
TIME = 9 hr.

FIGURE 18

D. MODEL (2)

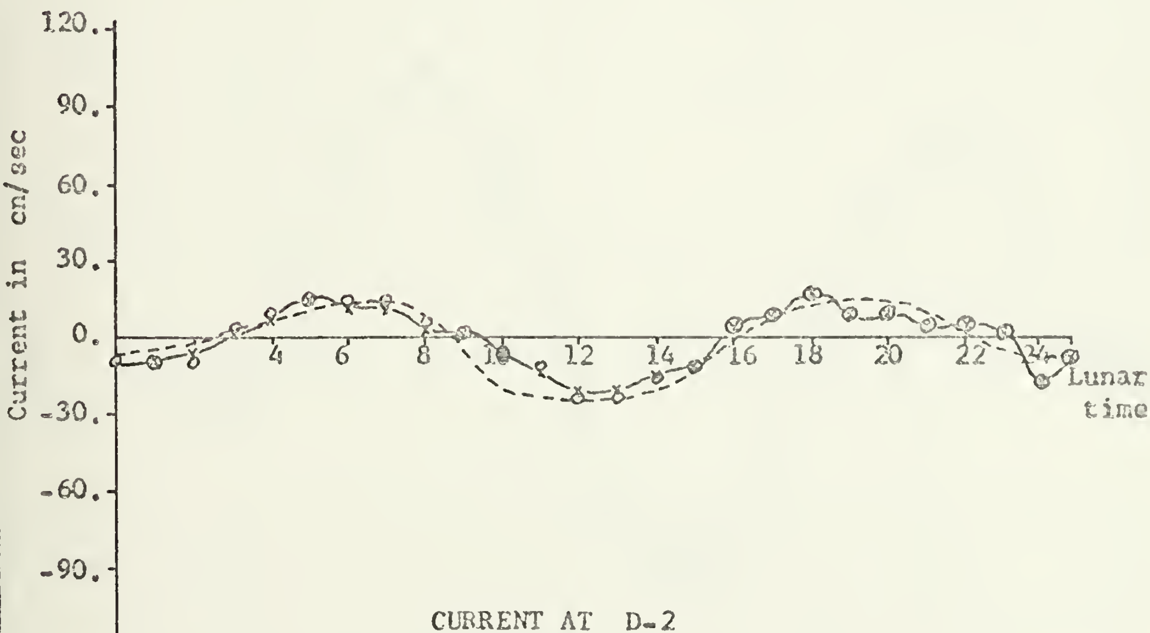
From the results of model (1), tidal values were obtained for a point at the middle of the channel in the vicinity of Navy Pier Tidal Station. These values were introduced as input to model (2). The computations were attempted with the same values of R (0.003) and α (0.992) as in model (1).

Using these prescribed conditions, oscillations in the current and tidal values developed (see Figures 19 and 20). These oscillations appear to be in phase and their magnitudes increase from zero at the open boundary to a maximum value of about 30 cm/sec. and 15 cm/sec. respectively at the end of the deeper channel at the near end of the bay, and from there, the values of the current reduce proceeding to the shallower and southern part of the bay.

The oscillations seem to be activated as the tide approaches the LLW, increase their values throughout the next HW and die out by the next LW, repeating the cycle 12 hours later when LLW is reached again. The period of the oscillations is greater than 2 hours.

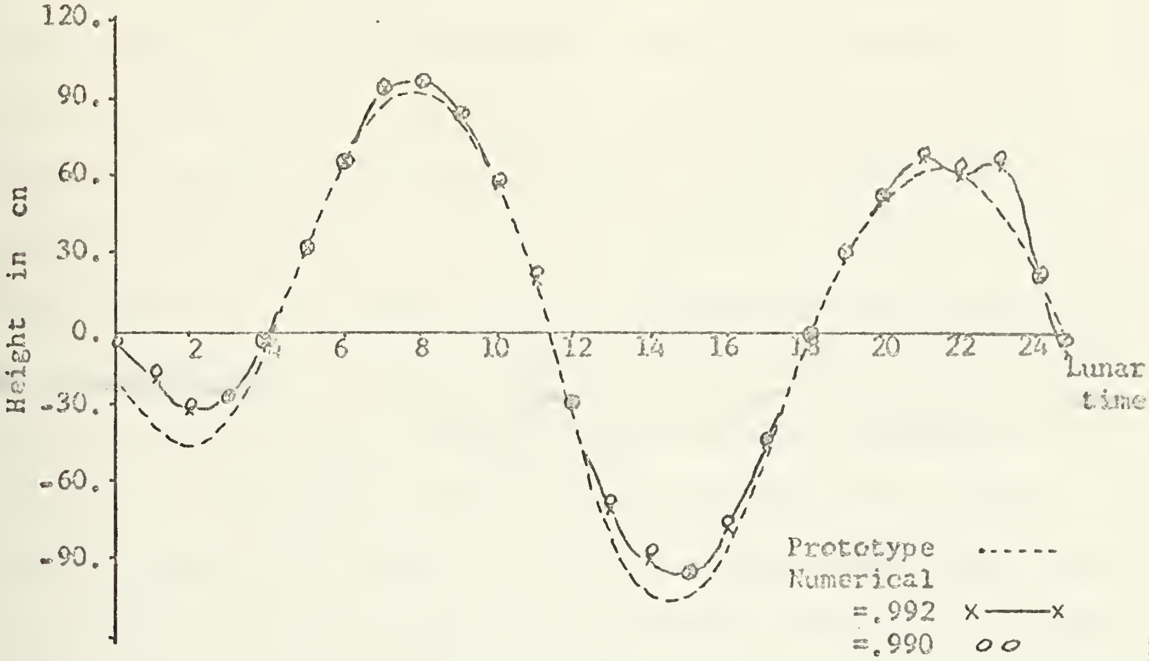
The causes of the oscillations could be some kind of seiching manifestations in the model, shallow water tide or oscillations characteristic of the model produced by attempting to work in extremely shallow water without introducing special prescribed conditions for these small values [8].

CURRENT AT C-2
MODEL (2)

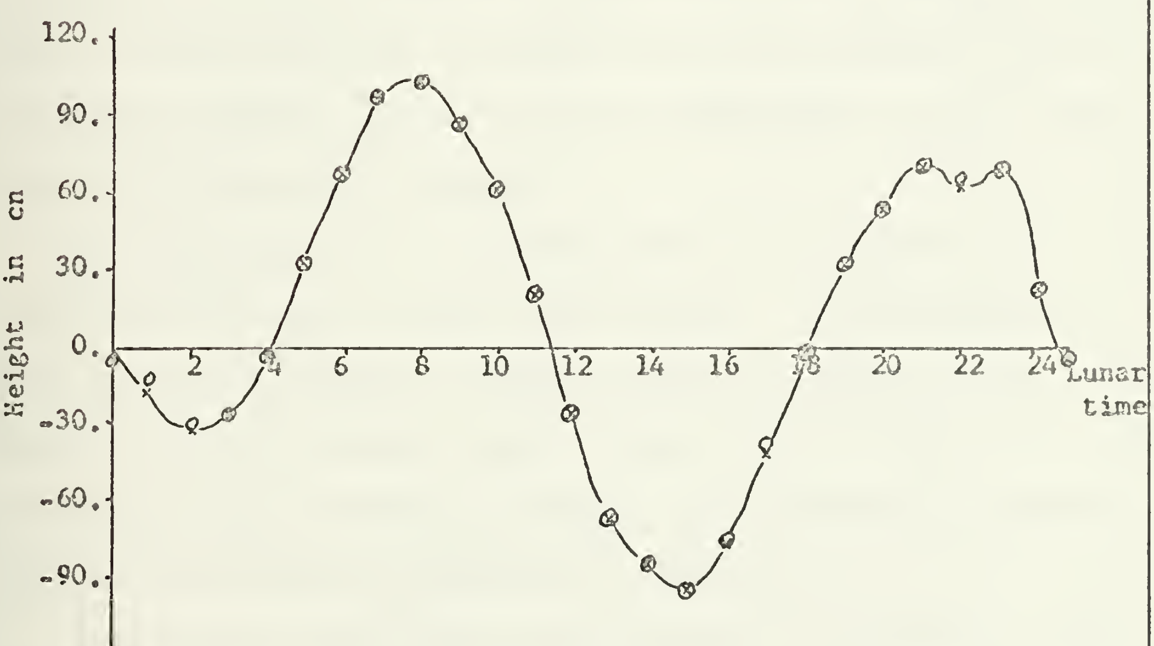


CURRENT AT D-2
MODEL (2)

FIGURE 19



HEIGHT AT PIER N.2
MODEL (2)



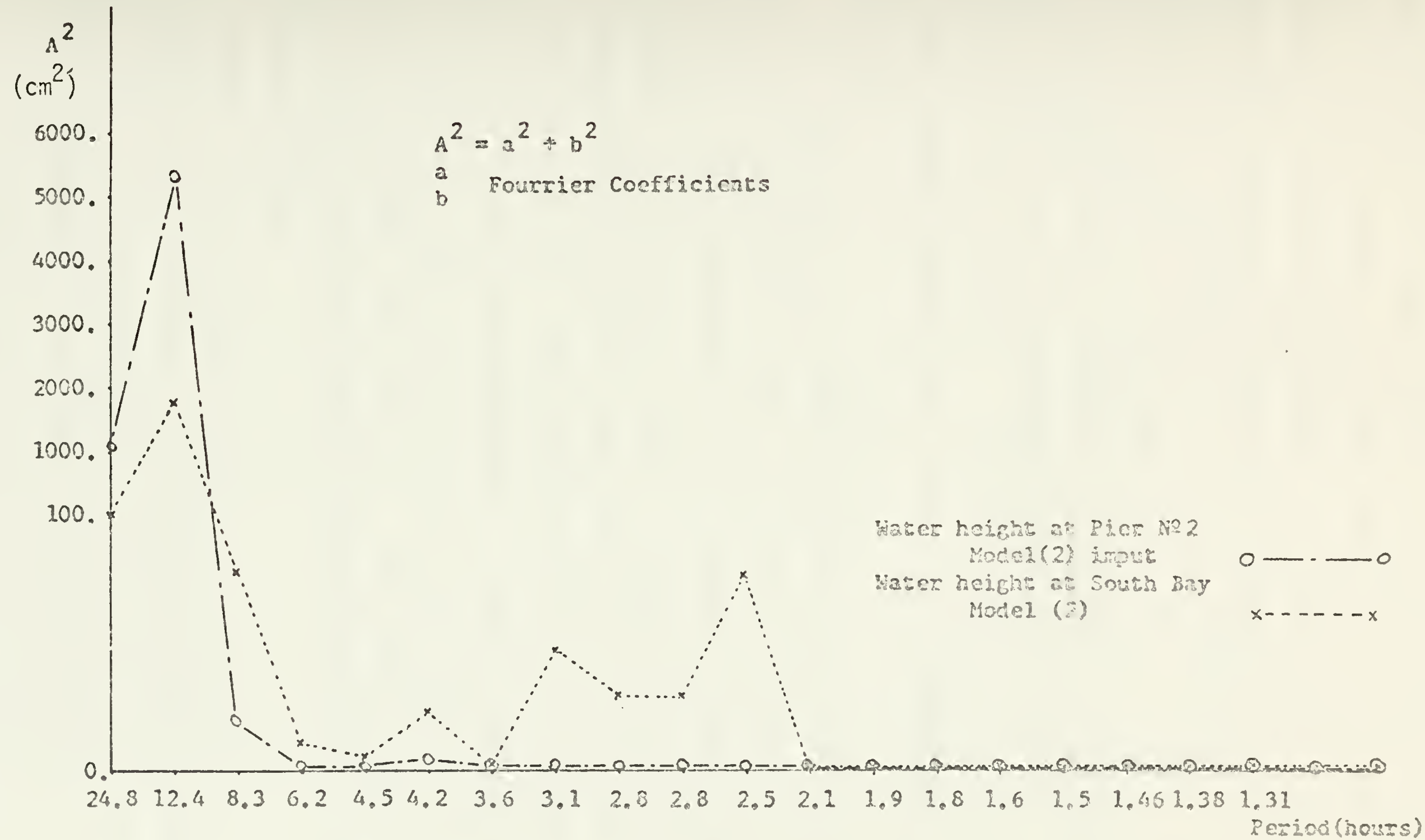
HEIGHT AT SOUTH BAY
MODEL (2)

FIGURE 20

A possible mode of seiching can be calculated assuming that model (2) is an independent bay with a length of 14. km and a medium depth of 4. meters. This bay will oscillate with a fundamental period of about 2.3 hr. which agrees with the resulting values. A Fourier analysis was made of the tidal input of the model (2) and the calculated water height at South Bay Gage. Calculation of the Energy Density Spectrum was performed to compare both and see if energy from some of the harmonics from the tidal input have excited the oscillations in the bay. The spectrum shows (see Fig. 23-1) that the oscillations have periods between 2.06 and 3.55 (with a maximum at 2.3) hours and that the tidal input has negligible energy in these periods. This seiching may be activated at the LLW and damped out by the smoothing parameter α. The existence of such anomalies are not shown in the published records of the observations and its appearance depends, in case of its existence, on the time spacing of the data obtained.

The possibility of a shallow water tide seems to be reasonable because in each tidal cycle, the oscillations seem to be activated by the tide when the depth of the water is at its minimum value. This shallow water tide produces a high frequency harmonic [3] which can be amplified by the model and damped out later by α.

Because the model has linear terms only (except in the bottom and wind friction terms), it is not possible to transfer energy from one harmonic to another; then, the



ENERGY DENSITY SPECTRUM

FIGURE 20-1

amplification of a high harmonic from the shallow water tide is questionable. One last possibility can be a deficiency of the difference scheme. As the tide is a continuous wave type propagation, errors are introduced in the time differential computation that could produce a harmonic that could be amplified by the same model.

An α of 0.99 was introduced in an attempt to eliminate the oscillations by increasing the smoothing, but no improvement was obtained. Lower values were not introduced because larger smoothing may affect other parameters in the model.

The need for a low value of Alpha in the model to damp out these oscillations makes the previous estimation of 0.999 of α not applicable for the southern portion of San Diego Bay. In the model 2 and 3, a minimum depth of 4. ft is established to prevent that portion of the bay from becoming dry at LLW. This minimum depth was increased up to 12. ft. to test the probability of shallow water tide with the result that similar oscillations appeared but with larger amplitudes, (see fig. 21). This new test made the possibility of seiching the most feasible mechanism causing the oscillations.

Model (3) was finally run with an α of 0.992 and an R of 0.003 and the results of current and height of water are shown in Figures 22 and 23. A pictorial description of the circulation of the Model (2) at the hours 3 and 9

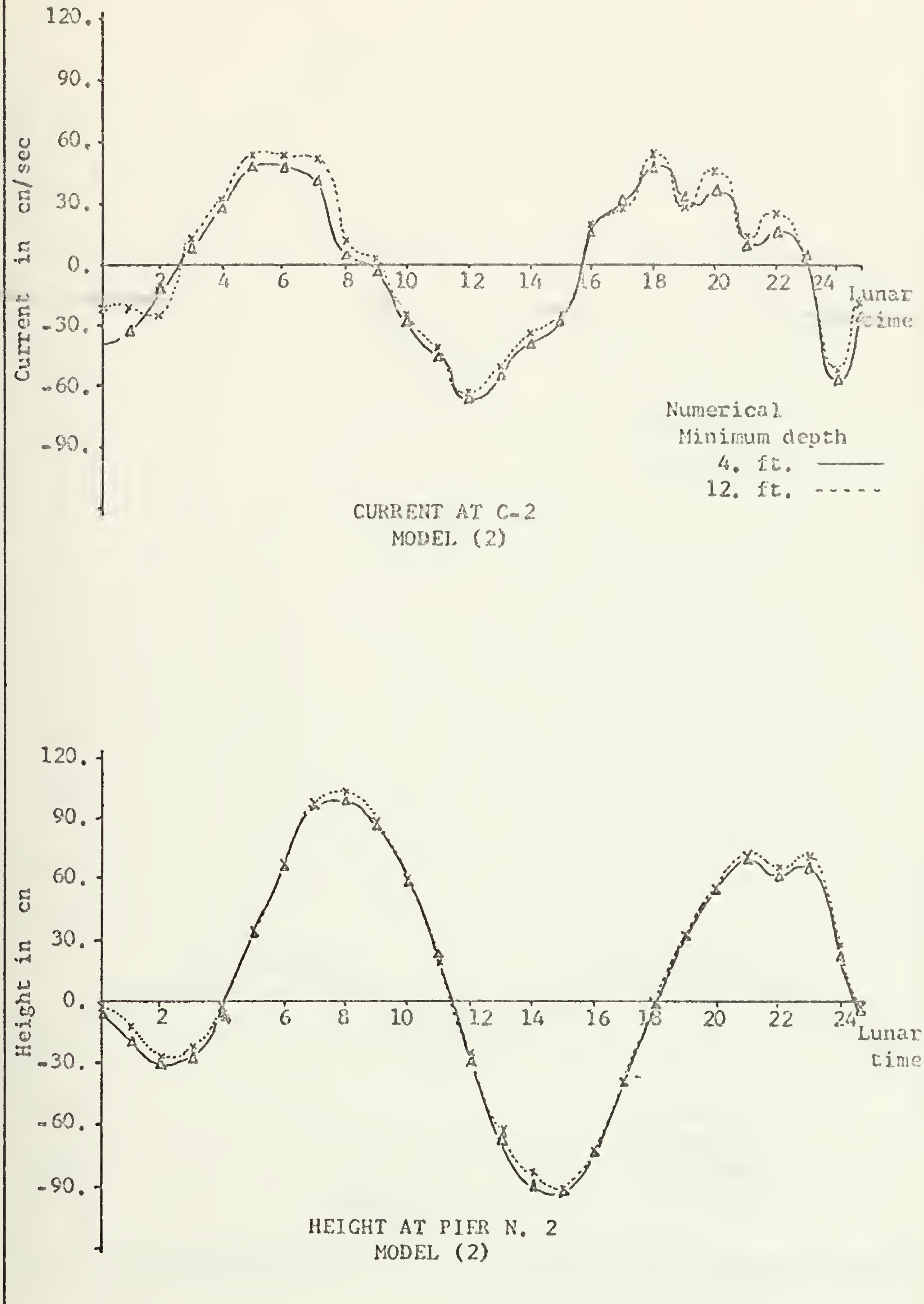
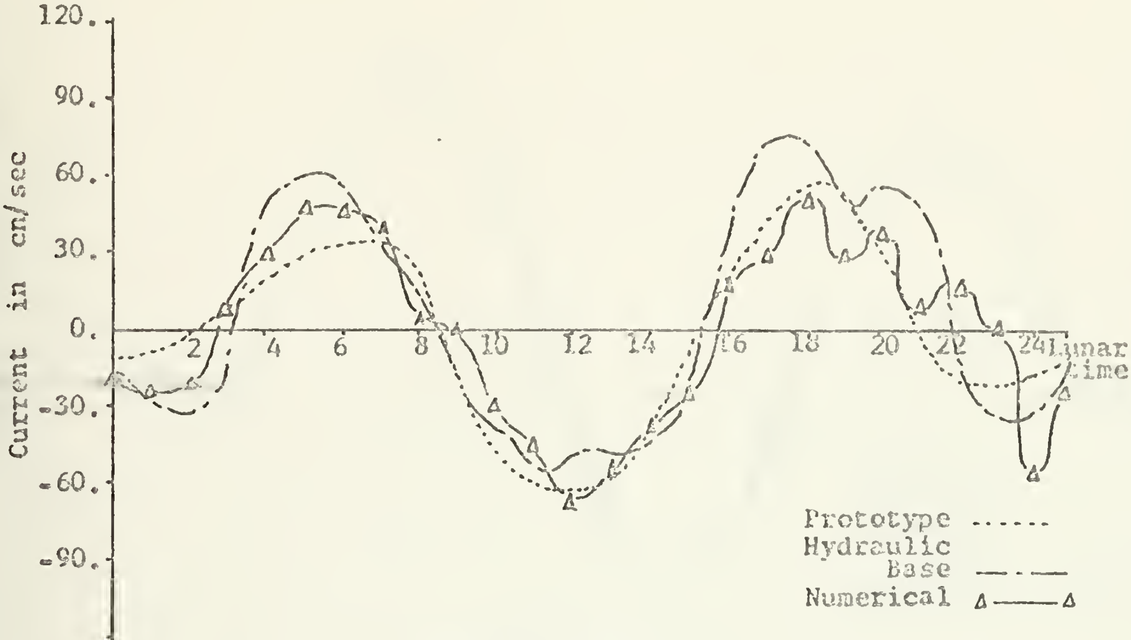
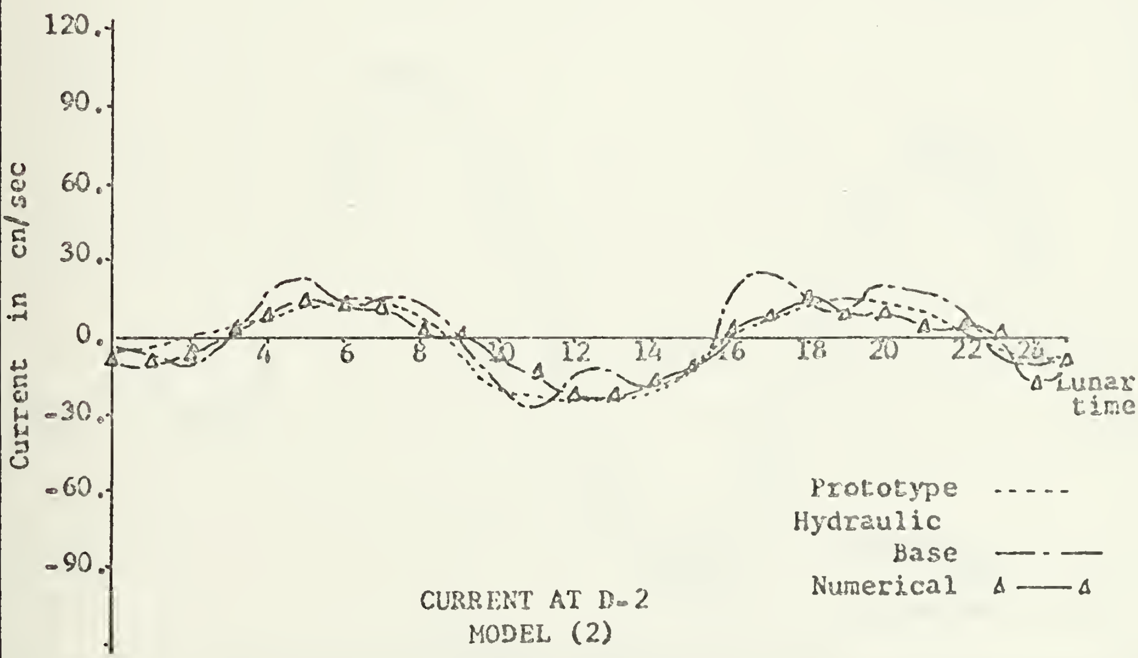

