# PREDICTION OF UNSTEADY SALINITY INTRUSION IN ESTUARIES: MATHEMATICAL MODEL AND USER'S MANUAL

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M. Llewellyn Thatcher

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M.I.T. RALPH M. PARSONS LABORATORY
FOR WATER RESOURCES AND HYDRODYNAMICS

Report No. 159

Prepared under the support of
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DEPARTMENT
OF
CIVIL
ENGINEERING

SCHOOL OF ENGINEERING
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Cambridge, Massachusetts 02139

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RALPH M. PARSONS LABORATORY

FOR WATER RESOURCES AND HYDRODYNAMICS

Department of Civil Engineering

Massachusetts Institute of Technology

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## FOREWORD

This report is intended as a documentation of the computer program and as a user's manual for the implementation of the mathematical model for the prediction of unsteady salinity intrusion in estuaries. The details of the model development and verification are contained in the following report:

> "A Mathematical Model for the Prediction of Unsteady Salinity Intrusion in Estuaries" by M. Llewellyn Thatcher and Donald R. F. Harleman, Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics, Technical Report No. 144, February 1972 [also published by M.I.T. Sea Grant Project Office as Report No. MITSG 72-7 (index No. 72-307-Ccb)].

The unsteady salinity intrusion model is one-dimensional, although varying degrees of stratification are accounted for in the assumed longitudinal dispersion relationship.

This model is a component in two additional studies, one of which is concerned with the two-dimensional aspects of salinity intrusion (i.e. vertical salinity and velocity distributions in estuaries):

> "Mathematical Simulation of Tidal Time-Averages of Salinity and Velocity Profiles in Estuaries" by John S. Fisher, John D. Ditmars and Arthur T. Ippen, Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics, Technical Report No. 151, July 1972 [also published by M.I.T. Sea Grant Project Office as Report No. MITSG 72-11 (index No. 72-311-Ccb)]

The second study is concerned with the development of a model for predicting the transient longitudinal distribution of water quality parameters in estuaries:

> "Numerical Model for the Prediction of Transient Water Quality in Estuary Networks" by James E. Dailey and Donald R. F. Harleman, Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics, Technical Report No. 158, October 1972 [also published by M.I.T. Sea Grant Project Office as Report No. MITSG 72-15 (index No. 72-315-Ccb)]

This user's manual therefore assists in the implementation of the analytical and numerical models listed above.

## ACKNOWLEDGEMENT

Primary support for this study came from the Office of Sea Grant, National Oceanic and Atmospheric Administration, U. S. Department of Commerce, Coherent Area Project Grant GH-88 and 2-35150, under the Estuary Modeling Program underway at the Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics of the Department of Civil Engineering. Partial support was also provided by a grant from the Henry L. and Grace Doherty Charitable Foundation, Inc. This program is under the administrative and technical supervision of Professor Arthur T. Ippen and Professor Donald R. F. Harleman (DSR 72602 and DSR 73479). The purpose of the Estuary Modeling Program is to develop analytical and numerical techniques for modeling the behavior of estuaries and coastal embayments in order to extend the basic understanding of estuarine dynamics and the ability to make predictions relating to the estuarine environment.

The authors wish to express their appreciation to Mr. David Najarian, Research Assistant, for his valuable assistance throughout the preparation of this manual.

## Table of Contents

# I. Introduction and Review

## 1.1 Introduction

This is a user's manual for the computer program implementing the transient salinity intrusion model developed by Thatcher and Harleman(1). The purpose of this manual is to enable researchers and engineers to use the computer program in an effective manner without requiring that they have other than a fundamental understanding of how digital computers accept input data, execute logical and numerical instructions, and present calculations in readable form. Although a knowledge of FORTRAN programming is helpful, it is not considered necessary for the prospective user of this program. However, to avoid unnecessary computing expense, it is recommended that a user not familiar with computer applications seek the assistance of someone who is experienced when it comes to the actual execution of the computer program.

## 1.2 Review of the Mathematical Model

Reference 1 describes the development of a predictive, one-dimensional mathematical model for longitudinal salinity distributions in estuaries under transient conditions of fresh water inflow and ocean tidal elevations. The governing equations for the tidal motion are:

the continuity equation,

$$b \frac{\partial h}{\partial t} + \frac{\partial Q}{\partial x} - q = 0 \qquad (1\text{-}1)$$

and the longitudinal momentum equation,

$$\frac{\partial Q}{\partial t} + u \frac{\partial Q}{\partial x} + Q \frac{\partial u}{\partial x} + g \frac{\partial h}{\partial x} A + g \frac{Ad_c}{\rho} \frac{\partial \rho}{\partial x} + g \frac{Q|Q|}{AC^2 R_h} = 0 \qquad (1\text{-}2)$$

Determination of the salinity distribution requires the conservation of salt, or salt balance equation,

$$\frac{\partial (A_{Total} s)}{\partial t} + \frac{\partial (Qs)}{\partial x} = \frac{\partial}{\partial x} \left[ EA_{Total} \frac{\partial s}{\partial x} \right] \qquad (1\text{-}3)$$

and an equation of state relating salinity and density,

$$\rho = 0.75\, s + 1000 \qquad (1\text{-}4)$$

where

$b$ = the total width of the channel [$b_{Total}$ in Reference 1]

$h$ = the depth of water from surface to a horizontal datum

$Q$ = cross-sectional discharge

$q$ = lateral inflow per unit length

$u$ = average cross-sectional velocity of the conveyance area

$g$ = acceleration of gravity

$A$ = cross-sectional area of conveyance area [$A_{core}$ of Reference 1]

$A_{Total}$ = total area of cross section, including storage

$d_c$ = depth of the centroid of conveyance area

$\rho$ = fluid density

$C$ = Chezy coefficient

$R_h$ = hydraulic radius

$E$ = longitudinal dispersion coefficient

$s$ = salinity representative of a cross-section (parts per thousand)

The boundary conditions required to solve these equations are:

(1) the specification of tidal elevation at the ocean entrance as a function of time

(2) the specification of fresh water inflow at the upstream boundary and of tributary inflows as functions of time

(3) the specification of zero salt flux across the upstream boundary and

(4) the specification of conditions on salinity at the downstream entrance of the estuary.