120.
90.
60.
30.
0.
-30.
-60.
-90.
Current in cm/sec
2
4
6
8
10
12
14
16
18
20
22
24
Lunar time
Numerical
Minimum depth
4. ft.
12. ft.
CURRENT AT C-2
MODEL (2)
120.
90.
60.
30.
0.
-30.
-60.
-90.
Height in cm
Lunar time
HEIGHT AT PIER N. 2
MODEL (2)

FIGURE 21

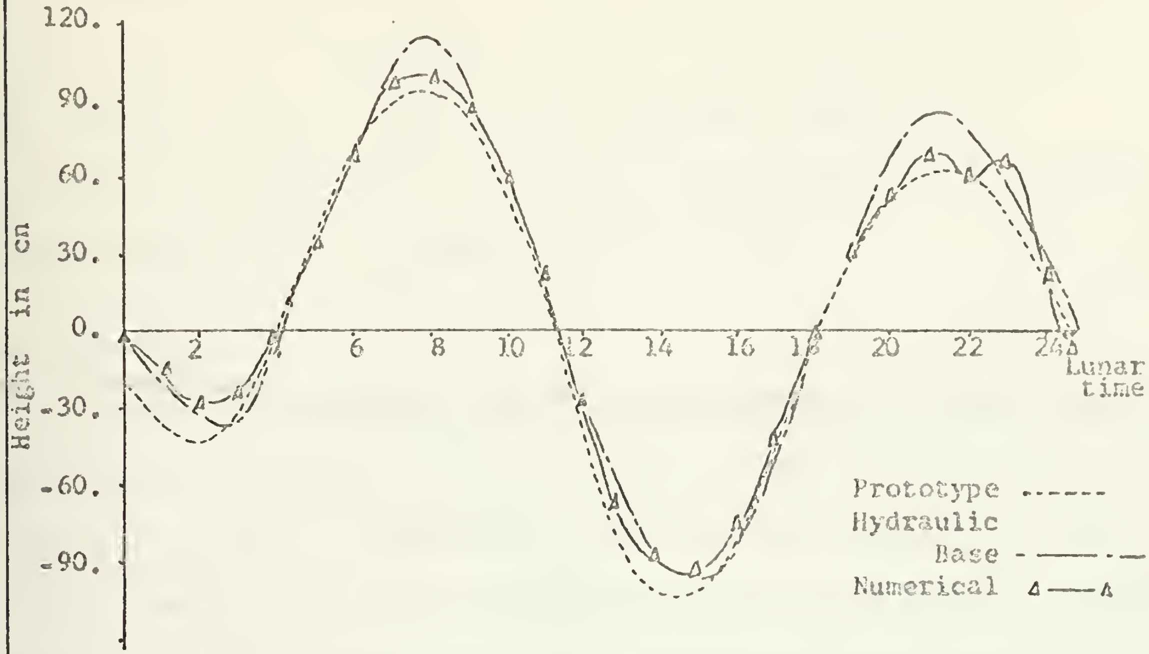


CURRENT AT C-2
MODEL (2)

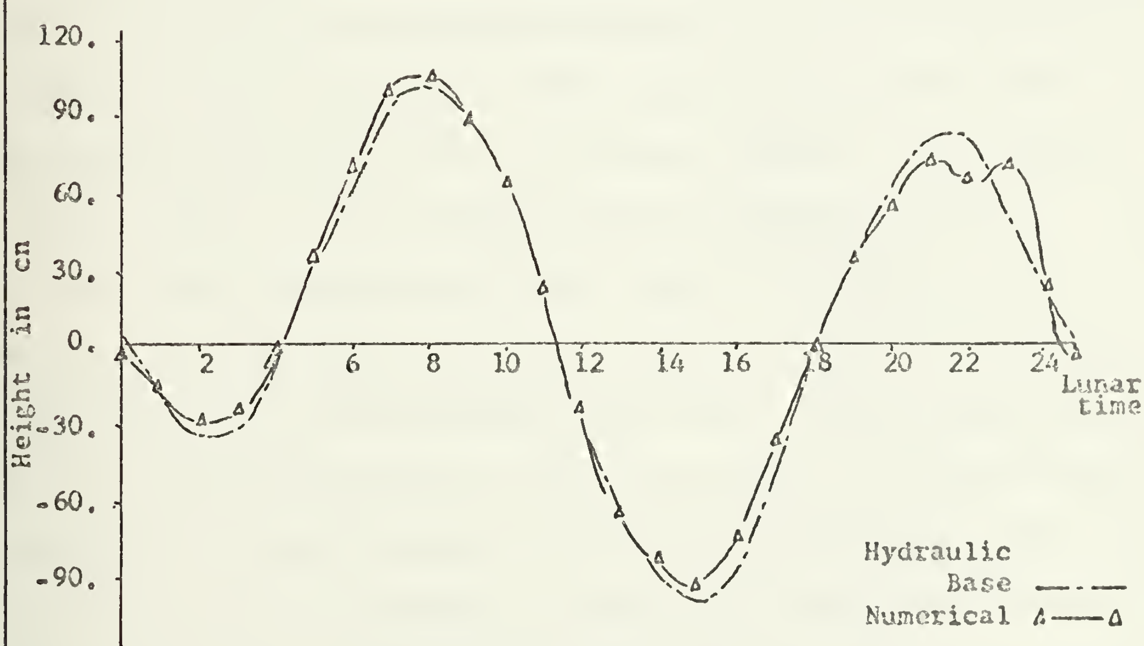


CURRENT AT D-2
MODEL (2)

FIGURE 22



HEIGHT AT PIER N. 2
MODEL (2)



HEIGHT AT SOUTH BAY
MODEL (2)

FIGURE 23

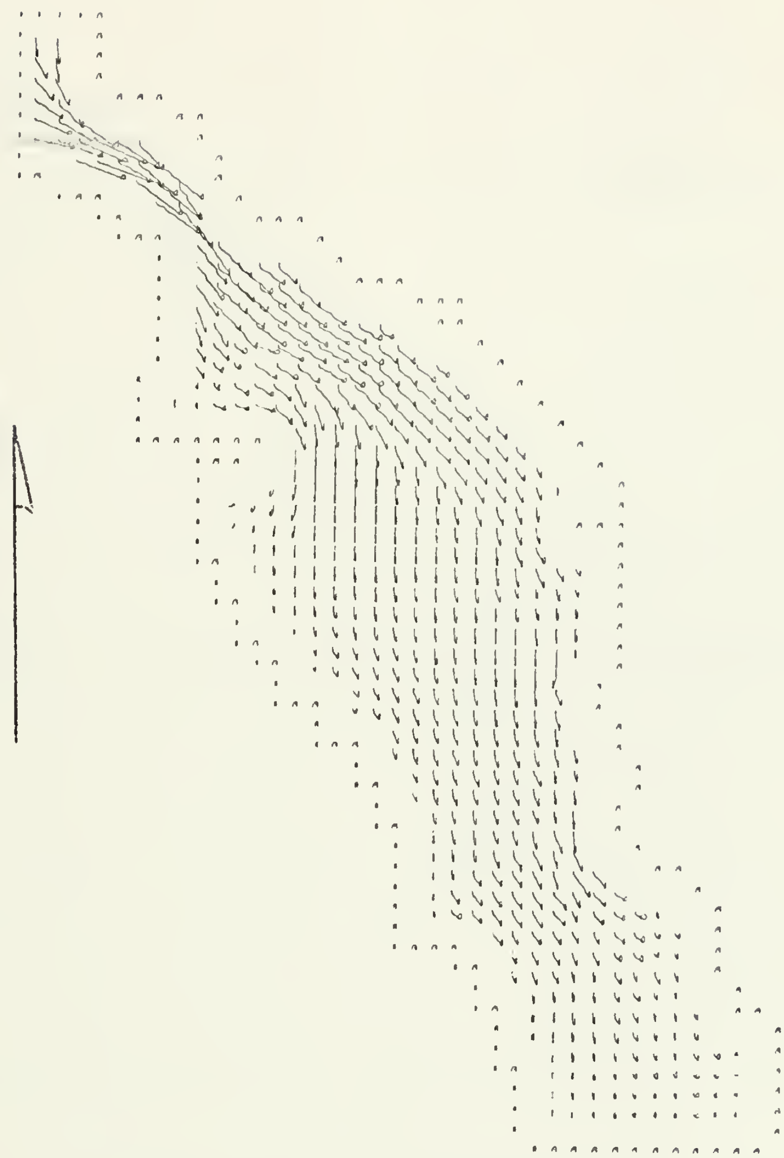
are shown in figures 24 and 25, and of the entire bay in which model (1) and model (2) have been matched is shown in Figures 26, 27, 28. In all of these figures, the direction and magnitude of the flow are represented by the direction and scaled length of the arrows.

E. MODEL (3)

Several alternatives of a second entrance and diffusion were tested by means of the hydraulic model conducted by the U. S. Corps of Engineers. Because the purpose of this work is mainly to make a comparison between different models, only one of the alternate second entrances was examined in the numerical model, and no diffusion study was made.

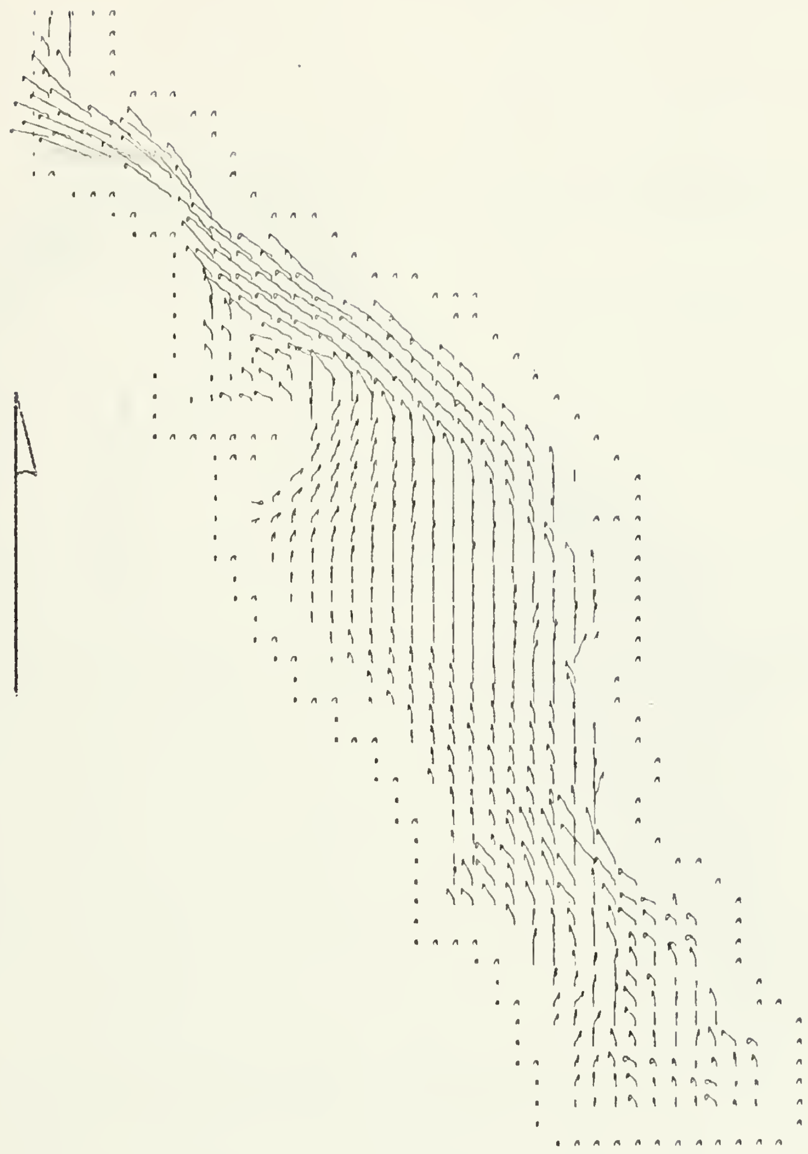
Model (3), with the proposed second open boundary at Crown Cove, was run in a similar manner to model (2). The input for the northern open boundary was obtained from the results of the model (1). The same oceanic tidal values measured at Ballast Point, in Zuniga channel, were chosen for the input at the proposed second channel entrance.

The same currents and tidal values developed in the model (2) using the prescribed conditions with α and R of 0.992 and 0.003 respectively were used. Their characteristics and interpretations were discussed in the previous section. No other values of the tuning parameters were tested because the purpose of this last model is to test model (2) with an additional open entrance.



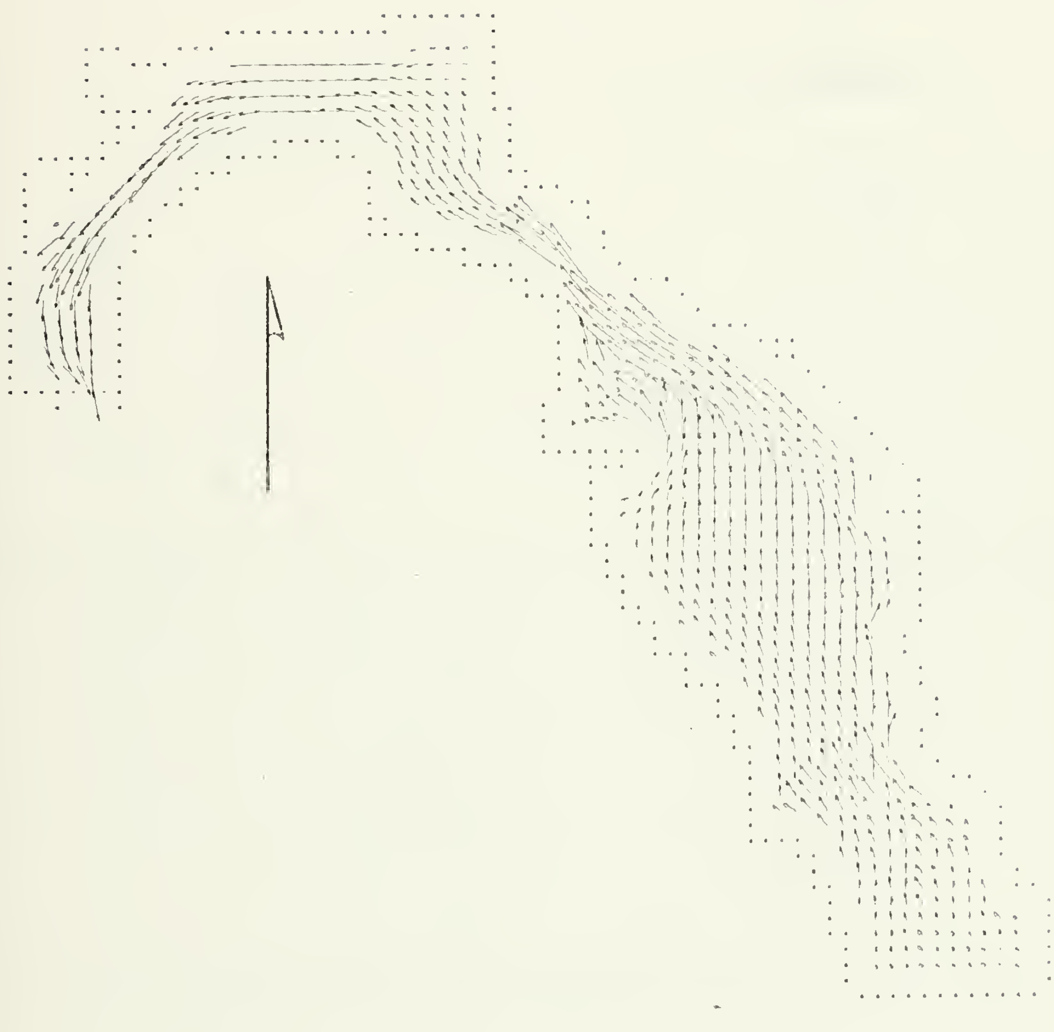
CURRENT DISTRIBUTION IN MODEL (2)
TIME = 3 hr.

FIGURE 24



CURRENT DISTRIBUTION IN MODEL (2)
TIME = 9 hr.

FIGURE 25



CURRENT DISTRIBUTION IN MODELS (1) and (2)
TIME = 9 hr.

FIGURE 26

CURRENT DISTRIBUTION IN MODELS (1) and (2)
TIME = 3 hr.

FIGURE 27

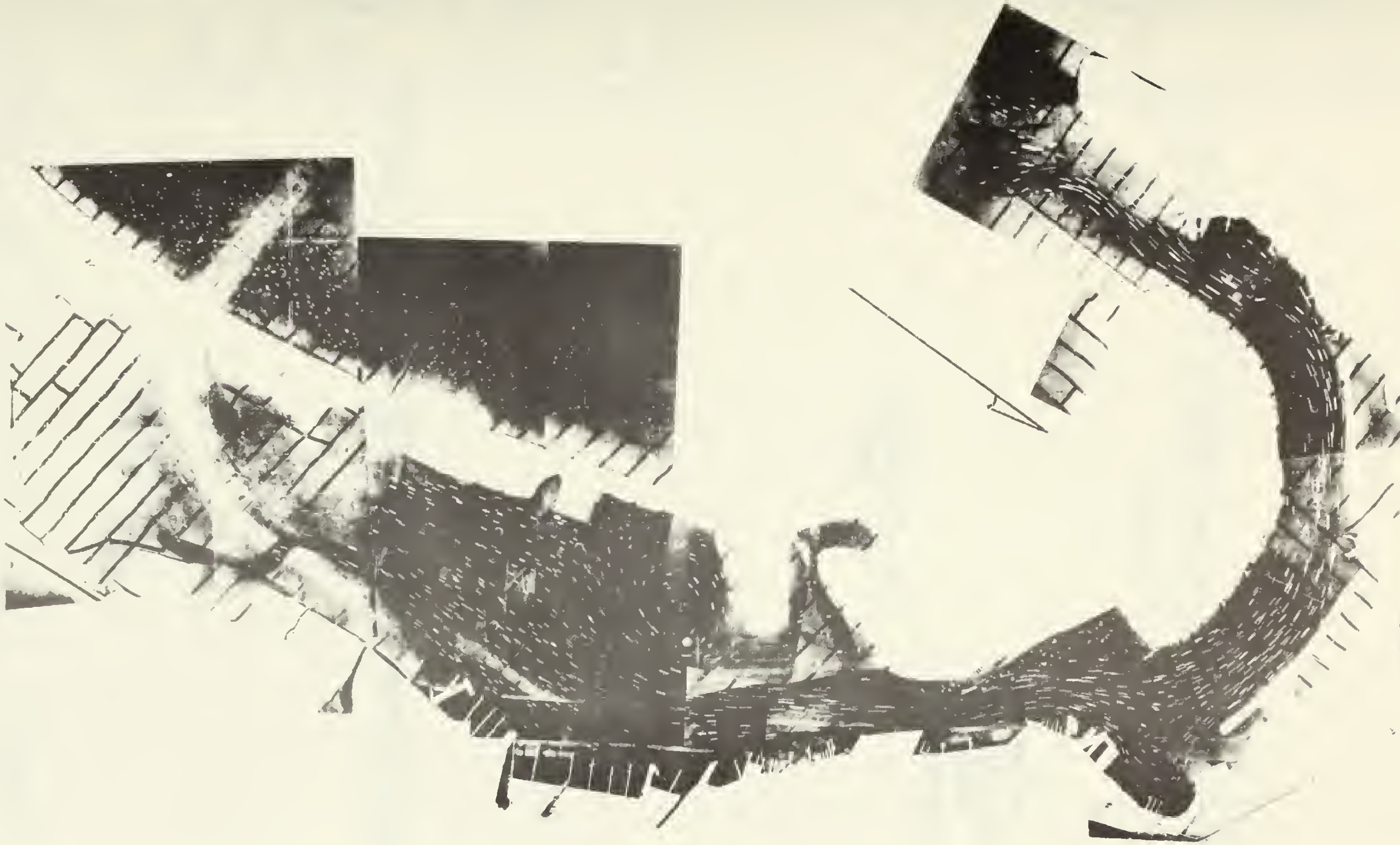
CURRENT DISTRIBUTION IN MODELS (1) and (2)
TIME = 15 hr.

FIGURE 28

The results obtained by the U. S. Corps of Engineers shown in Figures 29 and 30 are compared to the results in currents and height of water for this model shown in Figures 31, 32 and 33. Pictorial representations of the current distributions are shown in Figures 34 and 35. The same representation obtained from the U. S. Corps of Engineers Hydraulic model for the complete Bay with the second open boundary are shown in Figures 36 and 37. In both groups, the flow of water throughout the proposed open entrance seems to be the dominating factor of the circulation in the southern portion of the bay. The northern portion is domained by the northern circulation and a very definite rest area is located between the two systems.

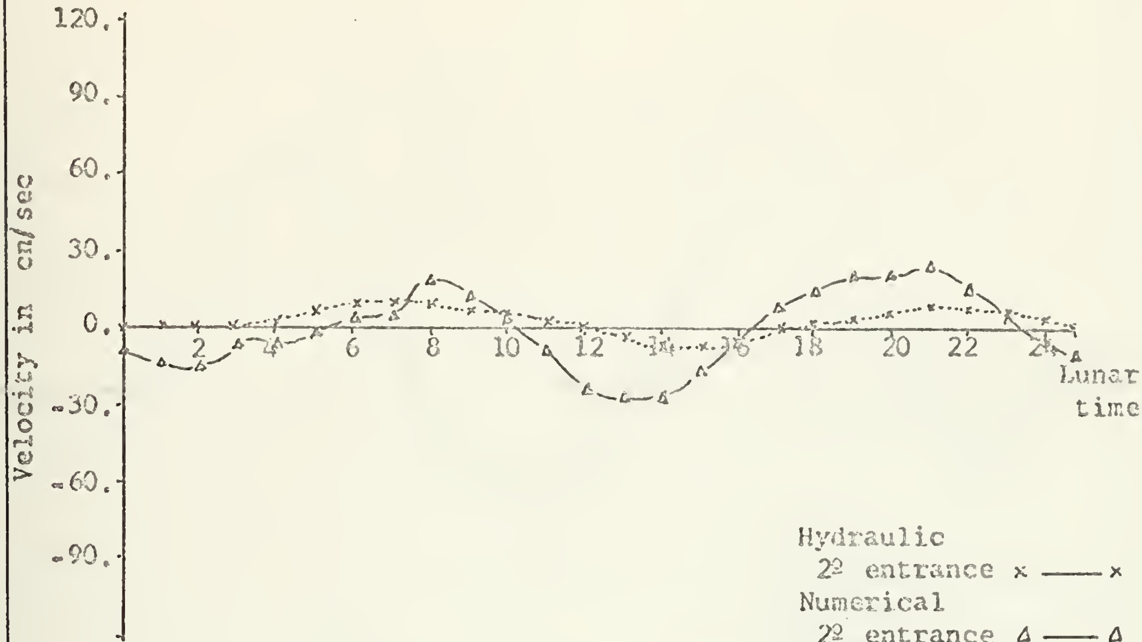
CURRENT DISTRIBUTION HYDRAULIC MODEL (BASE TEST)
TIME = 12 hr.

FIGURE 29)

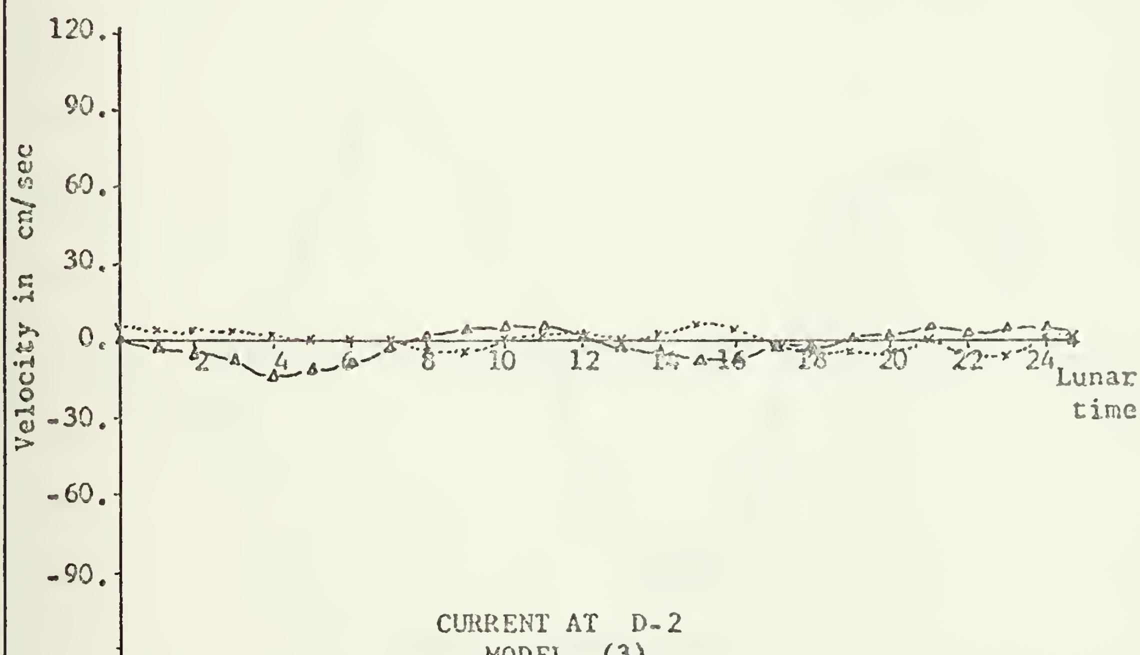


CURRENT DISTRIBUTION HYDRAULIC MODEL (BASE TEST)
TIME = 18 hr.

FIGURE 30

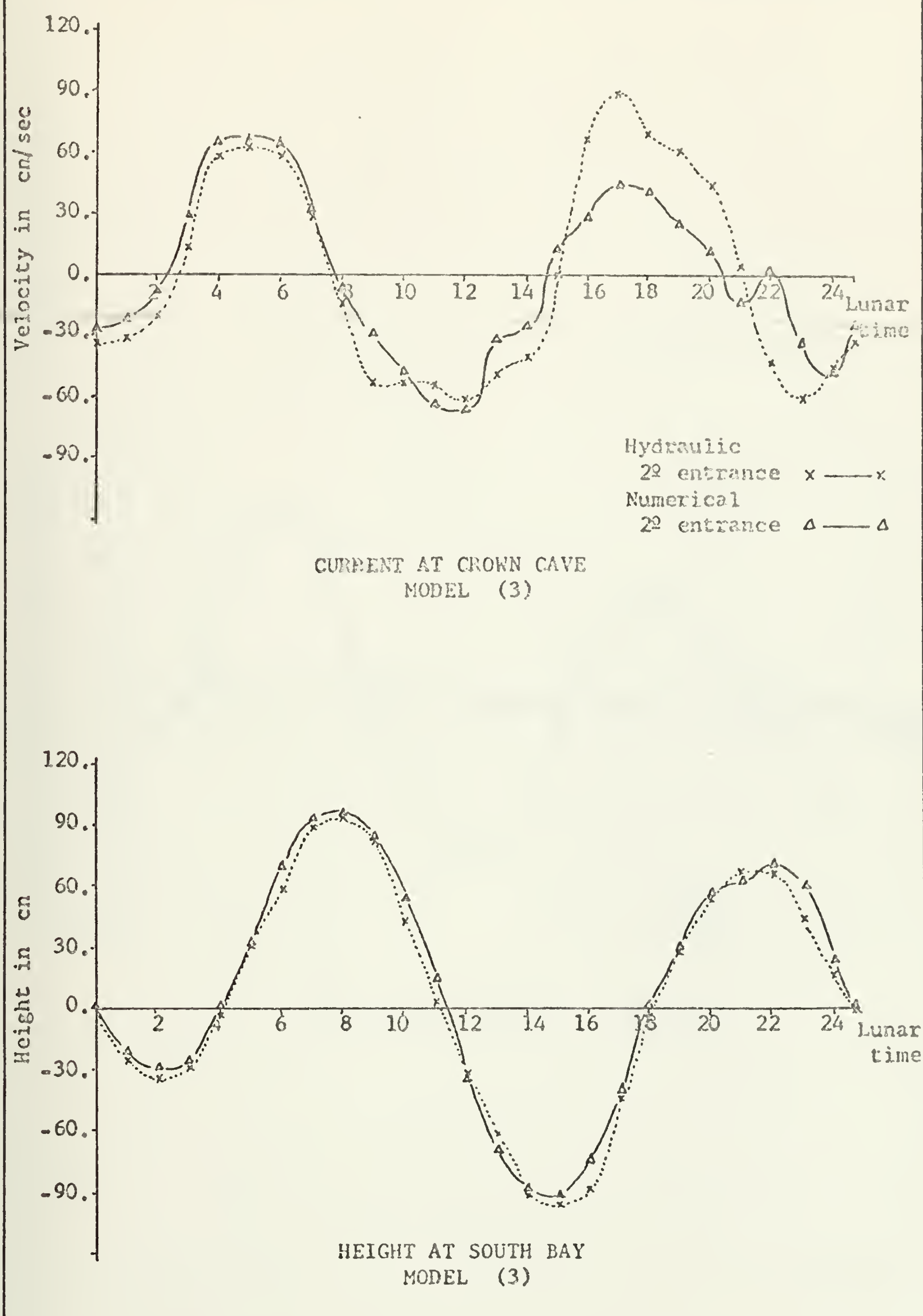


CURRENT AT C-2
MODEL (3)



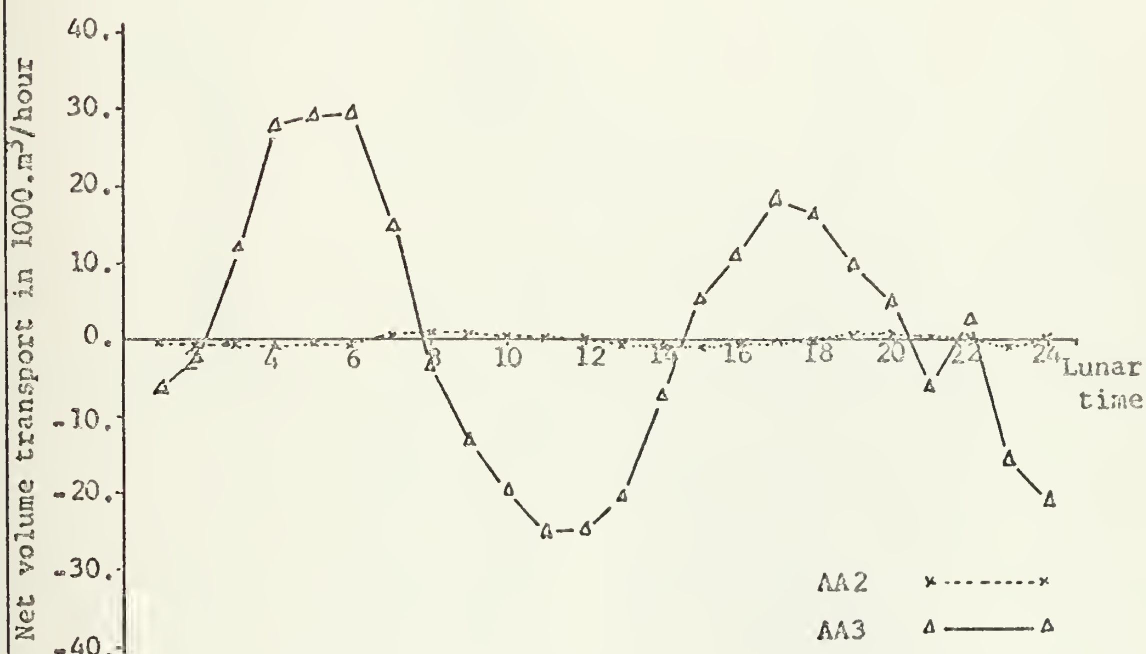
CURRENT AT D-2
MODEL (3)

FIGURE 31



Velocity in cm/sec
120.
90.
60.
30.
0.
-30.
-60.
-90.
2
4
6
8
10
12
14
16
18
20
22
24
Lunar time
Hydraulic
2º entrance x——x
Numerical
2º entrance Δ——Δ
CURRENT AT CROWN CAVE
MODEL (3)
Height in cm
120.
90.
60.
30.
0.
-30.
-60.
-90.
2
4
6
8
10
12
14
16
18
20
22
24
Lunar time
HEIGHT AT SOUTH BAY
MODEL (3)

FIGURE 32



NET VOLUME TRANSPORT MODEL (3)

FIGURE 33

CURRENT DISTRIBUTION MODEL (3)
TIME = 3 hr

FIGURE 34

CURRENT DISTRIBUTION MODEL (3)
TIME = 9 hr

FIGURE 35

CURRENT DISTRIBUTION HYDRAULIC MODEL (PROPOSED SECOND ENTRANCE)
TIME = 12 hr

FIGURE 36

CURRENT DISTRIBUTION HYDRAULIC MODEL (PROPOSED SECOND ENTRANCE)
TIME = 18 hr

FIGURE 37

IV. MERITS OF BOTH THE HYDRAULIC AND NUMBERICAL MODELS

A comparison between both models cannot be made without the results of a proper test of the models under the same conditions and on an area where accurate measurements of actual conditions have been made to compare with their results. The merits of each have previously been enumerated and the goal of this work is to evaluate them.

Before ordering the merits of the numerical and hydraulic models, it is good to recall that for this specific case, the numerical model in discussion (Hansen Model), by definition, is a barotropic (ρ = constant) single-layer model, and the hydraulic model used a constant density fluid. The hydraulic model was based on the Froude similarity concept (inertial and gravitational forces predominate). Although the discussion is restricted by these conditions and are not applicable to general numerical and hydraulic models, these are the most commonly applied types of models.

The spatial resolution of the hydraulic model depends on the length scale and the measuring capability. In the numerical model, topographic features are represented in terms of grid points. To obtain a good representation of bathymetry, small grid size is needed that results in an extremely large array. A compromise between spatial resolution and core size must be reached.

The time resolution in the hydraulic model depends on the similitude criteria and can be scaled to obtain a reliable result. In the numerical model, it is governed by the availability of computer time, i.e., the smaller the time step, the more computer time required.

The scaling in the hydraulic model is given by the similitude criteria. As was pointed out in the section dealing with the hydraulic model, these criteria compromise scales causing distortions in the model and oblige the use of some specific dimensionless number for each specific case. The introduction of distortions in the model limits its uses because some other terms ignored in the selection of the dimensionless number may become important.

In the numerical models, the flow is described by the solution of the equations of motion which includes terms of different orders and degrees. Each term describes some specific characteristic of the flow. The characteristics of the flow will depend on the shape, location, external forces applied, bathymetry, and properties of the fluid. In describing these flows by the equations of motion, some of the terms become dominant and some others can be considered negligible or included in some coefficients. In the case of the Hansen Model, this was accomplished by neglecting the non-linear momentum flux terms. The choosing of the proper terms becomes invalid if improper considerations are done. Then, an improper scaling can invalidate these selected portions of the equation.

Furthermore, the finite solution of this equation does not permit the continuous computation of the flow. The computation is done by time and spatial steps that may cause large errors in the model if proper precautions are not taken. For example, the coefficient of Eddy Diffusion is defined in the finite solution in terms of spatial and time steps. Then, its value becomes affected by the grid size and time step.