Information on water surface elevations at the ocean entrance is usually available from tide tables, and it is assumed that the user has fresh water inflow hydrographs. Conditions on salinity at the downstream boundary require only a specification of ocean salinity, $s_o$ or a maximum salinity. This salinity specification constitutes the boundary condition during the flood (incoming) flow. During ebb (outgoing) flow, the ocean boundary salinity is not specified, as the solution is continued in terms of a convective transport across the downstream boundary. When the ebb flow ceases and flood begins, the salinity at the downstream boundary will return to its maximum value $s_o$. When the downstream boundary coincides with the ocean entrance, the time of return of salinity to its maximum value will be relatively rapid due to longshore currents which sweep away much of the diluted water. It is assumed that this return is linear in time, and for the ocean entrance good results have been obtained using 5% of a tidal period as the time span over which the salinity returns to its maximum.

Figure 1.1 shows that this time span can be specified as considerably longer than 5% in order to account for the cases in which the downstream boundary is not at the ocean entrance.

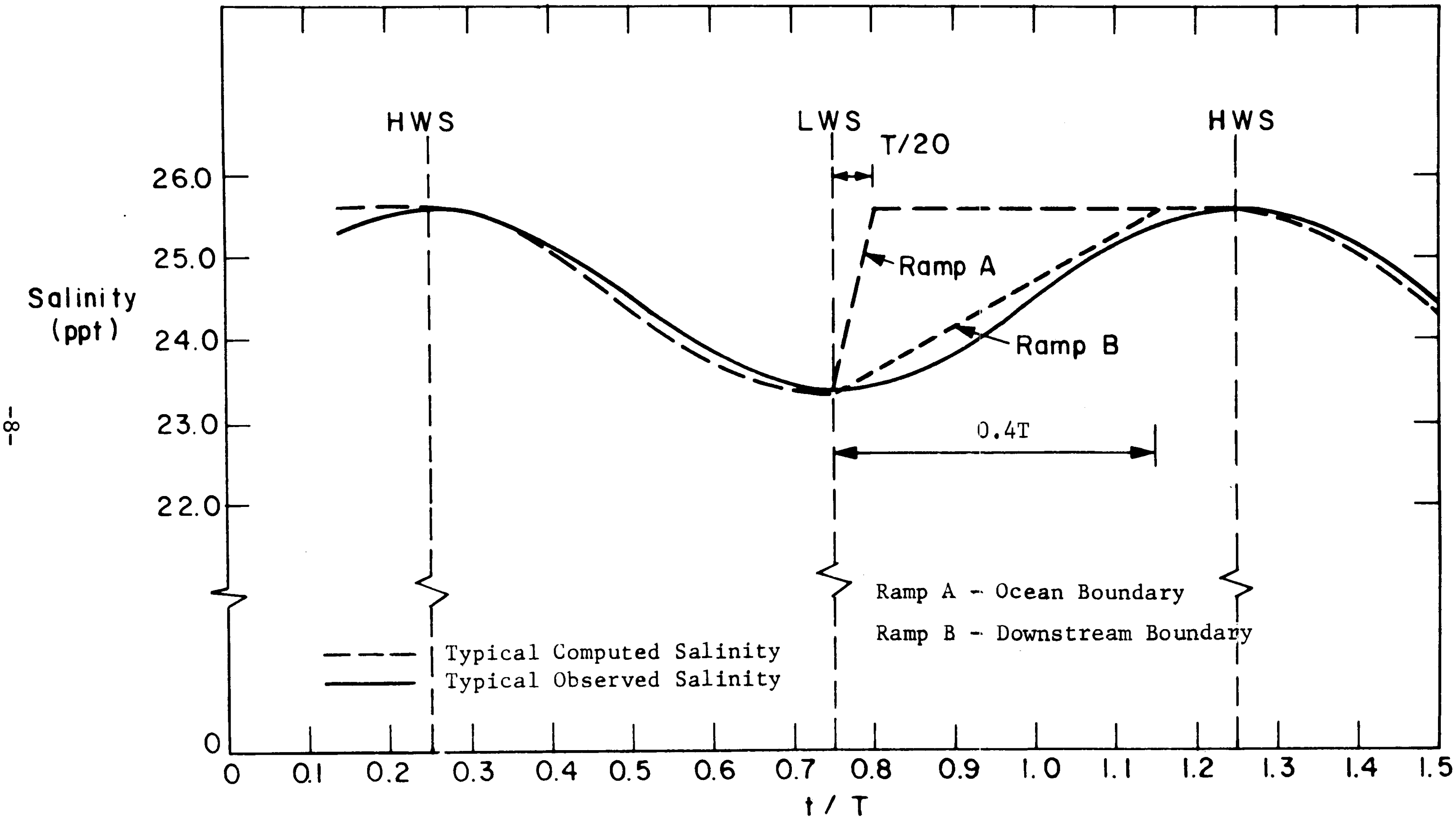
The longitudinal dispersion coefficient is related to the local non-dimensional salinity gradient, $\frac{\partial s/s_o}{\partial x/L}$, (where L = length of estuary) in the salinity intrusion region. The dispersion coefficient for the entire estuary is

$$E(x,t) = K\left|\frac{\partial s/s_o}{\partial x/L}\right| + 77\ n\ u\ R_h^{5/6} \tag{1-5}$$

where K is a constant of proportionality related to the degree of stratification as measured by gross estuarine parameters. The second term represents the dispersion in the fresh water region where n is the Manning resistance coefficient, u is the cross-sectional average velocity and $R_h$ is the hydraulic radius.

Reference 1 has shown that a correlation exists between $K/u_oL$ and an estuary number $\mathbb{E}_D$. This permits the determination of a value for K for each tidal period based on the previous tidal period's calculated value of the tidal prism, $P_T$, the densimetric Froude number, $\mathbb{F}_D$, the fresh water inflow, $Q_f$, and the tidal period, T. These are the gross parameters which define the estuary number

$$\mathbb{E}_D = \frac{P_T \mathbb{F}_D^{\,2}}{Q_f T} \tag{1-6}$$



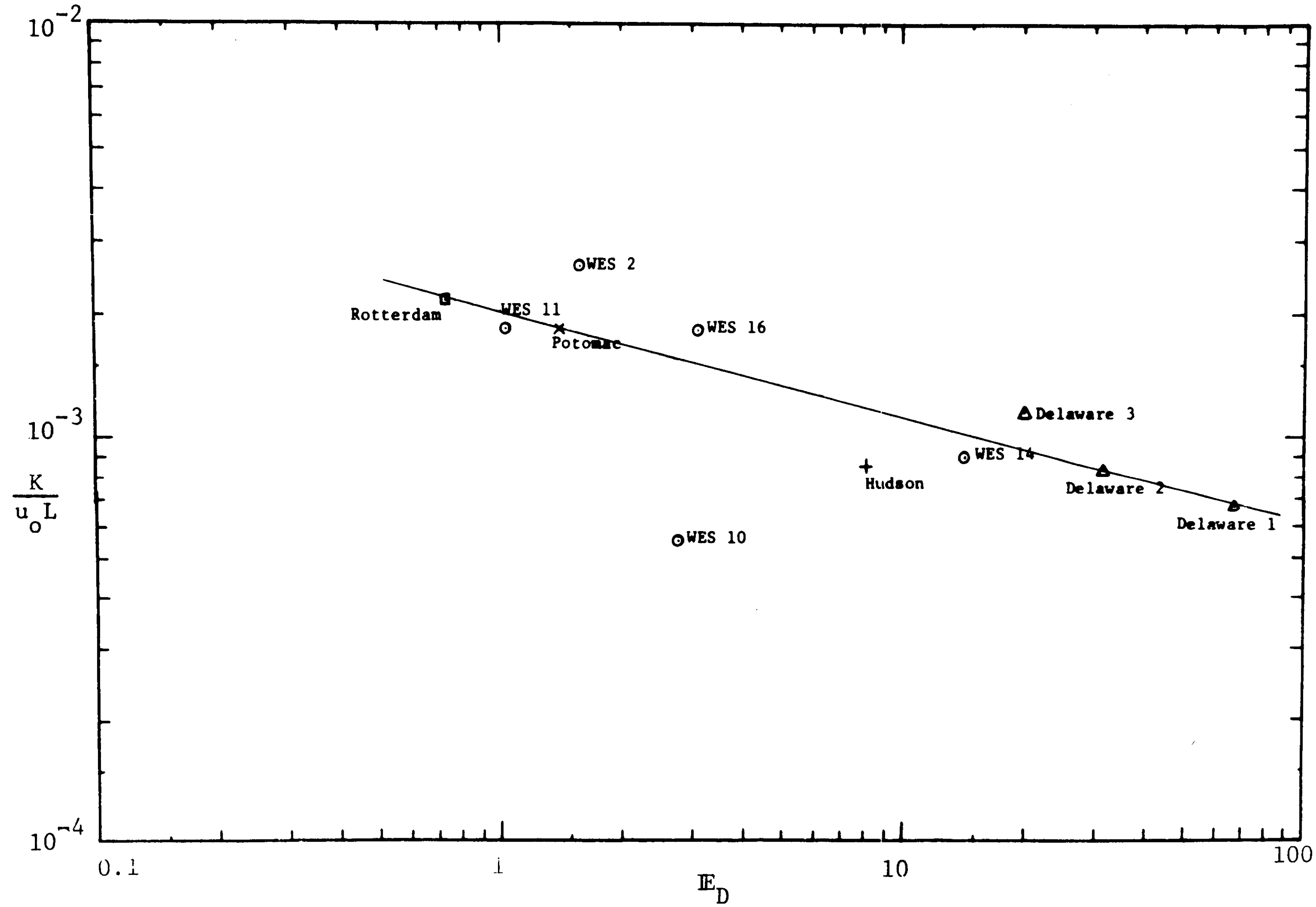

Representation of Entrance Boundary Condition
on Salinity for Estuary

Figure 1.1

The correlation between $K/u_oL$ and $\mathbb{E}_D$, developed using steady-state salinity distribution data, covers a wide range of stratification conditions. This relationship is shown in Figure 1.2.