Obtaining data from a hydraulic model is difficult and limited by the instruments and the distortion in the scale of the model. Sizes and numbers of the measurement instruments are limited, and the region where these instruments can perform a measurement in the model is restricted by their sizes. In the numerical models, the characteristics of the flow is computed at each grid point; thus, it is available at each point and at each time step. Deficiencies in the differential solutions introduce errors in these grid points in the vicinities of the coast lines and input boundaries. In the hydraulic model, equivalent errors exist in the input boundaries; good resolutions have been claimed for near shore regions that can be questionable because difficulties in the measurements of quantities, such as current speed, in these regions makes it a not always tested assumption. Besides, surface tension becomes important in these regions that compromises the model.

The cost and time are some of the larger limitations in programs and research. Hydraulic models are expensive

and take months and sometimes years to achieve a satisfactory calibration. The use of the numerical models generally decreases considerably these limiting factors. A limitation of numerical models is that they require large computers that are not always available.

Simulated diffusion or dispersion of pollutants has been accomplished in both types of models with comparable results [1 and 5]. In the hydraulic models, this is achieved by direct measurements of dye materials introduced into the model. The conservation of mass equation is used for this computation in the numerical model. All the previous measurement and computation problems are taken into consideration for a proper evaluation of these factors.

V. CONCLUSIONS

The comparisons between the hydraulic and numerical models dealing with the modeling of San Diego Bay and its proposed modifications, are considered separately for general cases and for each of the different tests involved in this study. The Hansen Hydro-numerical Model was applied to the Bay to compare its solution against the U. S. Army Corps of Engineers hydraulic model. The description of both models and the manner of how these numerical and hydraulic models were applied to San Diego Bay has been discussed in detail.

In general, the numerical model is more easily handled for topographic changes than the hydraulic. The latter cannot be stored for future uses after being run as is done with the numerical model because of space limitation. A comparison of time and cost is not possible because no data are available for the model of the U. S. Corps of Engineers. The three numerical models consumed for final runs a total of 7 hours 15 minutes CPU time in the IBM 360/67. Adding an average of three times this amount for calibration, the cost becomes approximately $21,000 (U.S. dollars). It would take about three weeks for a trained programmer to obtain the complete answer for this specific case.

The added easier possibility of including the input of wind gives to the numerical model better ability to represent

the prevailing conditions. The same numerical model can include the wind. Usually completely different hydraulic models must be built to simulate wind because of similitude considerations.

The hydraulic model has better space resolution than the numerical model. A method was tested for transferring boundary values from one numerical model to another to give the model the ability to divide long estuaries into smaller areas improving in this way the resolution of the numerical model. With the use of this method, two different but dependent models were run to represent the complete bay. A constriction in the configuration of the bay was chosen for the overlapping region. A similar procedure is used in the hydraulic model to save space in long hydraulic models. To achieve it, the bay is distorted in a narrow location in a fold-like procedure. The model is calibrated at both sides of the curve. This procedure gives the possibility of dealing with a model of a smaller scale that gives more details of the area, but special care must be taken so as not to introduce errors in the time scale. A similar procedure can be done in the numerical model if the excess area is small and can be accomodated in the free space of the first grid. The possibility of running two completely different hydraulic models seems to be impracticable because of economics.

The numerical model reproduced very well the sea level and currents for the cases tested, provided boundary

treatments are correct. The boundary treatments sometimes are not easily achieved and are a matter of decision in order to represent properly the coast line and channels in the grid. Representation of sea level seems to be equally correct in both models, but the current results seem to be better in the numerical model except near boundaries and shorelines. The seich-like oscillations developed in the numerical model must be taken into consideration if the model is to be representative of the total bay. If only a part of the bay is under consideration (for example model (2)), the sieche oscillations should be smoothed out because they are not representative of the bay.

No comparison can be made of net volume transport because no evaluation in the hydraulic model is available. These computations were made in the numerical model based on the computed velocities. The computed values seem to be reliable enough.

It was pointed out in the section dealing with model (2), that the boundary conditions in the numerical model must be given special treatment when the area becomes dry during low tide. A minimum depth of 120 cm was fixed in the numerical model in order to prevent any problem, and the southern extreme of the bay was eliminated because its depth was below 50 cm. No special problem seems to appear in hydraulic models, for the case of portions of the area becoming dry, but special care must be taken if areas become shallower than 1 cm. because then surface tension is important. This

minimum depth had not been discussed in previous literature for numerical models, and no attempt to evaluate these conditions was made in this study.

In the model with the proposed second entrance, the initial assumption of increasing the flushing of the bay seems to be reasonable. The circulation of the southern portion of San Diego Bay will be almost entirely governed by the second entrance. But, from the computed net volume transport in the section AA2, it is shown that the interchange of water between the northern and southern portion of the bay at this section will be almost negligible. Comparing the pictorial representations of both models for this special case, an area of decrease of current speed can be noticed between Pier No. 2 and D-2 gages where both models indicate that the flow of the bay will be divided into two separate systems and the projected second entrance will provide the water for the southern system. This would result in decreased dispersion of pollutants introduced to the bay in this region.

APPENDIX A

NUMERICAL PROGRAMS

```
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<*>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
                 HANSEN'S HYDRODYNAMICS MODEL
                      SAN DIEGO BAY (1)
                               OF LEOPOLDO SALAS R.
<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<*>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
      LIST OF PARAMETERS IN THE PROGRAM
*************************************************************************

    M             GRID INDEX(PARALLEL TO ENTRANCE)
    N             GRID INDEX(PERPENDICULAR TO ENTRANCE)

    Z(N,M)        WATER ELEVATION (CN)
    U(N,M)        U-COMPONENT OF VELOCITY (CN/SEC)

    V(N,M)        V-COMPONENT OF VELOCITY (CM/SEC)
    RAD(N,M)      RESULTANT CURRENT SPEED (CM/SEC)
    ANG(N,M)      ANGLE (FROM GEOGRAPHIC NORTH) OF RESULTANT CURRENT
                  SPEED (THE CURRENT DIRECTION)

    QU(N,M)       FIELDS FOR SUMMATION OF U AND V COMPENENTS OF CURR
    QV(N,M)       ENTS FOR COMPUTATION OF REST CURRENTS

    REST(N,M)     AVERAGE SPEED OF REST CURRENT (CM/SEC)
    DIR(N,M)      DIRECTION OF REST CURRENT (IN GEOGRAPHIC COORDINAT
                  ES)

    ZM(N,M)       USED IN J05 AS INTERMEDIATE FOR SMOOTHING
    ZST(N,M)      USED IN J05 AS INTERMEDIATE FOR AVERAGING

    HTZ(N,M)      SYMBOLIC WATER DEPTHS AT WATER ELEVATION (Z) POINT

                  HTZ = 1 INNER POINT (OVER WATER)
                  HTZ = 0 OUTER POINT (OVER LAND)
                  HTZ = -1 NORMAL BOUNDARY POINT
                  HTZ = -2 POINT ON OPEN (ENTRANCE) BOUNDARY

    HTU(N,M)      WATER DEPTH AT U POINTS
    HTV(N,M)      WATER DEPTH AT V POINTS
                  INNER POINT    HTU, HTV = DEPTH (CM)
                  OUTER POINT    HTU, HTV = 0
                  BOUNDARY POINT HTU, HTV = -1
```

```
HGU(N,M)        ACTUAL WATER DEPTH AT U POINTS (HGU = HTU+Z)
HGV(N,M)        ACTUAL WATER DEPTH AT V POINTS (HGV = HTV+Z)

XK(N,M)         U COMPONENT OF WIND CURRENT DIVIDED BY DEPTH
YK(N,M)         V COMPONENT OF WIND CURRENT DIVIDED BY DEPTH

Q(N,M)          FIELDS USED FOR A SPECIAL COMPUTATION (NOT SHOWN
VAC(N,M)        IN THE PROGRAM)

A(I)            CHARACTERISTICS OF THE WIND FIELD
A(I)            TIME WHEN WIND STARTS (SEC)
A(2)            WIND SPEED (M/SEC)
A(3)            WIND DIRECTION (DEGREES COUNTED COUNTERCLOCKWISE
                FROM 0 GRID COORDINATE)

NU(I)           WIND FIELD DELIMETERS (N AND M COORDINATES OF THE
MN(I)           UPPER AND LOWER LEFT CORNERS OF THE WIND FIELD)

NZ(I)           COORDINATES (N,M) OF OPEN (ENTRANCE) BOUNDARY POIN
MZ(I)           TS (I=1,11) SELECTED POINTS (I=12,24)

NA(I)           COORDINATES (N,M) OF THE BOUNDARY POINTS AT THE SE
MA(I)           COND OPEN BOUNDARY

Z1(I)           AMPLITUDES OF FOUR DIFFERENT TIDAL COMPONENTS AT
Z2(I)           THE OPEN BOUNDARY (CM)
U1(I)
U2(I)

Z3(I)           AMPLITUDES OF FOUR DIFFERENT TIDAL COMPONENTS AT
Z4(I)           THE SECOND OPEN BOUNDARY (CM)
U3(I)
U4(I)

X(I)            INTERMEDIATE PARAMETERS IN J03 AND J05 FOR COMPUTA
ARG(I)          TION OF ASTRONOMICAL TIDES AT OPEN (ENTRANCE) BOUN
                DARY

Y(I)            INTERMEDIATE PARAMETERS FOR TIDAL COMPUTATIONS AT
CON(I)          THE OPEN BOUNDARY

V1(I)           NAMES OF SELECTED POINTS
V2(I)           WATER ELEVATION AT SELECTED SPECIAL POINTS
V3(I)           SPEED OF CURRENT AT SPECIAL POINTS
V4(I)           DIRECTION OF CURRENT AT SPECIAL POINTS

AFGN            ARBITRARY PROBLEM NUMBER
```

```
F              CORIOLIS PARAMETER (SEC-1)
G              GRAVITY ACCELERATION (CM SEC2)
SIGMA          ANGULAR VELOCITY OF M2- TIDE (RADIANS/SEC) (USED
               IN COMPUTATIONS WHERE M2 TIDE ONLY IS ENTERED AT
               THE OPEN BOUNDARY)
ALPHA          SMOOTHING PARAMETER (USUALLY 0.92 TO 0.99)
R              FRICTION COEFFICIENT (0.003)
ROL            DENSITY OF THE AIR (GM CM-3) (1-162( X 10-3)
RBETA          COEFFICIENT OF GEOSTROPHIC WIND (USUALLY 0.65)
C              DRAG COEFFICIENT (3.2X10-6)
DL             1/2 STEP IN SPACE (CM) (1/2 OF GRID SIZE)
DT             1/2 STEP IN TIME (SEC)
T              TIME (SEC)
T1             TIME INTERVAL BETWEEN FIELD PRINTOUTS (SEC)
T2             FIELD OUTPUT COUNTER (SEC)
T3             INITIAL TIME COUNT FOR PLOT PROGRAM
NE             DELIMETERS OF ENTIRE FIELD (THE GRID SIZE)
ME
TE             END TIME OF COMPUTATION (SEC)
KKE            NUMBER OF A(I) (NUMBER OF WIND FIELDS)
IZE            NUMBER OF OPEN (ENTRANCE) BOUNDARY POINTS
NG             NUMBER OF POINTS AT SECOND OPEN BOUNDARY
IUE            TWICE THE NUMBER OF WIND FIELDS
TW             TIME WHEN THE WIND STARTS (SEC)

TIC
LEN            COUNTERS
POC
TRAN           SUMMATION OF TRANSPORT THROUGH A SPECIFIED SECTION

BETA           (1-ALFA)/4
A1             2(DT)
A2             F(A1)                INTERMEDIATE PARAMETERS
A3             R(A1)
A4             DT/DL
A5             G(A4)

C1             O FI NO WIND, ELSE ANY VALUE DIFFERENT THAN 0
CE             C(A(2))X(10000)

NOTE     10000 IS UNIT CONVERSION FACTOR. A(2) IS READ IN AS M/SEC
         AND MUST BE CHANGED TO CM/SEC AFTER BEING SQUARED

SI             TIME WHEN WIND STOP
NURU           NUMBER OF SELECTED POINTS
NURV           PRINTOUT LINE LINE COUNTER USED IN S08
JA             INDICATOR    JA DIFF. 0 READ INITIAL VALUES
                            JA EQAL. 0 SET Z,U,V=0
```

```
NEH              NE-1
MEH              ME-1
NEHH             NE-2
MEHH             NE-2

WERTO            USED IN J05 AS INTERMEDIATE STORAGE LOCATIONS FOR U
WERTU            AND V VALUES DURING SMOOTHING AND AVERAGING OPERATIO
WERTL            NS
WERTR
WERTOL
WERTOR
WERTUL
WERTUR
WURZEL           SQRT(ZM**2+ZST**2)
GRZ              A3(WURZEL)

T3,T4,STV,ETV,TINCV,STH,ETH,TINCH  ARE PARAMETERS USED IN THE
    PLOTTING PROGRAM

T2               START TIME FOR STORING SPECIAL VALUES ON CYLINDER
                 USUALY SET TO ZERO.WHEN JA=1,SET TO STARTING TIME
T3               START TIME FOR PRINTING VALUE ARRAYS HORIZONTALLY
ETH              TIME OF THE LAST WATER HEIGT PLOT
ETV              TIME OF THE LAST VECTOR PLOT
TINCH            TIME INCREMENT BETWEEN WATER HEIGHT PLOT
TINCV            TIME INCREMENT BETWEEN VECTOR PLOTS
STH              TIME OF THE FIRST WATER HEIGHT PLOT.MOST BE GREATER
                 THAN T2 AND LESS THAN (T+T1+T1/2)
STV              TIME OF THE FIRST VECTOR PLOT.MOST BE GREATER THAN T2
                 AND LESS THAN (T+T1+T1/2)
HT               PLOT FLAG FOR WATER HEIGHTS
                      0 = DO NOT PLOT
                      1 = PLOT
VEC              PLOT FLAG FOR VECTOR PLOTS AND A CONTROL FLAG FOR D01
                      0 = DO NOT PLOT
                      1 = PLOT

NALL             COUNT OF THE NUMBER OF PLOTS EXPECTED
TE1              TIME SAVED FOR START AND END OF THE PROGRAM

AA1
AA2              PROFILES FOR MASS COMPUTATIONS
```

```
************************************************************************
************************************************************************
                      THE DATA IMPUT CARDS
************************************************************************

CARD 1        FORMAT 24I3

JA,NE,ME,IZE,IUE,KKE,NURU,NG

CARD 2        FORMAT 9F8.3

AFGN,G,ALPHA,RBETA,C1

CARD 3        FORMAT 9F8.0

DT,TE,TW,T1,T2,SI,T,T3

   DT         102 TIME STEP (SEC)
   TE         LENGTH OF THE COMPUTATION
   TW         TIME WHEN WIND START
   T1         TIME INTERVAL BETWEEN PRINTPOINTS
   T2         FIELD OUTPUT COUNTER (O IF OUTPUT DESIRED FROM START
              OF THE COMPUTATION,OTHERWISE ANY OTHER DELAYED
              STARTING TIME.MOST BE GRATEROR EQUAL THAM  T+A1
   SI         TIME WHEN WIND STOP
   T          TIME (INIZIALIZED 0. IF PREVIOUS COMPUTATIONS MADE
              AND Z,U,V,READ FROM TAPE,GIVE THE TIME PREVIOUS
              COMPUTATION ENDED.)
   T3         IF PLOT DESIRED,TIME WHEN FIELD ARE REQUIRED FOR
              PLOTING

CARD 4        FORMAT 6E12.4

DL,F,SIGMA,R,ROL,C

CARD 5        FORMAT 24I3

NZ,MZ         (FIRST BOUNDARY)

CARD 6        FORMAT 24I3

NZ,MZ         (SECOND BOUNDARY)

CARD 7        FORMAT 24I3
```

```
NU,MU
CARD 8        FORMAT 26I3
NA,MA
CARD 9        FORMAT 10A4
V1(I)
CARD 10       FORMAT 9F8.2
A(I)
CARD 11       FORMAT 12F6.0
HTZ
CARD 12       FORMAT 12F6.0
HTU
CARD 13       FORMAT 12F6.0
CARD 14       FORMAT 9F8.3
Z1,Z2,U1,U2
CARD 15       FORMAT 9F8.3
Z3,Z4,U3,U4
CARD 16       FORMAT (A8,2X,3F10.0)
HEAD,STV,ETV,TINCV
CARD 17       FORMAT (A8,2X,3F10.0)
HEAD1,STH,ETH,TINCH
Z3( ) Z4( )  TIDE COEFF.        BALAST POINT
Z5( ) Z6( )  TIDE COEFF.        PIER N. 2
Z7( ) Z8( )  TIDE COEFF.        NAVY PIER
Z9( ) Z10( ) TIDE COFF.         SOUTH BAY
*******************************************************************
```

SAN DIEGO BAY AREA   PROGRAM 1

```
      COMMON/A/Z(53,30),U(53,30),V(53,30),ZM(53,30),ZST(53,30),
     1HGV(53,30),HGU(53,30),HTU(53,30),HTV(53,30),HTZ(53,30),XK(53,30),
     2YK(53,30),RAD(53,30),ANG(53,30),Q(53,30)
      COMMON/B/A(60),NZ(90),MZ(90),NU(60),MU(60),Z1(60),Z2(60),V1(60),
     1V2(60),U1(60),U2(60),V3(60),V4(60),X(4),ARG(4),NA(60),MA(60),
     2Z3(12),Z4(12),Z5(8),Z6(8),Z7(8),Z8(8),Z9(8),Z10(8)
      COMMON/C/ AFGN,F,AA1,AA2
     3,G,SIGMA,ALPHA,R,ROL,RBETA,C,DL,DT,T,T1,T2,NE,ME,TE,KKE,IZE,IUE,TW
     4,BETA,A1,A2,A3,A4,A5,C1,C3,SI,NURJ,NURV,JA,NEH,MEH,NEHH,MEHH,NG
     5,T3,STV,ETV,TINCV,STH,ETH,TINCH,HT,VEC,NALL,TE1
      REAL*8 V1
      REWIND 1
      REWIND 2
      REWIND 3
      REWIND 8
      NALL=0
      CALL J02
      CALL J03
      CALL DB1
      IF(JA)2,21,2
   21 CONTINUE
    1 CALL J04
      CALL DB2
      T2=T2+T1
    2 T=T+A1
      CALL J05
      IF(T-TE) 3,5,5
    3 IF(ABS(T-T2)-A1/2.) 1,1,4
    4 GO TO 2
    5 CONTINUE
      CALL J04
      CALL DB2
      CALL S08
      CALL J06
      STOP
      END
```

```
      SUBROUTINE J02
J02       READING THE CONSTANTS AND DEPTHS
      COMMON/A/Z(53,30),U(53,30),V(53,30),ZM(53,30),ZST(53,30),
     1HGV(53,30),HGU(53,30),HTU(53,30),HTV(53,30),HTZ(53,30),XK(53,30),
     2YK(53,30),RAD(53,30),ANG(53,30),O(53,30)
      COMMON/B/A(60),NZ(90),MZ(90),NU(60),MJ(60),Z1(60),Z2(60),V1(60),
     1V2(60),U1(60),U2(60),V3(60),V4(60),X(4),ARG(4),NA(60),MA(60),
     2Z3(12),Z4(12),Z5(8),Z6(8),Z7(8),Z8(8),Z9(8),Z10(8)
      COMMON/C/ AFGN,F,AA1,AA2
     3,G,SIGMA,ALPHA,R,RCL,RBETA,C,DL,DT,T,T1,T2,NE,ME,TE,KKE,IZE,IUE,TW
     4,BETA,A1,A2,A3,A4,A5,C1,C3,SI,NURJ,NURV,JA,NEH,MEH,NEHH,MEHH,NG
     5,T3,STV,ETV,TINCV,STH,ETH,TINCH,HT,VEC,NALL,TE1
      REAL*8 V1
    3 FORMAT(1X,45HWIND INPUT(STARTING TIME,MAGNITUDE,DIRECTION),//,15F8
     1.2//)
  100 FORMAT(9F8.2)
  101 FORMAT(10A8)
  102 FORMAT(26I3)
  103 FORMAT(9F8.3)
  104 FORMAT(9F8.0)
  105 FORMAT(6E12.4)
  106 FORMAT(12F6.0)
  110 FORMAT(' ',//////////,'PROBLEM NUMBER  ',F8.3,'  SAN DIEGO BAY
     1 PART  A',/////)
  112 FORMAT(5X,19HHALF TIME STEP DT =,F5.0,5H  SEC,29X,20HHALF SPACE ST
     1EP DL =,E11.4,4H  CM///)
  113 FORMAT(5X,27HSMOOTHING PARAMETER ALPHA =,F6.3,25X,24HFRICTION COEF
     1FICIENT R =,E11.4///)
  114 FORMAT(5X,22HCORIOLIS PARAMETER F =,E11.4,7H  1/SEC,16X,39HANGULAR
     1 VELOCITY OF THE M2-TIDE SIGMA =,E11.4,7H  1/SEC/////)
  115 FORMAT(5X,13HWIND IS CALM./////)
  116 FORMAT(5X,21HTHE WIND BEGINS AFTER,F7.0,6H  SEC.,19X,13HAIR DENSIT
     1Y =,E11.4,6H  G/CC///)
  117 FORMAT(5X,23HREDUCTION FACTOR BETA =,F6.3,26X,25HDRAG COEFFICIENT
     1LAMBDA =,E11.4,11H (CONSTANT)/////)
  119 FORMAT(5X,43HTHERE ARE NO Z POINTS ON THE OPEN BOUNDARY.)
  120 FORMAT(5X,54H(N,M) COORDINATES OF THE Z POINTS ON THE OPEN BOUNDAR
     1Y//5X,12(1H(,I2,1H,,I2,1H),2X)//5X,12(1H(,I2,1H,,I2,1H),2X)//5X,5(
     11H(,I2,1H,,I2,1H),2X)//)
  121 FORMAT(1H1,14X,36HSYMBOLIC WATER DEPTH AT THE Z POINTS///7X,I7,18I
     17/)
  122 FORMAT(///8X,I7,18I7/)
  123 FORMAT(1H1,14X,32HWATER DEPTH AT THE U POINTS (CM)///6X,18I7/)
  124 FORMAT(1H1,14X,32HWATER DEPTH AT THE V POINTS (CM)///6X,18I7/)
  125 FORMAT(5X,54H(N,M) COORDINATES OF THE Z POINTS SECOND OPEN BOUNDAR
     1Y//5X,12(1H(,I2,1H,,I2,1H),2X)//5X,12(1H(,I2,1H,,I2,1H),2X)//5X,5(
```

```
   11H(,I2,1H,,I2,1H),2X)//)
130 FORMAT(I7,18F7.0)
131 FORMAT(///7X,I7,18I7/)
132 FORMAT(I7,12F7.0)
133 FORMAT(I7,17F7.0)
134 FORMAT(8F10.6)
135 FORMAT('                    TIDAL COEFFICIENTS',//,30X,6F12.5,//)
140 FORMAT(I4,9(F5.0,2X,F7.0))
141 FORMAT(I4,9(F7.0,7X))
142 FORMAT(///,I11,9(7X,I7),/)
701 FORMAT(12(F5.2,1X))
702 FORMAT(6(F5.2,1X))
    READ 102,JA,NE,ME,IZE,IUE,KKE,NURU,NG
    READ 103,AFGN,G,ALPHA,RBETA,C1
    READ 104,DT,TE,TW,T1,T2,SI,T,T3
    READ 105,DL,F,SIGMA,R,ROL,C
    READ 102, (NZ(I),MZ(I),I=1,IZE)
    IN=IZE+1
    INN=IZE+NURU
    READ 102,(NZ(I),MZ(I),I=IN,INN)
    READ 102,(NU(I),MU(I),I=1,IUE)
    READ 102,(NA(I),MA(I),I=1,NG)
    READ 101,(V1(I),I=1,NURU)
    READ 100,(A(I),I=1,KKE)
    READ 134,(Z3(N),Z4(N),N=1,4)
    READ 134,(Z3(N),Z4(N),N=5,8)
    READ 134,(Z3(N),Z4(N),N=9,11),Z3(12)
    READ 134,(Z5(N),Z6(N),N=1,3),Z5(4)
    READ 134,(Z7(N),Z8(N),N=1,3),Z7(4)
    PRINT 135,(Z3(N),Z4(N),N=1,11),Z3(12)
    PRINT 135,(Z5(N),Z6(N),N=1,3),Z5(4)
    PRINT 135,(Z7(N),Z8(N),N=1,3),Z7(4)
    NEH=NE-1
    MEH=ME-1
    NEHH=NE-2
    MEHH=ME-2
    DO 713 N=1,NE
    READ(5,701)(HTZ(N,M),M=1,12)
    READ(5,701)(HTZ(N,M),M=13,24)
    READ(5,702)(HTZ(N,M),M=25,ME)
713 CONTINUE
    DO 714 N=1,NE
    READ(5,701)(HTU(N,M),M=1,12)
    READ(5,701)(HTU(N,M),M=13,24)
    READ(5,702)(HTU(N,M),M=25,ME)
714 CONTINUE
    DO 715 N=1,NE
    READ(5,701)(HTV(N,M),M=1,12)
```

```
      READ(5,701)(HTV(N,M),M=13,24)
      READ(5,702)(HTV(N,M),M=25,ME)
  715 CONTINUE

      SET THE MINIMUM DEPTH

      DO 50  N=1,NE
      DO 50  M=1,ME
      IF(HTU(N,M).LT.4..AND.HTU(N,M).GT.0.)HTU(N,M)=4.
      IF(HTV(N,M).LT.4..AND.HTV(N,M).GT.0.)HTV(N,M)=4.
   50 CONTINUE

      PRINT CONTROL DATA

      PRINT 110,AFGN
      PRINT 112,DT,DL
      PRINT 113,ALPHA,R
      PRINT 114,F,SIGMA
      IF(C1)2,1,2
    1 PRINT 115
      GO TO 5
    2 PRINT 116,TW,ROL
      PRINT 117,PBETA,C
      PRINT 3,(A(I),I=1,KKE)
    5 IF(IZE)6,6,7
    6 PRINT 119
      GO TO 8
    7 PRINT 120,(NZ(I),MZ(I),I=1,IZE)
      PRINT 125,(NA(I),MA(I),I=1,NG)
    8 PRINT 121,(N,N=1,18)

      PRINT THE FIELDS

      PRINT 130,(N,(HTZ(N,M),M=1,18),N=1,NE)
      PRINT 131,(N,N=19,30)
      PRINT 132,(N,(HTZ(N,M),M=19,30),N=1,NE)
      PRINT 123,(N,N=1,18)
      PRINT 130,(N,(HTU(N,M),M=1,18),N=1,NE)
      PRINT 131,(N,N=19,30)
      PRINT 132,(N,(HTU(N,M),M=19,30),N=1,NE)
      PRINT 124,(N,N=1,18)
      PRINT 130,(N,(HTV(N,M),M=1,18),N=1,NE)
      PRINT 131,(N,N=19,30)
      PRINT 132,(N,(HTV(N,M),M=19,30),N=1,NE)

WRITING OUT DEPTH GRID AT U,V POINTS SIMULTANEOUSLY

      PRINT 142,(M,M= 1, 9)
```

```
      DO 21  N=1,NE
      PRINT  140,(N,(HTZ(N,M),HTU(N,M),M=1, 9))
      PRINT  141,(N,(HTV(N,M),M= 1, 9))
   21 CONTINUE
      PRINT  142,(M,M=10,18)
      DO 22  N=1,NE
      PRINT  140,(N,(HTZ(N,M),HTU(N,M),M=10,18))
      PRINT  141,(N,(HTV(N,M),M=10,18))
   22 CONTINUE
      PRINT  142,(M,M=19,27)
      DO 23  N=1,NE
      PRINT  140,(N,(HTZ(N,M),HTU(N,M),M=19,27))
      PRINT  141,(N,(HTV(N,M),M=19,27))
   23 CONTINUE
      PRINT  142,(M,M=28,30)
      DO 24  N=1,NE
      PRINT  140,(N,(HTZ(N,M),HTU(N,M),M=28,30))
      PRINT  141,(N,(HTV(N,M),M=28,30))
   24 CONTINUE
      BETA=(1.-ALPHA)/4.
      A1=2.*DT
      A2=F*A1
      A3=R*A1
      A4=DT/DL
      A5=G*A4
      C3=C*A1*10000.
      AA1=0.
      AA2=0.
      REWIND 4
      WRITE(4) HTZ,V1,NURU,ME,NE
      ENDFILE 4
      RETURN
      END
```

```
      SUBROUTINE J03
C J03      READING THE BEGINNING VALUES
      COMMON/A/Z(53,30),U(53,30),V(53,30),ZM(53,30),ZST(53,30),
     1HGV(53,30),HGU(53,30),HTU(53,30),HTV(53,30),HTZ(53,30),XK(53,30),
     2YK(53,30),RAD(53,30),ANG(53,30),O(53,30)
      COMMON/B/A(60),NZ(90),MZ(90),NJ(60),MJ(60),Z1(60),Z2(60),V1(60),
     1V2(60),U1(60),U2(60),V3(60),V4(60),X(4),ARG(4),NA(60),MA(60),
     2Z3(12),Z4(12),Z5(8),Z6(8),Z7(8),Z8(8),Z9(8),Z10(8)
      COMMON/C/ AFGN,F,AA1,AA2
     3,G,SIGMA,ALPHA,R,ROL,RBETA,C,DL,DT,T,T1,T2,NE,ME,TE,KKE,IZE,IJE,TW
     4,BETA,A1,A2,A3,A4,A5,C1,C3,SI,NUPU,NURV,JA,NEH,MEH,NEHH,MEHH,NG
     5,T3,STV,ETV,TINCV,STH,ETH,TINCH,HT,VEC,NALL,TE1
      REAL*8 V1
  100 FORMAT(9F8.3)
  113 FORMAT(18F4.1)
 2000 FORMAT('   PROBLEM INITIATED FROM PREVIOUS COMPUTATION WITH TIME
     1 =   ',F10.0,'    SECONDS',////)
C CONVERT THE DEPTH'S CHART IN FEET TO CENTIMITERS
      DO 3 N=1,NE
      DO 3 M=1,ME
      IF(HTU(N,M).LE.0)GO TO 21
      HTU(N,M)=HTU(N,M)*30.48
   21 CONTINUE
      IF(HTV(N,M).LE.0)GO TO 22
      HTV(N,M)=HTV(N,M)*30.48
   22 CONTINUE
    3 CONTINUE
C     READ CONTINUATION VALUES WHEN PREVIOUS COMPUTATION EXIST
      IF(JA)2,7,2
    2 READ(8) ((Z(N,M),M=1,ME),N=1,NE),
     1        ((U(N,M),M=1,ME),N=1,NE),
     2        ((V(N,M),M=1,ME),N=1,NE),
     3        ((HGU(N,M),M=1,ME),N=1,NE),
     4        ((HGV(N,M),M=1,ME),N=1,NE),
     5        TE1
      WRITE(6,2000)TE1
      GO TO 14
C     CLEAN THE ARRAIES
```

```
      SET INITIAL WATER ELEVATIONS
    7 DO 12 N=1,NE
      DO 12 M=1,ME
      Z(N,M)=0.
      U(N,M)=0.
      V(N,M)=0.
   12 CONTINUE

      SET SMALL VALUES TO PREVENT UNDERFLOW

      DO 30 N=1,NE
      DO 30 M=1,ME
      IF(HTZ(N,M))30,30,31
   31 Z(N,M)=0.2
   30 CONTINUE
      DO 32 N=1,NE
      DO 32 M=1,ME
      IF (HTU(N,M))34,34,33
   33 U(N,M)=0.2
   34 IF(HTV(N,M))32,32,35
   35 V(N,M)=0.2
   32 CONTINUE

      INITIALIZATION OF ACTUAL DEPTH

   15 DO 14 N=1,NE
      DO 14 M=1,ME
      IF(HTU(N,M))5,5,4
    4 HGU(N,M)=HTU(N,M)+(Z(N,M)+Z(N,M+1))/2.
      GO TO 13
    5 HGU(N,M)=0.
   13 IF(HTV(N,M))8,8,6
    6 HGV(N,M)=HTV(N,M)+(Z(N,M)+Z(N+1,M))/2.
      GO TO 14
    8 HGV(N,M)=0.
   14 CONTINUE

      INITIALIZATION OF VARIOUS PARAMETERS

      DO 10 N=1,NE
      DO 10 M=1,ME
      Q(N,M)=0.
      XK(N,M)=0.
      ZST(N,M)=0.
      ZM(N,M)=0.
   10 YK(N,M)=0.
      RETURN
      END
```

```
      SUBROUTINE J04
C J04      WRITING OF THE VALUE FIELDS
      COMMON/A/Z(53,30),U(53,30),V(53,30),ZM(53,30),ZST(53,30),
     1HGV(53,30),HGU(53,30),HTU(53,30),HTV(53,30),HTZ(53,30),XK(53,30),
     2YK(53,30),RAD(53,30),ANG(53,30),Q(53,30)
      COMMON/B/A(60),NZ(90),MZ(90),NU(60),MJ(60),Z1(60),Z2(60),V1(60),
     1V2(60),U1(60),U2(60),V3(60),V4(60),X(4),ARG(4),NA(60),MA(60),
     2Z3(12),Z4(12),Z5(8),Z6(8),Z7(8),Z8(8),Z9(8),Z10(8)
      COMMON/C/ AFGN,F,AA1,AA2
     3,G,SIGMA,ALPHA,R,ROL,RBETA,C,DL,DT,T,T1,T2,NE,ME,TE,KKE,IZE,IUE,TW
     4,BETA,A1,A2,A3,A4,A5,C1,C3,SI,NURU,NURV,JA,NEH,MEH,NEHH,MEHH,NG
     5,T3,STV,ETV,TINCV,STH,ETH,TINCH,HT,VEC,NALL,TE1
      REAL*8 V1
   50 FORMAT('   WROTE(1) SUBROUTINE J04 T = ',F10.0,'T,V2,V3,V4',/)
  224 FORMAT(1H1,14X,21HWATER HEIGHT AFTER T=,F9.0,9H SEC (CM)/7X,I7,18I
     17/)
  228 FORMAT(I7,18F7.0/)
  229 FORMAT(I8,3F8.0,/)
  230 FORMAT(12(2X,F4.0,1X,F4.0),/)
  232 FORMAT(6(2X,F4.0,1X,F4.0),/)
  233 FORMAT('   SPECIAL POINT  WATER ELEVATION   SPEED(CN/SEC)   DIRECT
     1ION CURRENT   TIME = ',F10.0,//,10(3X,A8 ,10X,F8.2,7X,F8.2,8X,F8.2
     1,//))
  298 FORMAT(' ',14X,'RESULTANT CURRENT VELOCITY MAGNITUDE(CN/SEC)
     1 AND DIRECTION(DEGREES) AFTER T = ',F9.0,' SECONDS ',//)
  328 FORMAT(I7,17F7.0/)
  404 FORMAT(//7X,I7,18I7/)
  405 FORMAT(//8X,I7,2I8)
  406 FORMAT(' ',//,5X,I3,11I11,//)
 1228 FORMAT(I7,12F7.0/)
C     PRINT OF Z VALUES
      PRINT 224,T,(N,N=1,18)
      PRINT 228,(N,(Z(N,M),M=1,18),N=1,NE)
      PRINT 404,(N,N=19,30)
      PRINT 1228,(N,(Z(N,M),M=19,30),N=1,NE)
      PIR=180./3.1415926
C     COMPUTATION OF CURRENT DIRECTION
      DO 432 N=1,NE
      DO 432 M=1,ME
      IF(V(N,M)**2+U(N,M)**2.EQ.0.)GO TO 101
```

```
100 PAD(N,M)=SQRT(V(N,M)**2+U(N,M)**2)
    GO TO 102
101 RAD(N,M)=0.
    ANG(N,M)=999.
    GO TO 432
102 ABC=ABS(V(N,M))/RAD(N,M)
    ABC1=ABC*(10**10)
    IF(ABC1.LT.0)GO TO 1
    ANG(N,M)=ARSIN(ABC)
    ANG(N,M)=ANG(N,M)*PIR
    GO TO 2
  1 ANG(N,M)=0.0
  2 IF(V(N,M).GE.0..AND.U(N,M).GE.0.)GO TO 433
    IF(V(N,M).GE.0..AND.U(N,M).LT.0.)GO TO 500
    IF(V(N,M).LT.0..AND.U(N,M).LE.0.)GO TO 501
    GO TO 502
500 ANG(N,M)=180.-ANG(N,M)
    GO TO 433
501 ANG(N,M)=180.+ANG(N,M)
    GO TO 433
502 ANG(N,M)=360.-ANG(N,M)
433 ANG(N,M)= 90.-ANG(N,M)
    IF(ANG(N,M).LT.0.)ANG(N,M)=360.+ANG(N,M)
432 CONTINUE
    DO 10 N=1,NE
    DO 10 M=1,ME
    IF(Q(N,M).EQ.0.)GO TO 10
    RAD(N,M)=-1.
    ANG(N,M)=666.
    Q(N,M)=0.
 10 CONTINUE

    WRITING THE SPETIAL POINTS

    IF(NURU.EQ.0)GO TO 12
    DO 9 I=1,NURU
    M = MZ(I+IZE)
    N = NZ(I+IZE)
    V2(I)=Z(N,M)
    V3(I)=RAD(N,M)
  9 V4(I)=ANG(N,M)
    NALL=NALL+1
    WRITE(1)T,(V2(I),I=1,NURU),
   1           (V3(I),I=1,NURU),
   2           (V4(I),I=1,NURU)
    PRINT 50,T
 12 CONTINUE
```