Calculations of salinity, water surface elevation and discharge are made by solving Equations 1-1, 1-2, 1-3 and 1-4 in finite difference form. The numerical model consists of two fundamental components of calculation. The first component solves for the water surface elevations and discharges and is a modification of the numerical model of Harleman and Lee(2). The second component is the finite difference solution of the salt balance Equation 1-3. Details of the finite-difference techniques used are described in Reference 1.

The solution requires initial conditions and advances in time in accordance with the values of the time-varying boundary conditions of tidal elevation at the entrance and fresh water inflows. The solution determines surface elevations, discharges and salinities as functions of longitudinal distance and time for any specified number of tidal periods. Details pertaining to the practical application of the transient salinity intrusion numerical model are presented in the following sections of this report.




Correlation of Dispersion Parameter to Degree of Stratification

Figure 1.2

## II. Principal Steps in the Application of the Numerical Model

### 2.1 Initial Decisions in Reducing Estuary Geometry to One-Dimensional Parameters

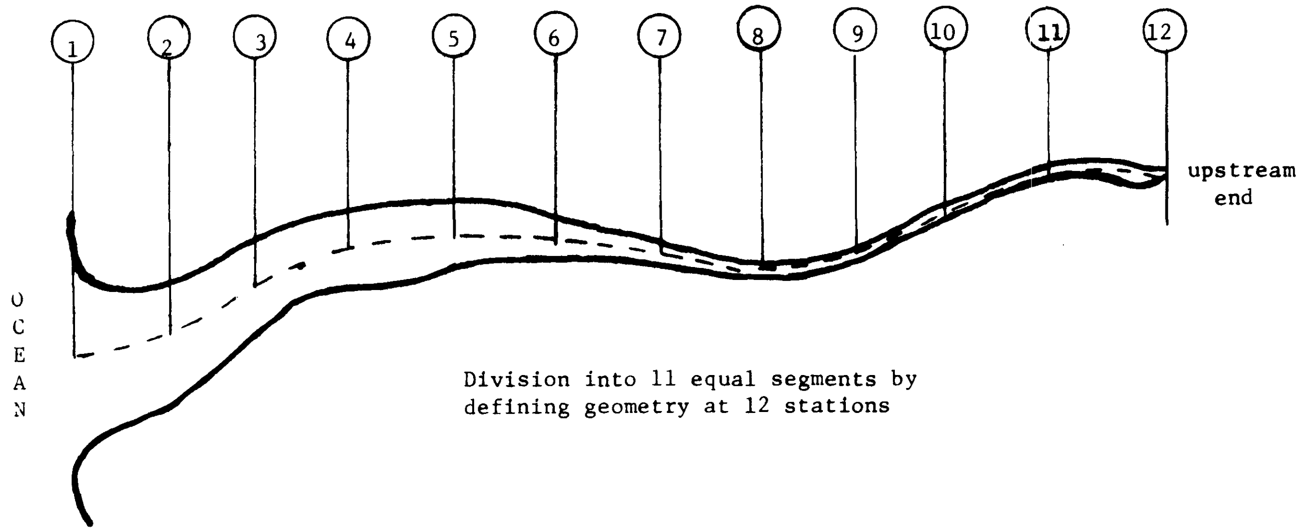
The geometric configuration of the estuary must be studied to determine the appropriate extent or domain of the estuary, and the degree of detail necessary in terms of discretization. The longitudinal extent of the estuary is the first determination to be made. The upstream boundary is usually taken at the head of tide. This can be a physical closed-end such as a dam, lock, waterfall or rapids. If no physical barrier exists, the estuary is of the open-end type, and the upstream boundary is set at a point far enough upstream so as to be unaffected by tidal action.

Ideally, the downstream boundary should coincide with the ocean entrance to the estuary. The case studies presented in Ref. (1) consider three different types of estuaries from the standpoint of downstream boundary location:

1. Delaware. The downstream boundary is at the ocean entrance (Cape Henlopen-Cape May).
2. Potomac. The downstream boundary is at the junction with Chesapeake Bay.
3. Hudson. The downstream boundary was chosen to be at the Battery. Below the Battery the estuary is no longer one-dimensional because of the connection to Long Island Sound through the East River.

The salinity boundary condition for the Delaware and Potomac were assumed to follow "ramp A" of Figure 1.1 with the value of $s_o$ being determined by salinity conditions in the Atlantic and in Chesapeake Bay respectively. In the case of the Hudson the salinity variation at the Battery was assumed to be more nearly sinusoidal as shown by "ramp B" of Figure 1.1.

Once the limits of the estuary have been defined, the next decision is that of determining the segment length, $\Delta x$, for discretization of the physical characteristics. This interval of discretization, $\Delta x$, must be small enough to be representative of the principal variation in geometry. Case studies made in Ref. (1) have shown that segment lengths of 2 to 3 miles generally provide sufficient detail. The computer model requires that the total number of stations be an even number. This is the result of a staggered finite-difference scheme in which water surface elevations and salinities are calculated at odd numbered stations and discharges at even numbered stations. Figure 2.1 illustrates




<u>Station Number</u>

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\eta$ | Q | $\eta$ | Q | $\eta$ | Q | $\eta$ | Q | $\eta$ | Q | $\eta$ | Q |
| S | | S | | S | | S | | S | | S | |

$\eta$ - water surface elevation and S - salinity; determined at odd numbered stations

Q - discharge; determined at even numbered stations

<u>Segmentation of the Estuary</u>

Figure 2.1

the division of a simplified estuary into 12 stations (11 segments).

After the identification of longitudinal stations has been accomplished the schematization of the natural geometry into basic parameters of depth and area is performed. Two basic types of schematization are available in this model and the user must choose that which best suits his particular study.

The first type, Figure 2.2a, is that of a trapezoidal cross-section. This type of schematization is especially useful in cases where it is important to represent the change in estuary width with change in depth. It assumes that the entire trapezoidal area participates in the longitudinal tidal flow and consequently it does not provide for portions of the estuary which act as storage. It is noted that schematization to a rectangular cross-section is a special case of the trapezoidal schematization.

The second type, Figure 2.2b, represents the area of the discrete interval by two rectangular areas; one for storage, the other for conveyance. This schematization simplifies the cross-section in terms of geometry, and allows the user to specially treat the cases of embayments and other portions of the estuaries which do not act directly or significantly in terms of the longitudinal tidal flow.

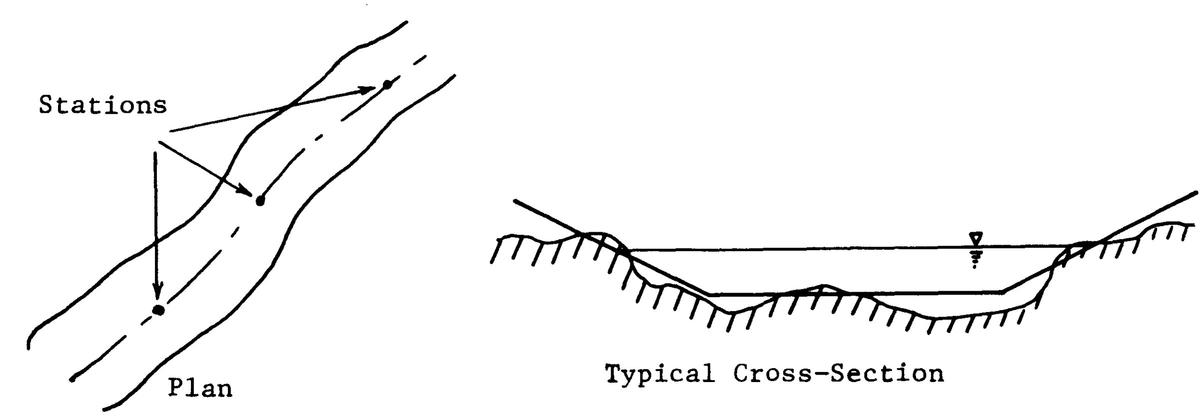
After the user has decided which of the types of schematization to use he can proceed to the schematization process itself. This process will depend on the particular case, the time available and sources of data. The following sections are intended to serve as an example of the schematization process.

## 2.2 General Principles of Schematization

The numerical model employs discrete quantities. At each station such as those indicated in Figure 2.2 the user must determine basic parameters which permit the calculation of a conveyance cross-sectional area, $A_{core}$, and, if so chosen, a storage area, $A_{storage}$. These areas are to be representative of the estuary in the region of the station being considered. More precisely, they represent an average for the segment centered on that station. The cross-section at the station itself may not be representative of the entire segment.

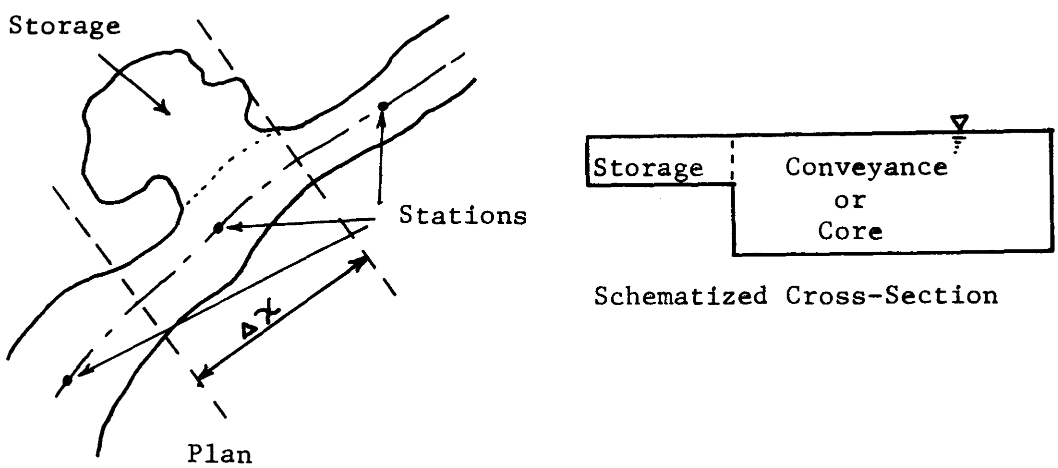
## 2.3 Establishing the Datum

In order to correctly represent the water surface the data defining each cross-section must be related to a common horizontal datum. Often this presents




Trapezoidal Schematization

Figure 2.2a




Storage and Conveyance (or Core) Area Schematization

Figure 2.2b

a problem because hydrographic charts are intended for navigation and not for numerical modeling. Chart depths are relative to some water surface such as local mean low water, local mean river level, or other local water surface which is not necessarily horizontal.