PRINTING OF CURRENTS AND DIRECTION

```
WRITE(6,298)T
WRITE(6,406)(N,N=1,12)
PRINT 230,((RAD(N,M),ANG(N,M),M=1,12),N=1,NE)
WRITE(6,406)(N,N=13,24)
PRINT 230,((RAD(N,M),ANG(N,M),M=13,24),N=1,NE)
WRITE(6,406)(N,N=25,ME)
PRINT 232,((RAD(N,M),ANG(N,M),M=25,ME),N=1,NE)
PRINT 233,T,(V1(I),V2(I),V3(I),V4(I),I=1,NURU)
RETURN
END
```

```
      SUBROUTINE J05
J05   COMPUTATION AND MANIPULATION
      COMMON/A/Z(53,30),U(53,30),V(53,30),ZM(53,30),ZST(53,30),
     1HGV(53,30),HGU(53,30),HTU(53,30),HTV(53,30),HTZ(53,30),XK(53,30),
     2YK(53,30),RAD(53,30),ANG(53,30),Q(53,30)
      COMMON/B/A(60),NZ(90),MZ(90),NU(60),MU(60),Z1(60),Z2(60),V1(60),
     1V2(60),U1(60),U2(60),V3(60),V4(60),X(4),ARG(4),NA(60),MA(60),
     2Z3(12),Z4(12),Z5(8),Z6(8),Z7(8),Z8(8),Z9(8),Z10(8)
      COMMON/C/ AFGN,F,AA1,AA2
     3,G,SIGMA,ALPHA,R,ROL,RBETA,C,DL,DT,T,T1,T2,NE,ME,TE,KKE,IZE,IUE,TW
     4,BETA,A1,A2,A3,A4,A5,C1,C3,SI,NUPU,NURV,JA,NEH,MEH,NEHH,MEHH,NG
     5,T3,STV,ETV,TINCV,STH,ETH,TINCH,HT,VEC,NALL,TF1
      REAL*8 V1
      SET TIDE VALUES AT OPEN BOUNDARIES
      IF(IZE.EQ.0)GO TO 709
      PER=24.833333*3600.
      PI = 3.1415927
      TT=T+0.
      DO 77 I = 1,IZE
      N = NZ(I)
      M = MZ(I)
      SUM=0.
      DO 10 L=1,11
      ZTIDE=Z3(L)*COS((L)*2.*PI*TT/PER)+Z4(L)*SIN((L)*2.*PI*TT/PER)
   10 SUM=SUM+ZTIDE
      Z(N,M)=SUM+Z3(12)
   77 CONTINUE
  172 IF(NG.EQ.0)GO TO 709
      DO 78 I=1,NG
      N=NA(I)
      M=MA(I)
      SUM=0.
      DO 20 L=1,3
      ZTIDE=Z7(L)*COS((L)*2.*PI*TT/PER)+Z8(L)*SIN((L)*2.*PI*TT/PER)
   20 SUM=SUM+ZTIDE
      Z(N,M)=SUM+Z7(4)
   78 CONTINUE
      CONTINUATION OF Z IN THE OPEN BOUNDARIES
  709 DO 30 N=6,8
      Z(N,4)=Z(N,5)
```

```
   30 CONTINUE

      SMOOTHING OF Z VALUES

      DO 470 N=2,NEH
      DO 470 M=2,MEH
      IF(HTZ(N,M))710,470,75
  710 IF(HTZ(N,M)+2)470,75,470
   75 IF(1-N)28,6,28
   28 IF(HTZ(N-1,M))57,6,57
   57 WERTO=Z(N-1,M)
      GO TO 7
    6 WERTO=Z(N,M)
    7 IF(NE-N)18,9,18
   18 IF(HTZ(N+1,M))58,9,58
   58 WERTU=Z(N+1,M)
      GO TO 5
    9 WERTU=Z(N,M)
    5 IF(1-M)29,12,29
   29 IF (HTZ(N,M-1))59,12,59
   59 WERTL=Z(N,M-1)
      GO TO 13
   12 WERTL=Z(N,M)
   13 IF(ME-M)17,15,17
   17 IF(HTZ(N,M+1))60,15,60
   60 WERTR=Z(N,M+1)
      GO TO 22
   15 WERTR=Z(N,M)
   22 ZM(N,M)=ALPHA*Z(N,M)+BETA*(WERTO+WERTU+WERTL+WERTR)
  470 CONTINUE
      DO 70 N=2,NEH
      DO 70 M=2,MEH
      IF((HGV(N,M).GT.900000.).OR.(HGU(N,M).GT.900000.))GO TO 91
      IF((V(N,M).GT.100000.).OR.(U(N,M).GT.100000.))GO TO 92
      IF(HTZ(N,M))70,70,3355

      CONTINUITY EQUATION FOR COMPUTATION OF Z

 3355 DHV = HGV(N-1,M)*V(N-1,M)-HGV(N,M)*V(N,M)
  355 DHU = HGU(N,M)*U(N,M)-HGU(N,M-1)*U(N,M-1)
  361 Z(N,M) =ZM(N,M)-A4*(DHU+DHV)
   70 CONTINUE

      CONTUNUATION OF THE OPEN BOUNDARIES

      DO 71 M=2,23
      Z(53,M)=Z(52,M)
   71 CONTINUE
```

```
      DO 171  N=11,53
      Z(N,1)=Z(N,2)
  171 CONTINUE
      DO 271  N=6,8
      Z(N,4)=Z(N,5)-(Z(N,6)-Z(N,5))
  271 CONTINUE

      ACTUAL DEPTH COMPUTATION

   72 DO 82  N=1,NEH
      DO 82  M=2,MEH
      IF(HTU(N,M))76,76,81
   81 HGU(N,M)=HTU(N,M)+(Z(N,M)+Z(N,M+1))/2.
   76 IF(HTV(N,M))82,82,87
   87 HGV(N,M)=HTV(N,M)+(Z(N,M)+Z(N+1,M))/2.
   82 CONTINUE
      DO 1001 M=2,6
      HGU(53,M)=HGU(52,M)
 1001 HGV(53,M)=HGV(52,M)
      DO 1002 N=43,53
      HGU(N,1)=HGU(N,2)
 1002 HGV(N,1)=HGV(N,2)
      IF(C1.EQ.0.)GO TO 103
      IF(T.LT.TW)GO TO 103

      CALL WIND SUBROUTINE
      CALL S01

      SMOOTHING OF U

  103 DO 512  N=2,NEH
      DO 512  M=2,MEH
      IF(HTU(N,M))512,512,128
  128 IF(HTU(N-1,M))157,106,157
  157 WERTO=U(N-1,M)
      GO TO 118
  106 WERTO=U(N,M)
  118 IF(HTU(N+1,M))158,109,158
  158 WERTU=U(N+1,M)
      GO TO 129
  109 WERTU=U(N,M)
  129 IF(HTU(N,M-1))159,112,159
  159 WERTL=U(N,M-1)
      GO TO 117
  112 WERTL=U(N,M)
  113 IF(ME-M)117,115,117
  117 IF(HTU(N,M+1))160,115,160
  160 WERTR=U(N,M+1)
```

```
      GO TO 23
  115 WERTR=U(N,M)
   23 ZM(N,M)=ALPHA*U(N,M)+BETA*(WERTO+WERTU+WERTL+WERTR)

      AVERAGING OF U

      IF(HTV(N-1,M))61,32,61
   61 WERTOL=V(N-1,M)
      IF(HTV(N-1,M+1))62,35,62
   62 WERTOR=V(N-1,M+1)
      GO TO 36
   32 WERTOL=V(N-1,M+1)
   35 WERTOR=WERTOL
   36 IF(HTV(N,M))63,38,63
   63 WERTUL=V(N,M)
      IF(HTV(N,M+1))64,41,64
   64 WERTUR=V(N,M+1)
      GO TO 42
   38 WERTUL=V(N,M+1)
   41 WERTUR=WERTUL
   42 ZST(N,M)=(WERTOL+WERTUL+WERTOR+WERTUR)/4.
  512 CONTINUE

      COMPUTATION OF U

      DO 412 N=2,NEH
      DO 412 M=2,MEH
      IF(HTU(N,M))412,412,513
  513 IF(ZM(N,M).EQ.0.AND.ZST(N,M).EQ.0)GO TO 514
      WURZEL=SQRT(ZM(N,M)**2+ZST(N,M)**2)
      GRZ=A3*WURZEL
      GO TO 515
  514 WURZEL=0.0
      GRZ=0.0
  515 IF(HGU(N,M)-GRZ)94,94,702
  702 IF(HTU(N,M)-9999.) 14,700,700
  700 ZM(N,M) = ZM(N,M)+A2*ZST(N,M)-A5*(Z(N,M+1)-Z(N,M))+XK(N,M)
   14 ZM(N,M)=(1.-GRZ/HGU(N,M))*ZM(N,M)+A2*ZST(N,M)-A5*(Z(N,M+1)-Z(N,M))
     1+XK(N,M)
      GO TO 412
   94 O(N,M)=1.
  412 CONTINUE

      AVERAGING OF U

      DO 528 N=1,NEH
      DO 528 M=2,MEH
      IF(HTV(N,M))528,528,429
```

```
429 IF(HTU(N,M-1))65,44,65
 65 WERTOL=U(N,M-1)
    IF(HTU(N+1,M-1))66,46,66
 66 WERTUL=U(N+1,M-1)
    GO TO 47
 44 WERTOL=U(N+1,M-1)
 46 WERTUL=WERTOL
 47 IF(HTU(N,M))67,49,67
 67 WERTOR=U(N,M)
    IF(HTU(N+1,M))68,52,68
 68 WERTUR=U(N+1,M)
    GO TO 53
 49 WERTOR=U(N+1,M)
 52 WERTUR=WERTOR
 53 ZST(N,M)=(WERTOL+WERTUL+WERTOR+WERTUR)/4.
528 CONTINUE

    SMOOTHING OF V

    DO 4100 N=2,NEH
    DO 4100 M=2,MEH
    IF(HTU(N,M))4100,4100,4101
4101 U(N,M)=ZM(N,M)
4100 CONTINUE
    DO 431 N=1,NEH
    DO 431 M=2,MEH
    IF(HTV(N,M))431,431,432
432 IF(1-N)228,206,228
228 IF(HTV(N-1,M))257,206,257
257 WERTO=V(N-1,M)
    GO TO 218
206 WERTO=V(N,M)
218 IF(HTV(N+1,M))258,209,258
258 WERTU=V(N+1,M)
    GO TO 229
209 WERTU=V(N,M)
229 IF(HTV(N,M-1))259,212,259
259 WERTL=V(N,M-1)
    GO TO 217
212 WERTL=V(N,M)
217 IF(HTV(N,M+1))260,215,260
260 WERTR=V(N,M+1)
    GO TO 25
215 WERTR=V(N,M)
 25 ZM(N,M)=ALPHA*V(N,M)+BETA*(WERTO+WERTU+WERTL+WERTR)
431 CONTINUE

    COMPUTATION OF V
```

```
      DO 428 N=2,NEH
      DO 428 M=2,MEH
      IF(HTV(N,M))428,428,529
  529 IF(ZM(N,M).EQ.0.AND.ZST(N,M).EQ.0)GO TO 530
      WURZEL=SQRT(ZM(N,M)**2+ZST(N,M)**2)
      GRZ=A3*WURZEL
      GO TO 531
  530 WURZEL=0.0
      GRZ=0.0
  531 IF(HGV(N,M)-GRZ)300,300,703
  703 IF(HTV(N,M)-9999.) 415,701,701
  701 V(N,M) = ZM(N,M)-A2*ZST(N,M)-A5*(Z(N,M)-Z(N+1,M)) +YK(N,M)
  415 V(N,M)=(1.-GRZ/HGV(N,M))*ZM(N,M)-A2*ZST(N,M)-A5*(Z(N,M)-Z(N+1,M))+
     1YK(N,M)
      GO TO 428
  300 Q(N,M)=1.
  428 CONTINUE

      COMPUTATION OF MASS TRANSPORT

   11 IF(T-T2)400,5250,5250
 5250 IF(T-ETH)5251,5251,400
 5251 AA1=AA1+(U(3,10)*HTU(3,10)*A1*2*DL+
     1          U(4,10)*HTU(4,10)*A1*2*DL+
     1          U(5,10)*HTU(5,10)*A1*2*DL+
     1          U(6,10)*HTU(6,10)*A1*2*DL+
     1          U(7,10)*HTU(7,10)*A1*2*DL+
     1          U(8,10)*HTU(8,10)*A1*2*DL)/1000000.
      AA2=AA2-(V(34,14)*HTV(34,14)*A1*2.*DL+
     1          V(34,15)*HTV(34,15)*A1*2.*DL+
     1          V(34,16)*HTV(34,16)*A1*2.*DL+
     1          V(34,17)*HTV(34,17)*A1*2.*DL+
     1          V(34,18)*HTV(34,18)*A1*2.*DL)/1000000.
  400 RETURN
   91 PRINT 1
   92 PRINT 2
      PRINT 3,T,N,M
    1 FORMAT(1X,9HERROR.HGU)
    2 FORMAT(1X,7HERROR.V)
    3 FORMAT(F11.0,5X,1H(,I2,1H,,I2,2H) )
      END
```

```
      SUBROUTINE S01
S01   VARIABLE WIND IN SUBAREAS,INTERMITANTLY
      COMMON/A/Z(53,30),U(53,30),V(53,30),ZM(53,30),ZST(53,30),
     1HGV(53,30),HGU(53,30),HTU(53,30),HTV(53,30),HTZ(53,30),XK(53,30),
     2YK(53,30),RAD(53,30),ANG(53,30),Q(53,30)
      COMMON/B/A(60),NZ(90),MZ(90),NU(60),MU(60),Z1(60),Z2(60),V1(60),
     1V2(60),U1(60),U2(60),V3(60),V4(60),X(4),ARG(4),NA(60),MA(60),
     2Z3(12),Z4(12),Z5(8),Z6(8),Z7(8),Z8(8),Z9(8),Z10(8)
      COMMON/C/ AFGN,F,AA1,AA2
     3,G,SIGMA,ALPHA,R,ROL,RBETA,C,DL,DT,T,T1,T2,NF,MF,TE,KKF,IZE,IUE,TW
     4,BETA,A1,A2,A3,A4,A5,C1,C3,SI,NURU,NURV,JA,NEH,MEH,NEHH,MEHH,NG
     5,T3,STV,ETV,TINCV,STH,ETH,TINCH,HT,VEC,NALL,TE1
      REAL*8 V1
      IF(SI-T)12,10,2
    2 KF=IUE/2
      DO 9 I=1,KF
      IF(T-A(I))9,4,9
    4 N1=NU(2*I-1)
      N2=NU(2*I)
      M1=MU(2*I-1)
      M2=MU(2*I)
      DO 8 N=N1,N2
      DO 8 M=M1,M2
    2 IF(T-A(1)) 9,4,4
    4 DO 8 N=1,NE
      DO 8 M=1,ME
      IF(HTU(N,M))1,1,3
    3 IF(HGU(N,M))1,1,5
    5 XK(N,M) =C3*A(   2)**2*COS(A(    3)*0.017453)/2000.
    1 IF(HTV(N,M))8,8,6
    6 IF(HGV(N,M))8,8,7
    7 YK(N,M) =C3*A(   2)**2*SIN(A(    3)*0.017453)/2000.
    8 CONTINUE
    9 CONTINUE
      GO TO 12
   10 DO 11 N=1,NF
      DO 11 M=1,ME
      XK(N,M)=0.
   11 YK(N,M)=0.
   12 RETURN
      END
```

for different fields

```
      SUBROUTINE SO8
C SO8  OUTPUT FOR SPECIAL POINTS
      COMMON/A/Z(53,30),U(53,30),V(53,30),ZM(53,30),ZST(53,30),
     1HGV(53,30),HGU(53,30),HTU(53,30),HTV(53,30),HTZ(53,30),XK(53,30),
     2YK(53,30),RAD(53,30),ANG(53,30),Q(53,30)
      COMMON/B/A(60),NZ(90),MZ(90),NU(60),MJ(60),Z1(60),Z2(60),V1(60),
     1V2(60),U1(60),U2(60),V3(60),V4(60),X(4),ARG(4),NA(60),MA(60),
     2Z3(12),Z4(12),Z5(8),Z6(8),Z7(8),Z8(8),Z9(8),Z10(8)
      COMMON/C/ AFCN,F,AA1,AA2
     3,G,SIGMA,ALPHA,R,RCL,RBETA,C,CL,DT,T,T1,T2,ME,NE,TE,KKF,IZE,IUE,TW
     4,BETA,A1,A2,A3,A4,A5,C1,C3,SI,NURU,NURV,JA,NEH,MEH,NEHH,MEHH,NG
     5,T3,STV,FTV,TINCV,STH,ETH,TINCH,HT,VEC,NALL,TF1
      REAL*8 V1
  130 FORMAT(//,7X,4HNAME,4X,15(2X,A6)/15X,14(2X,A6)/)
  131 FORMAT(1H1,5X,114HWATER ELEVATION(CM) AND CURRENT VELOCITY RESULTA
     1NT(MAGNITUDE IN CM/SEC AND DIRECTION IN DEGREES) AT SPECIAL POINTS
     2///7X,4HNAME,4X,15(2X,A6)/15X,14(2X,A6)/)
  132 FORMAT(6X,5HCOORD,4X,15(2X,I2,1H,,I2,1X)/15X,14(2X,I2,1H,,I2,1X)//
     1)
  133 FORMAT('      TIME OF COMPUTATION = ',F10.0,'SECONDS',/,6X,'HEIGHT
     1',4X,14F8.2/14X,14F8.2,/)
  134 FORMAT(5X,14HEND OF PROGRAM,/////////)
  135 FORMAT('     VELOC,DIR',2X,F7.0,1H,,F4.0,14(F4.0,1H,,F4.0)/
     114X,14(F4.0,1H,,F4.0)/)
      TF1=T
      NURV=0
      PRINT 131,(V1(I),I=1,NURU)
      PRINT 132,(NZ(I+IZE),MZ(I+IZE),I=1,NURU)
      ENDFILE 1
      REWIND 1
    1 READ(1)T,(V2(I),I=1,NURU),
     1         (V3(I),I=1,NURU),
     2         (V4(I),I=1,NURU)
      NURV=NURV+1
      IF(NURV-50)3,3,4
    4 PRINT 130,(V1(I),I=1,NURU)
      NURV=1
    3 PRINT 133,T,(V2(I),I=1,NURU)
      PRINT 135,(V3(I),V4(I),I=1,NURU)
      WRITE(2) T,(V2(I),I=1,NURU)
     1          ,(V3(I),I=1,NURU)
     2          ,(V4(I),I=1,NURU)
      IF(TF-T)2,2,1
    2 ENDFILE 2
      PRINT 134
      RETURN
```

```
      END

      SUBROUTINE DB1

      COMMON/A/Z(53,30),U(53,30),V(53,30),ZM(53,30),ZST(53,30),
     1HGV(53,30),HGU(53,30),HTU(53,30),HTV(53,30),HTZ(53,30),XK(53,30),
     2YK(53,30),RAD(53,30),ANG(53,30),Q(53,30)
      COMMON/B/A(60),NZ(90),MZ(90),NU(60),MU(60),Z1(60),Z2(60),V1(60),
     1V2(60),U1(60),U2(60),V3(60),V4(60),X(4),ARG(4),NA(60),MA(60),
     2Z3(12),Z4(12),Z5(8),Z6(8),Z7(8),Z8(8),Z9(8),Z10(8)
      COMMON/C/ AFGN,F,AA1,AA2
     3,G,SIGMA,ALPHA,R,ROL,RBETA,C,DL,DT,T,T1,T2,NE,ME,TE,KKE,IZE,IUF,TW
     4,BETA,A1,A2,A3,A4,A5,C1,C3,SI,NURU,NURV,JA,NEH,MEH,NEHH,MEHH,NG
     5,T3,STV,FTV,TINCV,STH,ETH,TINCH,HT,VEC,NALL,TE1
      REAL*8 V1
      REAL*8 HEAD,HEAD1
  111 FORMAT('   CHECK PARAMETERS IN DB1    ',/,
     1' T =',F7.0,'T1 =',F7.0,'STV =',F7.0,'STH =',F7.0)
  400 FORMAT('   WROTE (3) SUBROUTINE DB2 T =',F10.0,'T,VEC,HT,RAD,ANG,Z
     1',/)
  401 FORMAT('    MASS TRANSPORT AT T = ',F10.0,'DURING THE LAST HOUR PE
     1RIOD',//,'    AA1 =',F10.2,'  M3/HOUR      AA2 = ',F10.2,'  M3/HOU
     1R',//)
 1000 FORMAT(A8,2X,3F10.0)
 1001 FORMAT(///,20X,A8,2X,3F10.0)

      ENTRY TO READ VECTOR + HEIGHT CARDS

      READ 1000,HEAD,STV,ETV,TINCV
      READ 1000,HEAD1,STH,ETH,TINCH
      PRINT 1001,HEAD,STV,ETV,TINCV
      PRINT 1001,HEAD1,STH,ETH,TINCH
      RETURN

      ENTRI TO WRITE DATA IN DISK FILE 3 FOR VECTOR AND WATER HEIGHT
      PLOTS

      ENTRY DB2
      HT=0.
      VEC=0.
      WRITE(6,111)T,T1,STV,STH
      IF(ABS(T-STV).GT.T1/2.)GO TO 100
      STV=STV+TINCV
      VEC=1.
  100 IF(ABS(T-STH).GT.T1/2.)GO TO 200
      STH=STH+TINCH
      HT=1.
```

```
200 IF(HT+VEC.EQ.0.)GO TO 300
    WRITE(3) T,VEC,HT,RAD,ANG,Z
    WRITE(6,400) T
    PRINT 401,T,AA1,AA2
    AA1=0.
    AA2=0.
300 RETURN
    END
```

```
    SUBROUTINE J06

    SOBROUTINE FOR WRIGTING IN TAPES FOR FUTURE USES OF COMPUTATIONS

    COMMON/A/Z(53,30),U(53,30),V(53,30),ZM(53,30),ZST(53,30),
   1HGV(53,30),HGU(53,30),HTU(53,30),HTV(53,30),HTZ(53,30),XK(53,30),
   2YK(53,30),RAD(53,30),ANG(53,30),Q(53,30)
    COMMON/B/A(60),NZ(90),MZ(90),NU(60),MJ(60),Z1(60),Z2(60),V1(60),
   1V2(60),U1(60),U2(60),V3(60),V4(60),X(4),ARG(4),NA(60),MA(60),
   2Z3(12),Z4(12),Z5(8),Z6(8),Z7(8),Z8(8),Z9(8),Z10(8)
    COMMON/C/ AFGN,F,AA1,AA2
   3,G,SIGMA,ALPHA,R,ROL,RBETA,C,DL,DT,T,T1,T2,NE,ME,TE,KKE,IZE,IUE,TW
   4,BETA,A1,A2,A3,A4,A5,C1,C3,SI,NURJ,NURV,JA,NEH,MEH,NEHH,MEHH,NG
   5,T3,STV,ETV,TINCV,STH,ETH,TINCH,HT,VEC,NALL,TE1
    REAL*8 V1
    ENDFILE 3
    REWIND 2
    REWIND 3
    REWIND 4
    REWIND 8
    REWIND 9
    READ(4) HTZ,V1,NURU,ME,NE
    WRITE(9)HTZ,V1,NURU,ME,NE,NALL
```

```
      PRINT 11
   11 FORMAT('    WROTE (9) SUBROUTINE J06 HTZ,V1,NURU,ME,NE,NALL',/)
    2 READ(2) T,(V2(I),I=1,NURU),(V3(I),I=1,NURU),(V4(I),I=1,NURU)
      WRITE(9) T,(V2(I),I=1,NURU),(V3(I),I=1,NURU),(V4(I),I=1,NURU)
      PRINT 10,T
   10 FORMAT('    WROTE (9) SUBROUTINE J06 T =',F10.0,'T,V2,V3,V4',/)
      IF(TE-T)4,4,2
    4 READ(3) T,VEC,HT,RAD,ANG,Z
      WRITE(9) T,VEC,HT,RAD,ANG,Z
      PRINT 12,T
   12 FORMAT('    WROTE (9) SUBROUTINE J06 T =',F10.0,'T,VEC,HT,RAD,ANG,Z
     1',/)
      IF(TE-T)5,5,4
    5 WRITE(8)((Z(N,M),M=1,ME),N=1,NE),
     1         ((U(N,M),M=1,ME),N=1,NE),
     2         ((V(N,M),M=1,ME),N=1,NE),
     3         ((HGU(N,M),M=1,ME),N=1,NE),
     4         ((HGV(N,M),M=1,ME),N=1,NE),
     5         TE1
      PRINT 1,TE1
    1 FORMAT(////,' PARTIAL RESULTS HAD BEEN WRITTEN IN TAPE 8 AT TIME
     1',F10.0,'  SECONDS',///)
      PRINT 6,NALL
    6 FORMAT('       - NALL - NUMBER OF PLOT ORDERED = ',I3,////)
      ENDFILE 8
      REWIND 8
      ENDFILE 9
      REWIND 9
      RETURN
      END
```

```
*****************************************************************

                  HANSEN  PROGRAM  PLOTS

          PLOTS OF TIDE AND VELOCITY CURVES

*****************************************************************


CARD 1

   THMIN      MINIMUM VALUE OF WATER HEIGHT ON Y AXIS SCALE
   THMAX      MAXIMUM VALUE OF WATER HEIGHT ON Y AXIS SCALE
   YPN        SCALE OF Y AXIS IN UNITS/INCH
   XPN        SCALE OF TIME AXIS IN UNITS/INCH
   SKIP       NO.OF TIME STEPS TO BE SKIPPED OVER BETWEEN PLOTED PO

CARD 2
   TMIN       START TIME OF FIRST WATER HEIGHT VECTOR PLOT
   TMAX       START TIME OF LAST WATER HEIGHT VECTOR PLOT
   TINC       TIME INTERVAL BETWEEN START TIMES
   TLEN       TIME INTERVAL TO BE PLOTED
   XPN        TIME AXIS SCALE IN UNITS/INCH
   YPN        WATER HEIGHT SCALE UNIT/INCH (MIN.QMAX VALUES ARE
              THOSE ON THE TIDE CARD CYCLE)
   ZPN        VECTOR SCALE IN UNITS/INCH
```