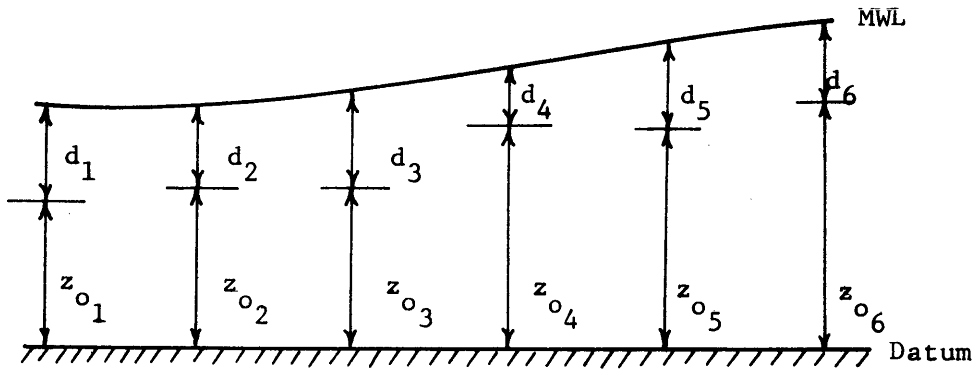
In order to accurately define the estuarine geometry the bottom elevations of the schematized cross-sections must be specified relative to a common horizontal datum. This entails obtaining information which defines the local datums. Such information is usually available from the organization that issued the charts. (For example, the National Ocean Survey of the U.S. Department of Commerce.)

Figure 2.3 shows how the common horizontal datum is used. Each station is schematized with reference to the mean water level (MWL). The depth from MWL to the bottom of the schematized cross-section is $d_j$. The location of the common horizontal datum is specified by the user, and the changes in local datums are included by defining $z_{o_j}$ so that $d_j + z_{o_j}$ measures the distance from the common horizontal datum to the local MWL. The changes in local datums are illustrated in Figure 2.3 by the fact that the MWL varies with respect to the horizontal.

If no data is available on the local datums it is possible to assume that the local datums are all the same. This means that the MWL is assumed to be horizontal from one end of the estuary to the other. The effect of such an assumption is the introduction of an error in the depth of the schematized cross-sections equal to the difference between the assumed local MWL and the actual local MWL.

## 2.4 Schematization to a Trapezoidal Cross-Section Without Storage

The cross-section which typifies each reach is considered to be centered on the station. The trapezoid which most closely represents the cross-section of the reach should be found. This can be achieved by a variety of techniques




Sketch of Common Datum

Figure 2.3

ranging from estimation by visual inspection to mathematical fitting techniques employing chart soundings. In terms of required input data to the computer program, the trapezoid selected must be defined by the following four parameters as shown in Figure 2.4a:

1. bottom width, $b_o$
2. depth, d
3. horizontal distance per unit vertical distance, SS
4. distance from common datum to the bottom of the channel, $z_o$

The depth is measured to mean water level (MWL).

## 2.5 Schematization Including Storage and Conveyance (or Core) Areas

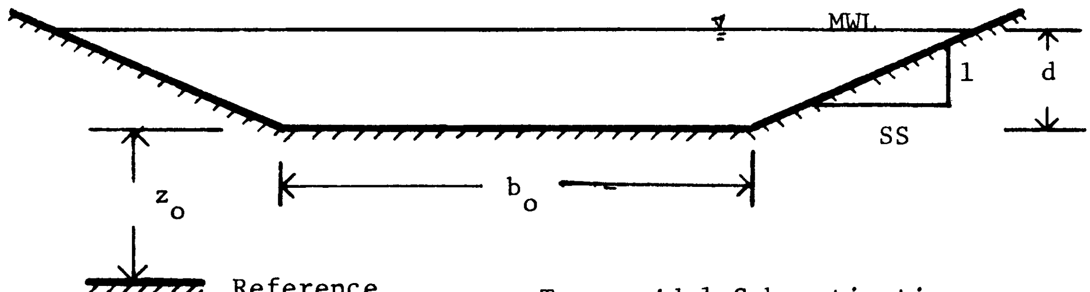
The plan view of Figure 2.2b shows a typical estuary reach containing an embayment. The water in the embayment does not participate in the longitudinal tidal transport, however it fills and empties with the change of water surface elevation. The embayment acts as storage, and in estuaries where the surface area of such embayments is a significant percentage of the total surface area, the schematization should represent the storage action.

The schematization employed is based on the determination of a conveyance or core area which is defined in terms of a width $b_{core}$ and a depth d. This requires that the user determine an average cross-sectional area and width for the segment. This area is then represented in rectangular form by dividing it by the average width to obtain the depth, d.