MAIN PROGRAM

```
      COMMON/A/ V1(60),V2(60),V3(60),V4(60),HTZ(53,30),RAD(53,30),
     1ANG(53,30),Z(53,30),X(3),Y(3),NURU,ME,NE,T,VEC,HT
      REAL*8 V1
      REWIND 2
      REWIND 3
      REWIND 4
      REWIND 9
      READ(9)  HTZ,V1,NURU,ME,NE,NALL
      PRINT 11,NALL,NURU
   11 FORMAT('    READED(9) HTZ,V1,NURU,ME,NE,NALL,       NALL = ',I3,'
     1NURU = ',I3,/)
      PRINT 1,((HTZ(N,M),M=1,20),N=1,NE)
      PRINT 7,((HTZ(N,M),M=21,ME),N=1,NE)
      PRINT 2,(V1(I),I=1,NURU)
      PRINT 3,NE,ME
      PRINT 4,NURU
    1 FORMAT(20F6.1)
    2 FORMAT(10A10)
    3 FORMAT('    HTZ(',I2,',',I2,')',//)
    4 FORMAT('    V1(',I2,')',//)
    7 FORMAT(10F6.1)
      DO 5 K=1,NALL
      READ(9) T,(V2(I),I=1,NURU),(V3(I),I=1,NURU),(V4(I),I=1,NURU)
      WRITE(2) T,(V2(I),I=1,NURU),(V3(I),I=1,NURU),(V4(I),I=1,NURU)
      WRITE(3) T,(V2(I),I=1,NURU),(V3(I),I=1,NURU),(V4(I),I=1,NURU)
      PRINT 20,T
   20 FORMAT('    READED (9) T,V2,V3,V4,    AT T = ',F10.0,/)
      PRINT 31,(V2(I),V3(I),V4(I),I=1,NURU)
   31 FORMAT('      V2(I)',10X,'V3(I)',10X,'V4(I)',/,5X,3F10.0,/)
    5 CONTINUE
      DO 6 I=1,NALL
      READ(9) T,VEC,HT,RAD,ANG,Z
      WRITE(4) T,VEC,HT,RAD,ANG,Z
      PRINT 12,T
   12 FORMAT('    READED (9) T,VEC,HT,RAD,ANG,Z,      AT T = ',F10.0,/)
      PRINT 1 ,((RAD(N,M),M=1,20),N=1,NE)
      PRINT 7 ,((RAD(N,M),M=21,ME),N=1,NE)
      PRINT 1 ,((ANG(N,M),M=1,20),N=1,NE)
      PRINT 7 ,((ANG(N,M),M=21,ME),N=1,NE)
      PRINT 1 ,((Z  (N,M),M=1,20),N=1,NE)
      PRINT 7 ,((Z  (N,M),M=21,ME),N=1,NE)
    6 CONTINUE
      ENDFILE 2
      ENDFILE 3
      ENDFILE 4
```

```
      REWIND 2
      REWIND 3
      REWIND 4
      REWIND 9
      PRINT 101,NURU,ME,NE,T,VEC,HT
  101 FORMAT('    NURU,ME,NE,T,VEC,HT BEEFORE PASSED TO SUBROUTINE T01',/
     1,10X,I5,I5,I5,F10.0,F10.0,F10.0,/)
      CALL T01
      CALL TEST(NALL,NURU)
      STOP
      END
```

```
      SUBROUTINE T01
      COMMON/A/ V1(60),V2(60),V3(60),V4(60),HTZ(53,30),RAD(53,30),
     1ANG(53,30),Z(53,30),X(3),Y(3),NUPU,ME,NE,T,VEC,HT
      DIMENSION VV2(10000),VV3(10000),VV4(10000),TT(1500)
      REAL*8 V1
      DIMENSION VV2(10000),VV3(10000),VV4(10000),TT(1500)
      COMPUTE UPPER BOUNDS OF STORAGE AREA.  DATA WILL BE  STORED IN
      THE FOLLOWING ORDER, AREA(TIME,NURU)
      KK = 10000/NURU
      CALL PLOTS
      PRINT 9000,NUPU,ME,NE,T,VEC,HT
      KK = 10000/NURU
      READ TIDE CYCLE CARD
      READ 1000, THMIN,THMAX,YPN,XPN,SKIP
      PRINT1001, THMIN,THMAX,YPN,XPN,SKIP
      M=SKIP
      DO 110 I = 1,KK
      KKK = (NURU-1)*KK+I
      READ(2,END=200)TT(I),(VV2(J),J=I,KKK,KK),(VV3(J),J=I,KKK,KK),
     1  (VV4(J),J=I,KKK,KK)
      PRINT 8000,I,TT(I)
  150 IF(M.EQ.0) GO TO 110
      DO 100 J=1,M
      READ(2,END=210)
  100 CONTINUE
  110 CONTINUE
      KKK=KK
      GO TO 250
  200 KKK=I-1
      GO TO 250
  210 KKK=I
      READ TIDEVECTOR CARD
  250 READ 1000, TMIN,TMAX,TINC,TLEN,XPN,YPN,ZPN
      PRINT 1002, TMIN,TMAX,TINC,TLEN,XPN,YPN,ZPN
      PLOT WATER HEIGHTS FOR ENTIRE RUN FOR EACH SPECIAL POINT
      DO 300 I = 1,NURU
      K = K K*(I-1)+1
  300 CALL TIMPL    (TT,VV3(K),VV4(K),VV2(K),KKK,V1(I),10,XPN,THMIN,YPN,
     1   THMAX,0,ZPN ,1,TT,TT(KKK),.07,7200.)
  350 DO 400 M=1,KKK
      IF (TT(M).GE. TMIN) GO TO 500
  400 CONTINUE
      M=KKK
      GO TO 900
  500 TIMEND =  TMIN+TLEN
      DO 600 J = M,KKK
      IF (TIMEND .LT. TT(J)) GO TO 700
  600 CONTINUE
```

```
      J=KKK+1
  700 PRINT 9999,J,M,KKK,TMIN,TIMEND,TT(M),TT(J)
      J = J-M
      DO 800  I = 1,NURU
      K =   KK*(I-1)+M
  800 CALL TIMPL    (TT(M),VV3(K),VV4(K),VV2(K),J,V1(I),8,XPN,THMIN,YPN,
     1  THMAX,1,ZPN,0,TT(M),TT(M)+TLEN,.07,7200.)
      TMIN=TMIN+TINC
      IF( TMIN.LT.TMAX) GO TO 350
  900 CALL PLOTE
      RETURN
 1000 FORMAT(10X             ,7F10.0)
 1001 FORMAT('    TIDECYCLE   ',7F10.0,/)
 1002 FORMAT('    OWHVECTOR   ',7F10.0)
 8000 FORMAT('      READ 2 TT(',I2,') = ',F10.0,/)
 9000 FORMAT('   NURU,ME,NE,T,VFC,HT PASED TO THE  SUBROUTINE TO1',/,
     110X,I5,I5,I5,F10.0,F10.0,F10.0,/)
 9999 FORMAT(3I10,4F10.0)
      END
```

```
      SUBROUTINE TIMPL   (TIME,VELOC,DIREC,HEIGHT,MAXDIM,PLNAM  ,N,XPN,
     1  THMIN,YPN,THMAX,SKIP,ZPN,NAROW  ,TST,TEND,H,TINC )
      INTEGER SKIP
      REAL*8 V1
      DIMENSION TIME(MAXDIM),VELOC(MAXDIM),DIREC(MAXDIM),HEIGHT(MAXDIM),
     1  PLNAM  (1),NAM1(4),NAM2(3),NAM3(9)
      DATA NAM1/'TIME',' IN ','SECO','NDS'/
      DATA NAM2/'HEIG','HT I','N CM'/
      DATA NAM3/'L.SA','LAS ','  HA','NSEN',' MOD','EL  ',' SAN','DIEG',
     1'O(1)'/
      X = (TEND-TST)/XPN
      CALL PLOT (0.,0.,3)
      PX = X/2.-6./7.*H*FLOAT(N)
      CALL SYMBOL(PX,-1.,H*2.,NAM3,0.0,37)
      CALL SYMBOL (PX,-.5 ,H*2.,PLNAM  ,0.0,N)
      CALL CXIS2    (TST,.25,NAM1       ,         15,TST,XPN,0.,1.,0.,TST,
     1  XPN,XPN  , 6.,TEND,6,-1,.07)
      ZERLIN =-THMIN/YPN
      CALL PLOT    (X,ZERLIN,3)
      CALL PLOT    (0.0,ZERLIN,2)
      CALL CXIS2    (TST,THMIN,NAM2               ,12,TST,XPN,THMIN,YPN,
     1 270.,THMIN,YPN,50.,4.,THMAX,4,-1,.07)
      DUM1=(TIME(1)-TST )/XPN
      DUM2=(HEIGHT(1)-THMIN)/YPN
      CALL PLOT(DUM1,DUM2,3)
      DO 300 I = 1,MAXDIM
      Y = (HEIGHT(I)-THMIN)/YPN
      X = (TIME(I)-TST)/XPN
      IF(SKIP.NE.0)GO TO 210
  200 CALL PLOT   (X,Y,3)
      GO TO 215
  210 CALL PLOT    (X,Y,2)
      IF(NAROW.EQ.0)GO TO 300
  215 DIST = VELOC(I)/ZPN
      IF( DIREC(  I).GT.360.) GO TO 300
      SI   =AMOD ( 450.0-DIREC(I)        ,360.)*.0174532925
      CO = COS(SI)
      SI=SIN(SI)
      VX = DIST*CO+X
      VY = DIST*SI+Y
      CALL PLOT   (VX,VY,2)
      CALL ARWPT    (VX,VY,CO,SI)
      IF(SKIP.EQ.0)GO TO 300
  250 CALL PLOT   (X,Y,3)
  300 CONTINUE
      CALL PLOT (0.,Y+6.,-3)
      RETURN
      END
```

```
      SUBROUTINE CXIS2    (X,Y,XNAME,NLET,XMIN,XPN,YMIN,YPN,THETA,
     1  ZVAL,ZPN,ZINT,ZNUM,ZMAX,NC,NS,H)
      INTEGER XNAME
      REAL*8 V1
      DIMENSION XNAME(2)
      XX = THETA*.0174532925
      SI =-SIN(XX)
      CO = COS(XX)
      XINT= CO*ZINT/ZPN
      YINT = SI*ZINT/ZPN
      XTIC =  SI*.05
      YTIC = CO*.05
      YY = H*1.5
      XX =  3./7. *H*FLOAT(NC)
      XLET =-SI*YY-CO*XX
      YLET = -CO*YY+SI*XX
      XLI = ZNUM*XINT
      YLI = ZNUM*YINT
      XX =  6./7.*H*FLOAT(NLET)
      YY = H*5.
      XTIT =-SI*YY-CO*XX
      YTIT = -CO*YY+SI*XX
      XX = (X-XMIN)/XPN
      YY = (Y-YMIN)/YPN
      CENT = ZVAL+(ZMAX-ZVAL)/2.
      XTIT = XX+XTIT+(CENT-ZVAL)/ZPN*CO
      YTIT = YY+YTIT+(CENT-ZVAL)/ZPN*SI
      Z=ZVAL
      ZZ=Z
      CALL PLOT  (XX,YY,3)
      XLET = XLET+XX
      YLET = YLET+YY
  100 IF( NC.LE.0.OR. ABS(ZZ-Z).GT.ZINT/2.)              GO TO 200
      CALL NUMBER (XLET,YLET,H,ZZ,THETA,NS)
      XLET = XLET+XLI
      YLET = YLET+YLI
      ZZ = ZZ+ZNUM*ZINT
      CALL PLOT   (XX,YY,3)
  200 XX = XX+XINT
      YY = YY+YINT
      Z = Z+ZINT
      CALL PLOT  (XX,YY,2)
      IF (Z.GE.ZMAX)  GO TO 500
      CALL PLOT  (XX+XTIC,YY+YTIC,2)
      CALL PLOT   (XX,YY,2)
      IF (Z.GT.CENT .AND. NLET.GT.0)GO TO 400
```

```
      GO TO 100
  400 CALL SYMBOL    (XTIT,YTIT,H*2.,XNAME,THETA,NLET)
      CALL PLOT  (XX,YY,3)
      CENT =3.*ZMAX
      GO TO 100
  500 IF(NC.LE.0 .OR. ZZ.NE.Z) RETURN
      CALL NUMBER (XLET,YLET,H,ZZ,THETA,NS)
      RETURN
      END


      SUBROUTINE ROT(X,Y,DEG,MM)
      DIMENSION  X(MM), Y(MM)
      SI=DEG*0.01745329
      CO=COS(SI)
      SI=SIN(SI)
      DO 100   I = 1,MM
```

```
      X1=X(I)
      Y1=Y(I)
      X(I) = X1*CO + Y1*SI
  100 Y(I) = Y1*CO - X1*SI
      RETURN
      END
```

```
      SUBROUTINE ARWPT    (X,Y,CO,SI)
      REAL*8 V1
      DATA H/.07/
      YY = SI*H
      XX = CO*H
      XXX=YY*.25
      YYY=XX*.25
      XX=X-XX
      YY=Y-YY
      CALL PLOT   (XX-XXX,YY+YYY,2)
      CALL PLOT  (XX+XXX,YY-YYY,2)
      CALL PLOT  (X,Y,2)
      CALL PLOT  (X,Y,3)
      RETURN
      END
```

```
      SUBROUTINE TEST(NALL,NURU)
      DIMENSION VA2(50,50),VA3(50,50),VD2(50),VD3(50),V2(50),V3(50),V4(5
     10),VE2(50),VE3(50),TA(50)
      REAL *8 NAME
      REAL*8 V1
      COMMON/C/ VB2(8),VB3(16),VC2,VC3,TB
```

```
      REAL*8 ITATLE(12)/'VALUES O','F WATER ','HEIGHT M','EASSURE','D AN
     1D CA','LCULATED','        ','        ','L.SALAS ','        ','SAN
     2DIEG','O BAY(  )'/
      REAL*8 ITETLE(12)/'VALUES O','F CJRREN','T      M','EASSURE','D AN
     1D CA','LCULATED','        ','        ','L.SALAS ','        ','SAN
     2DIEG','O BAY(  )'/
      REAL*8 LABEL(2)/8HMSSURED ,8HMSSURED /
      REAL* 8 LEBEL(2)/8HMODEL   ,8HMODEL   /
      DO 1 I=1,NALL
      READ(3) T,(V2(K),K=1,NURU),(V3(K),K=1,NURU),(V4(K),K=1,NURU)
      PRINT 600,T
      TA(I)=T
      DO 2 K=1,NURU
      VA2(I,K)=V2(K)
      VA3(I,K)=V3(K)
      IF(V4(K).GT.180.)VA3(I,K)=-VA3(I,K)
    2 CONTINUE
    1 CONTINUE
      DO 3 K=1,NURU
      CALL REC1
      READ 21,NAME
      DO 4 I=1,NALL
      TB=TA(I)
      CALL REC2
      VD2(I)=VC2
      VD3(I)=VC3
      VE2(I)=VA2(I,K)
      VE3(I)=VA3(I,K)
    4 CONTINUE
      CALL DRAW(NALL,TA,VD2,1,0,LABEL,ITATLE,0.0,0.0,4,2,2,2,8,8,1,LAST)
      PRINT 750,NAME
      PRINT 900,LAST
      CALL PLOT(0.,0.,3)
      CALL SYMBOL(3.0,0.5,0.14,NAME,0.0,8)
      CALL PLOT(0.,0.,-3)
      CALL DRAW(NALL,TA,VE2,3,1,LEBEL,ITATLE,0.0,0.0,4,2,2,2,8,8,1,LAST)
      PRINT 750,NAME
      PRINT 900,LAST
      CALL DRAW(NALL,TA,VD3,1,0,LABEL,ITETLE,0.0,0.0,4,2,2,2,8,8,1,LAST)
      PRINT 750,NAME
      PRINT 900,LAST
      CALL PLOT(0.,0.,3)
      CALL SYMBOL(3.0,0.5,0.14,NAME,0.0,8)
      CALL PLOT(0.,0.,-3)
      CALL DRAW(NALL,TA,VE3,3,1,LEBEL,ITETLE,0.0,0.0,4,2,2,2,8,8,1,LAST)
      PRINT 750,NAME
      PRINT 900,LAST
    3 CONTINUE
```

```
      RETURN
  21  FORMAT(A8)
 600  FORMAT('   READED IN TEST DISC(3)    T = ',F10.0,//)
 750  FORMAT('   NAME = ',A8,/)
 900  FORMAT('   LAST = ',I1,/)
      END



      SUBROUTINE REC
      COMMON/C/ VB2(8),VB3(16),VC2,VC3,TB
      ENTRY REC1
      READ 20,(VB2(I),I=1,6),VB2(7)
      READ 20,(VB3(I),I=1,3)
      READ 20,(VB3(I),I=4,6),VB3(7)
      GO TO 10
      ENTRY REC2
      PER=24.*3600.
      PI=3.1415927
      TB=TB+39800.
      SUM=0.
      DO 1 L=1,3
      ZTIDE=VB2(L)*COS((L)*2.*PI*TB/PER)+VB2(L+3)*SIN((L)*2.*PI*TB/PER)
     1+VB2(7)
   1  SUM=SUM+ZTIDE
      VC2=SUM
      SUM=0.
      DO 2 L=1,3
      ZCURR=VB3(L)*COS((L)*2.*PI*TB/PER)+VB3(L+3)*SIN((L)*2.*PI*TB/PER)
     1+VB3(7)
   2  SUM=SUM+ZCURR
      VC3=SUM
  10  RETURN
  20  FORMAT (8F10.5)
      END
```

```
C     ******************************************************************
C                         HANSEN  PROGRAM  PLOTS
C     ******************************************************************
C     GPPI        GRID POINTS PER INCH ON VECTOR AND HEIGHT PLOTS
C     VVS         VELOCITY VECTOR SCALE  UNITS/INCH
C     WHS         WATER HEIGHT SCALE
C     ROTDEG      RIGHT ANGLE FROM NORTH TO Y AXIS OF HANSE PROG GRID
C     NS          NO.OF STRIPES
C     X(I),I=1,3  STRIP  ORIGIN IN TENS OF GRID POINTS
C     NTHPT       DISTANCE BETWEEN PLOTED POINTS
C     LAND        DISTANCE FROM LAND
C
C     CARD 2
C
C     TITLE OF THE PROGRAM
C
C     CARD 3
C
C     THMIN       MINIMUM VALUE OF WATER HEIGHT ON Y AXIS SCALE
C     THMAX       MAXIMUM VALUE OF WATER HEIGHT ON Y AXIS SCALE
C     YPN         SCALE OF Y AXIS IN UNITS/INCH
C     XPN         SCALE OF TIME AXIS IN UNITS/INCH
C     SKIP        NO.OF TIME STEPS TO BE SKIPPED OVER BETWEEN PLOTED PO
C
C     CARD 4
C     TMIN        START TIME OF FIRST WATER HEIGHT VECTOR PLOT
C     TMAX        START TIME OF LAST WATER HEIGHT VECTOR PLOT
C     TINC        TIME INTERVAL BETWEEN START TIMES
C     TLEN        TIME INTERVAL TO BE PLOTED
C     XPN         TIME AXIS SCALE IN UNITS/INCH
C     YPN         WATER HEIGHT SCALE UNIT/INCH (MIN.QMAX VALUES ARE
C                 THOSE ON THE TIDE CARD CYCLE)
C     ZPN         VECTOR SCALE IN UNITS/INCH
      COMMON/A/ V1(60),V2(60),V3(60),V4(60),HTZ(53,30),RAD(53,30),
     1ANG(53,30),Z(53,30),X(3),Y(3),NURU,ME,NE,T,VEC,HT
      REAL*8 V1
      REWIND 2
      REWIND 3
      REWIND 4
      REWIND 9
      READ(9)  HTZ,V1,NURU,ME,NE,NALL
      PRINT 11,NALL,NURU
```

```
11 FORMAT('    READED(9) HTZ,V1,NURU,ME,NE,NALL,      NALL = ',I3,'
  1NURU = ',I3,/)
   PRINT 1,((HTZ(N,M),M=1,20),N=1,NE)
   PRINT 7,((HTZ(N,M),M=21,ME),N=1,NE)
   PRINT 2,(V1(I),I=1,NURU)
   PRINT 3,NE,ME
   PRINT 4,NURU
 1 FORMAT(20F6.1)
 2 FORMAT(10A10)
 3 FORMAT('    HTZ(',I2,',',I2,')',//)
 4 FORMAT('    V1(',I2,')',//)
 7 FORMAT(10F6.1)
   DO 5 K=1,NALL
   READ(9) T,(V2(I),I=1,NURU),(V3(I),I=1,NURU),(V4(I),I=1,NURU)
   WRITE(2) T,(V2(I),I=1,NURU),(V3(I),I=1,NURU),(V4(I),I=1,NURU)
   PRINT 20,T
20 FORMAT('    READED (9) T,V2,V3,V4,    AT T = ',F10.0,/)
   PRINT 31,(V2(I),I=1,NURU),(V3(I),I=1,NURU),(V4(I),I=1,NURU)
31 FORMAT(10F10.0,/,10F10.0,/,10F10.0,/)
 5 CONTINUE
   DO 6 I=1,NALL
   READ(9) T,VEC,HT,RAD,ANG,Z
   WRITE(4) T,VEC,HT,RAD,ANG,Z
   WRITE(3) T,Z
   PRINT 12,T
12 FORMAT('    READED (9) T,VEC,HT,RAD,ANG,Z,     AT T = ',F10.0,/)
   PRINT 1 ,((RAD(N,M),M=1,20),N=1,NE)
   PRINT 7 ,((RAD(N,M),M=21,ME),N=1,NE)
   PRINT 1 ,((ANG(N,M),M=1,20),N=1,NE)
   PRINT 7 ,((ANG(N,M),M=21,ME),N=1,NE)
   PRINT 1 ,((Z  (N,M),M=1,20),N=1,NE)
   PRINT 7 ,((Z  (N,M),M=21,ME),N=1,NE)
 6 CONTINUE
   ENDFILE 2
   ENDFILE 3
   ENDFILE 4
   REWIND 2
   REWIND 3
   REWIND 4
   REWIND 9
   PRINT 100,NURU,ME,NE,T,VEC,HT
100 FORMAT('    NURU,ME,NE,T,VEC,HT BEEFORE PASSED TO SUBROUTINE P01',/
  1,10X,I5,I5,I5,F10.0,F10.0,F10.0,/)
   CALL P01
   CALL WATLV(NALL)
   STOP
   END
```

```
      SUBROUTINE P01
      COMMON/A/ V1(60),V2(60),V3(60),V4(60),HTZ(53,30),RAD(53,30),
     1ANG(53,30),Z(53,30),X(3),Y(3),NURU,ME,NE,T,VEC,HT
      DIMENSION SMBOL (3),TITLE(20),XCOORD(53,30),YCOORD(53,30)
     1,TATLE(20)
      REAL*8 V1
      INTEGER SMBOL,TITLE,TATLE
      DATA SMBOL/'* ','+ ','- '/
      CALL PLOTS
      READ1000,GPPI,VVS,WHS,ROTDEG,NS,(X(I),Y(I),I=1,3),NTHPT,LAND
      PRINT1001,GPPI,VVS,WHS,ROTDEG,NS,(X(I),Y(I),I=1,3),NTHPT,LAND
      READ 2000,(TITLE(I),I=1,20)
      READ 2000,(TATLE(I),I=1,20)
      READ 1002,THMIN,THNAX,YPN,XPN,SKIP
      READ 1002,TMIN,TMAX,TINC,TLEN,XPN,YPN,ZPN
      VVS=ZPN
      WHS=YPN
      SET UP X,Y GRID
      DO 100 J=1,ME
      DO 100 I=1,NE
      XCOORD(I,J)=J
  100 YCOORD(I,J)=-I
      DO 150 I=1,NS
  150 Y(I)=-Y(I)
      ROTATE ORIGIN  POINTS
      CALL ROT(X,Y,ROTDEG,NS)
      ROTATE GRID POINTS
      CALL ROT(XCOORD,YCOORD,ROTDEG,ME*NE)
  200 READ(4,END=900)T,VEC,HT,RAD,ANG,Z
      PRINT 8000,T
      IF(T.LT.TMIN.OR.T.GT.TMAX)GO TO 270
      TMIN=TMIN+TINC
      GO TO 260
  270 IF(T.EQ.TMAX)GO TO 260
      GO TO 400
  260 PRINT 4000,((TITLE(MM),MM=1,20),T)
      IF( VEC.EQ.0.) GO TO 300
      CALL VECTOR(.07,SMBOL ,NTHPT,GPPI,TITLE,LAND,ME,NE,HTZ,X,Y,NS,
     1XCOORD,YCOORD,RAD,ANG,VVS,T)
  300 IF(HT.EQ.0.)GO TO 200
      PRINT 4000,((TATLE(MM),MM=1,20),T)
      CALL WATHT  (.07,SMBOL ,NTHPT,GPPI,TATLE,LAND,ME,NE,HTZ,X,Y,NS,
     1XCOORD,YCOORD,Z,WHS,T)
  400 GO TO 200
  900 CALL PLOTE
      RETURN
 1000 FORMAT(10X           ,F10.0,3F6.0,4X,I1,6F3.0,I3,4X,I1)
 1001 FORMAT('  PARAMETER',F10.0,3F6.0,4X,I1,6F3.0,I3,4X,I1,/)
```

```
1002 FORMAT(10X           ,7F10.0)
2000 FORMAT(20A4)
8000 FORMAT('    READED 4   T = ',F10.0,/)
3000 FORMAT(6H TIME F10.0,4H SEC)
4000 FORMAT(10H PLOT FOR ,20A4,F10.0)
     END




      SUBROUTINE VECTOR(SSIZE  ,SMBOL ,NTHPT,GPPI,TITLE,LAND,ME,NE,
     1HTZ,X,Y,NS,XCOORD,YCOORD,VELOC,ANG,VVS,T)
      DIMENSION HTZ(53,30),VELOC(53,30),ANG(53,30),XCOORD(53,30),
     1YCOORD(53,30),X(NS),Y(NS),TITLE(20),SMBOL(3)
     1,TATLE(20)
      REAL*8 V1
      INTEGER SMBOL,TITLE,TATLE
      DO 400 I=1,NS
      NN=MAX0(NE,ME)
      CALL PLOT(0.,0.,3)
      CALL PLOT(0.,2.,-3)
      CALL SYMBOL (0.0,-0.5,0.14,TITLE,0.0,80)
      CALL NUMBER(8.5,-.5,0.14,T,0.0,0)
      DO 300 J=1,NE
      DO 300 K=1,ME
      TOPOG=HTZ(J,K)
      IF( TOPOG.EQ.0.) GO TO 300
      IF( TOPOG.EQ.1..AND.(MOD(J,NTHPT).NE.0 .OR.MOD(K,NTHPT) .NE.0))
     1GO TO 300
 200  YJK=(YCOORD(J,K)-Y(I))/GPPI
      IF( YJK.LT.0..OR.YJK.GT.15.) GO TO 300
      XJK=(XCOORD(J,K)-X(I))/GPPI
      IF( XJK.LT.-1.) GO TO 300
      IF( TOPOG+1.) 210,220,230
```

```
 210 CONTINUE
211  CALL SYMBOL (XJK,YJK,SSIZE  ,SMBOL (2),0.,1)
     GO TO 300
 220 CONTINUE
221  CALL SYMBOL (XJK,YJK,SSIZE  ,SMBOL (1),0.,2)
     GO TO 300
 230 IF(LAND.EQ.0) GO TO 260
     J1=J-LAND
     K1=K-LAND
     J2=J+LAND
     K2=K+LAND
     DO 240 L=J1,J2
     DO 240 M=K1,K2
     IF( HTZ(L,M).EQ.-1.) GO TO 300
 240 CONTINUE
 260 DIST=VELOC(J,K)/VVS
     IF( ANG(J,K).GT.360.) GO TO 300
     SI=(450.-ANG(J,K)        )*.0174532925
     CO=COS(SI )
     SI=SIN(SI )
     CALL PLOT  (XJK,YJK,3)
     XJK=XJK+DIST*CO
     YJK=YJK+DIST*SI
     CALL PLOT  (XJK,YJK,2)
     CALL ARWPT  (XJK,YJK,CO,SI)
 300 CONTINUE
 400 CALL PLOT(0.,NN/GPPI+3.,-3)
     RETURN
     END
```

```
      SUBROUTINE WATHT  (SSIZE  ,SMBOL ,NTHPT,GPPI,TATLE,LAND,ME,NE,
     1HTZ,X,Y,NS,XCOORD,YCOORD,Z,WHS,T)
      DIMENSION SMBOL (3),TITLE(20),HTZ(53,30),X(NS),Y(NS),XCOORD(53,30)
     1,TATLE(20)
     1,YCOORD(53,30),Z(53,30)
      REAL*8 V1
      INTEGER SMBOL,TITLE,TATLE
      DO 400 I=1,NS
      NN=MAX0(NE,ME)
      CALL PLOT(0.,0.,3)
      CALL PLOT(0.,2.,-3)
      CALL SYMBOL (0.0,-0.5,0.14,TATLE,0.0,80)
      CALL NUMBER(8.5,-.5,0.14,T,0.0,0)
      DO 300 J=1,NE
      DO 300 K=1,ME
      TOPOG=HTZ(J,K)
      IF( TOPOG.EQ.0.) GO TO 300
      IF( TOPOG.EQ.1..AND.(MOD(J,NTHPT).NE.0 .OR.MOD(K,NTHPT) .NE.0))
     1GO TO 300
  200 YJK=(YCOORD(J,K)-Y(I))/GPPI
      IF( YJK.LT.0..OR.YJK.GT.15.) GO TO 300
      XJK=(XCOORD(J,K)-X(I))/GPPI
      IF( XJK.LT.-1.) GO TO 300
      IF( TOPOG+1.) 210,220,230
  210 CONTINUE
 211  CALL SYMBOL (XJK,YJK,SSIZE  ,SMBOL (2),0.,1)
      GO TO 300
  220 CONTINUE
 221  CALL SYMBOL (XJK,YJK,SSIZE  ,SMBOL (1),0.,2)
      GO TO 300
  230 IF(LAND.EQ.0) GO TO 260
      J1=J-LAND
      K1=K-LAND
      J2=J+LAND
      K2=K+LAND
      DO 240 L=J1,J2
      DO 240 M=K1,K2
      IF( HTZ(L,M).EQ.-1.) GO TO 300
  240 CONTINUE
  260 CALL SYMBOL (XJK,YJK,SSIZE  ,SMBOL (3),0.,2)
      IF(    Z(J,K).EQ.0.) GO TO 300
      CALL PLOT  (XJK,YJK,3)
      YJK=YJK+  Z(J,K)/WHS
      CALL PLOT  (XJK,YJK,2)
      UP=1.
      IF( Z(J,K).LT.0.) UP=-1.
      CALL ARWPT  (XJK,YJK,0.,UP)
  300 CONTINUE
```

```
400 CALL PLOT(0.,NN/GPPI+3.,-3)
    RETURN
    END


    SUBROUTINE ROT(X,Y,DEG,MM)
    DIMENSION  X(MM), Y(MM)
    REAL*8 V1
    SI=DEG*0.01745329
    CO=COS(SI)
    SI=SIN(SI)
    DO 100    I = 1,MM
    X1=X(I)
    Y1=Y(I)
    X(I) = X1*CO + Y1*SI
100 Y(I) = Y1*CO - X1*SI
    RETURN
    END


    SUBROUTINE ARWPT   (X,Y,CO,SI)
    REAL*8 V1
    DATA H/.06/
    YY = SI*H
    XX = CO*H
    XXX=YY*.25
    YYY=XX*.25
    XX=X-XX
    YY=Y-YY
    CALL PLOT   (XX-XXX,YY+YYY,2)
    CALL PLOT  (XX+XXX,YY-YYY,2)
    CALL PLOT  (X,Y,2)
    CALL PLOT  (X,Y,3)
    RETURN
    END
```

```
      SUBROUTINE WATLV(NALL)
      DIMENSION Z(58,40),CL(11)
      LOGICAL*1 LTG(3)
      REAL*8TITLE(12)/'WATER HE','IGHT CON','TOURS   ','SAN DIEG',
     1'O BAY(  )',' TIME   ','        ','L.SALAS ','        ','        ',
     2'        ','        '/
      LTG(1)=.TRUE.
      LTG(2)=.TRUE.
      LTG(3)=.TRUE.
      CL(1)=-125.
      DO 200 KKK=2,11
      CL(KKK)=CL(KKK-1)+25.
  200 CONTINUE
      DO 100 KK=1,NALL
      READ(3) T,Z
      CALL CONTUR(Z,58,40,58,CL,11,TITLE,8,8,LTG)
  100 CONTINUE
      RETURN
```

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ABSTRACT

The Hydro-Numerical Prediction Model developed by Hansen is applied to San Diego Bay, and the results compared both with the hydraulic model and the real data obtained by field measurements. This allows one of the few good comparisons between numerical and hydraulic models for the prediction of actual conditions.

The bay was divided into two sections that were run separately in order to obtain the desirable spatial resolution. This division required solving the problems of proper tuning and matching techniques between both portions. The solution involved the addition of an appended pseudo-bay to the first section of the model in order to compensate for the correct tidal prism. The effects of a proposed second open entrance in the southern part of the bay were studied. This resulted in an increase of flushing in the southern portion of the bay but caused the currents in the center of the bay to be small which decreased dispersion in the central portion of the bay. In general, both models produced similar and reliable results, but there was a considerable reduction of cost and time with the numerical model.

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