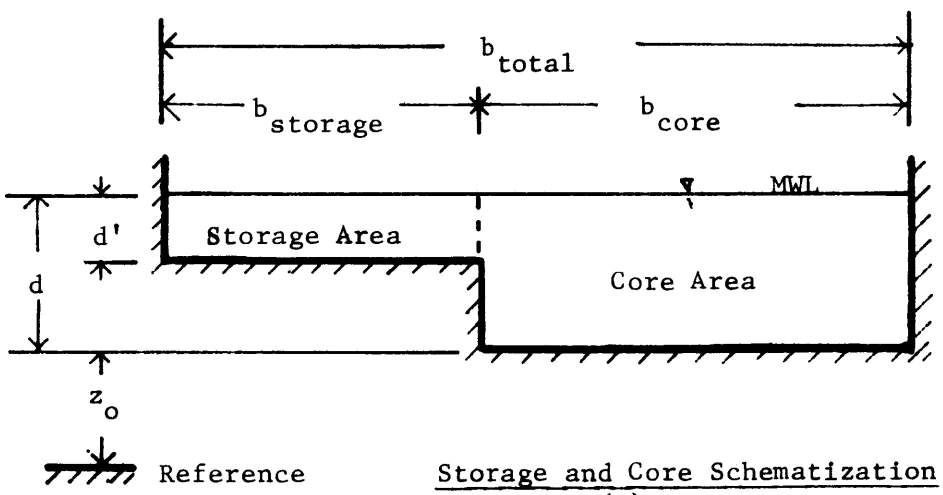
Figure 2.4b shows how this core area is joined to a storage area. To define the storage area it is necessary to define a depth of the storage area, d'. This depth, multiplied by the surface area of storage, $A^s_{storage}$, yields a volume of storage $V_{storage}$. To obtain an equivalent cross-sectional storage area $A_{storage}$, the volume of storage is divided by the segment length, $\Delta x$. Further division of this cross-sectional storage area by the storage depth, d' gives the equivalent width, $b_{storage}$, of the schematized rectangular cross-section. These relationships are:

$$V_{storage} = A^s_{storage}\, d'$$

$$A_{storage} = \frac{V_{storage}}{\Delta x}$$




Trapezoidal Schematization
(a)




Storage and Core Schematization
(b)

Basic Schematized Cross-Sections

Figure 2.4

$$b_{storage} = \frac{A_{storage}}{d'} = \frac{A^s_{storage}}{\Delta x} \qquad (2\text{-}1)$$

The final relationship shows how the schematization process spreads out the surface area over the reach length $\Delta x$.

The data required by the computer program for each section are:

1. the core width, $b_{core}$
2. the core depth, d
3. the total width, $b_{total} = b_{core} + b_{storage}$
4. the storage depth, d'
5. the distance from the common datum to the bottom of the schematized section, $z_o$

Again, it must be remembered that the depth is with respect to mean water level.

## 2.6 Verification of Tidal Hydraulics

### 2.6.1 Choice of Δt, Based on Stability Requirements

The explicit finite-difference solution of the continuity and the momentum equations (1-1 and 1-2) imposes a limit on the size of time increment, $\Delta t$. This requirement can be approximated by

$$\Delta t \leq \frac{\Delta x}{u+c} \qquad (2\text{-}2)$$

where u is the average cross-sectional velocity and c is the wave speed $\sqrt{gh}$ at the same location. Equation 2-2 can be used to estimate the $\Delta t$ corresponding to a particular $\Delta x$ by estimating u and c. For example, if the maximum depth of an estuary is 40 ft. and the expected tidal velocity will not be greater than 2 feet per second, Equation 2-2 limits $\Delta t$ to a maximum of about $\frac{\Delta x}{38}$ seconds. For $\Delta x$ = 10,000 feet, $\Delta t \leq 263$ seconds, and for a tidal period of 12.4 hours, this would require 170 time intervals per tidal cycle.

### 2.6.2 Channel Roughness as the Variable Parameter in Tidal Hydraulics Verification

Tide table data on tidal range and phase is utilized to insure that the numerical model correctly represents the advective characteristics of the estuary. The tidal verification process is executed by varying the channel roughness (Manning's n) so as to achieve the best fit with available data. Often the data is presented in terms of local tidal range and phase lags for a particular tidal range at the ocean, or downstream boundary. The tidal verification runs are made by assuming typical fresh water inflows and holding these constant for each tidal cycle of calculation. The time varying surface elevation at the ocean is repeated for each tidal cycle. Such a repetition of boundary conditions defines a quasi-steady state condition. Initial conditions of surface elevation and discharge can be approximated (or set equal to zero) and any reasonable approximation of the longitudinal salinity distribution can be used for an initial condition on salinity. The numerical model is then run and it has been found that about 5 to 8 tidal periods of calculation will result in tidal elevations and discharges which are essentially the same from one period to the next. This procedure can be applied for different variations in channel roughness until the resulting convergent surface elevations give a satisfactory verification of the tidal data. The unsteady salinity intrusion study can then be continued using this distribution of channel roughness. It is noted that the tidal hydraulics are not very sensitive to small changes in the salinity distribution and this is why the above procedure can be successfully executed using only an approximate salinity distribution.

Typical values of Manning's n found in Ref. (1) are:

Delaware $n = 0.017$ to $0.033$ (ave. $= 0.024$)

Potomac $n = 0.018$

Hudson $n = 0.015$

## 2.7 Treatment of Entrance Salinity for Different Entrance Configurations

When the estuary being studied can be schematized as far downstream as the ocean, the boundary treatment requires the specification of the ocean salinity, $s_o$, and the portion of the tidal period during which the salinity returns from the value at low water slack (LWS) to the maximum value, $s_o$. For such cases it has been found that a time equal to 0.05T for the return portion gives reasonable results. A well defined ocean boundary permits the prediction of salinity distributions starting with initial conditions requiring only the specification of the ocean salinity, $s_o$.

In cases where the downstream boundary cannot be taken at the ocean, but must be located farther upstream, the assumption that longshore currents will sweep away most of the diluted ebb flow is not as valid as it was for the ocean boundary. The user can predict longitudinal salinity distributions under such conditions by specifying the maximum salinity at the downstream boundary and also by specifying a reasonable return time during which the salinity will return from its low water slack value to the maximum value. This return time will be between 0.05T and 0.4T. Ref. (1) has shown that for the Hudson a satisfactory representation of the downstream boundary at the Battery was achieved using 0.4T. The observed depth averaged salinity variation at the Battery was approximately sinusoidal. Figure 1.1 illustrates how the different specifications of return time affect the representation of the temporal variation of salinity at the downstream boundary.

### 2.8 Initial Conditions

An initial longitudinal salinity distribution must be specified to begin the calculation. In addition initial values of surface elevations and discharges are required. As discussed in Section 2.6.2, the effect of arbitrary initial conditions of surface elevation and discharge is negligible after 5 to 8 tidal cycles of calculation, and this characteristic can be used to generate realistic initial conditions of surface elevations and discharges for the unsteady salinity intrusion study.

Coast and Geodetic Tide Tables can be used to specify the maximum and minimum tidal elevations at the downstream boundary. By assuming an approximate salinity distribution, the user can back-up eight tidal cycles from the beginning of the study period and initiate a calculation using initial values of elevation and discharges equal to zero. The tidal surface elevations and the discharges produced after eight cycles are appropriate initial conditions for the unsteady study. The user can combine the elevations and discharges at the end of the introductory eight cycles of calculation with the initial salinity distribution and thus obtain a complete set of initial conditions for the unsteady salinity intrusion study.

## III. Objective and Scope of the Computer Program

The objective of the computer program is to calculate water surface elevations, salinities and discharges as functions of time and of longitudinal distance along the estuary. This calculation is an implementation of the finite difference mathematical model developed in Ref. 1.

The scope of the program is defined in terms of three areas of user control. These areas of control are (1) specification of estuarine geometry and roughness, (2) specification of time-varying boundary conditions and of initial conditions, and (3) selection of the frequency and content of the output from the computer.

In the specification of geometry the user describes the estuary cross-sections in terms of either a rectangular or trapezoidal channel, or in terms of a rectangular channel with a storage area (Sections 2.2, 2.3, 2.4 and 2.5). Simplified descriptions can be used for the special cases of a uniform rectangular section and for a rectangular section whose width varies in an exponential manner. The channel roughness is described in terms of Manning's n and wind shear effects can be specified.

The boundary conditions are: tidal surface elevations at the downstream boundary, fresh water inflows at the head and at other locations along the estuary, and the maximum salinity, $s_o$, at the downstream boundary. If the tidal surface elevations at the downstream boundary are repeating from tidal cycle to tidal cycle, then the specification of this boundary condition can be made in terms of harmonic components or in tabular form. For the situation in which tidal variations are expressed in terms of a series of high and low water elevations (as from data found in tide tables), the user can specify the time series and the program will fit a cosine curve to the specified values of high and low water elevations. The specification of fresh water inflows and the maximum entrance salinity $s_o$ is made for each tidal period of calculation.

The initial conditions of surface elevation, discharge, and salinity can be specified in a convenient form; either from the result of a previous calculation stored as a "data set", or in punch card form.

The computer output can be printed or stored on a sequential data device such as a magnetic tape. The program provides the user with the ability to specify the frequency of printing the surface elevations, salinities and discharges. It is also possible to print out high water slack salinities and to punch the final calculated values into cards so that these values can become the initial conditions of a subsequent calculation. The storing of calculated values of elevations, salinities and discharges on a sequential data device is convenient for subsequent plotting of these results by a plotting program such as that included in Appendix III. It is also possible to store the calculated values of the longitudinal dispersion coefficient, E, on a sequential data device.

## IV. Structure of the Program

The program consists of two principal multipurpose routines and several single purpose routines.

The first principal multipurpose routine is the main-line program, hereafter referred to as MAIN. MAIN executes the input routines TIDIN and OSIN and proceeds, cycle by cycle, to read in the time varying boundary specifications and execute the basic calculation routine, MARCH. When the calculation is completed MAIN outputs the final values of surface elevation, discharge and salinity.

The second principal multipurpose routine is MARCH. MARCH performs the basic calculation in time steps of $2\Delta t$, solving first the continuity equation, then the momentum equation, and finally the salt balance equation. In the solution of the salt balance equation, three routines are executed: (1) TDISP, which calculates the dispersion coefficient; (2) TOCNB, which performs the entrance or ocean boundary calculation; and (3) TRIDG, which solves the resulting tri-diagonal simultaneous equations.

The output is produced by executing routine SPEW.

At the end of each tidal cycle MARCH calculates the total mass of salt in the estuary. If requested by the user, the time of high water slack is found and the corresponding high water slack salinities are printed. Finally, the value of the dispersion parameter K is determined by executing routine ESNOD which determines the estuary number $\frac{P_T \mathbb{F}_D^{\,2}}{Q_f T}$ and determines K in terms of the specified $K/u_o L$ correlation with the estuary number.

The single purpose routines executed ("called") by MAIN and by MARCH are:

TIDIN: An input routine for geometry, roughness, wind effects and entrance tidal variation.

OSIN: An input routine for specification of parameters related to the solution of the salt balance equation and for the specification of output frequencies and options.

TDISP: A calculation of the dispersion coefficient from the equation

$$E = K \left| \frac{\partial \overset{o}{s}}{\partial \overset{o}{x}} \right| + n\, E_T \qquad (4\text{-}1)$$

where n = 1, unless otherwise specified by the user.

TOCNB: This routine supplies the finite-difference equation for the downstream element of the estuary (entrance boundary treatment).

TRIDG: A solver of simultaneous equations in tri-diagonal form.

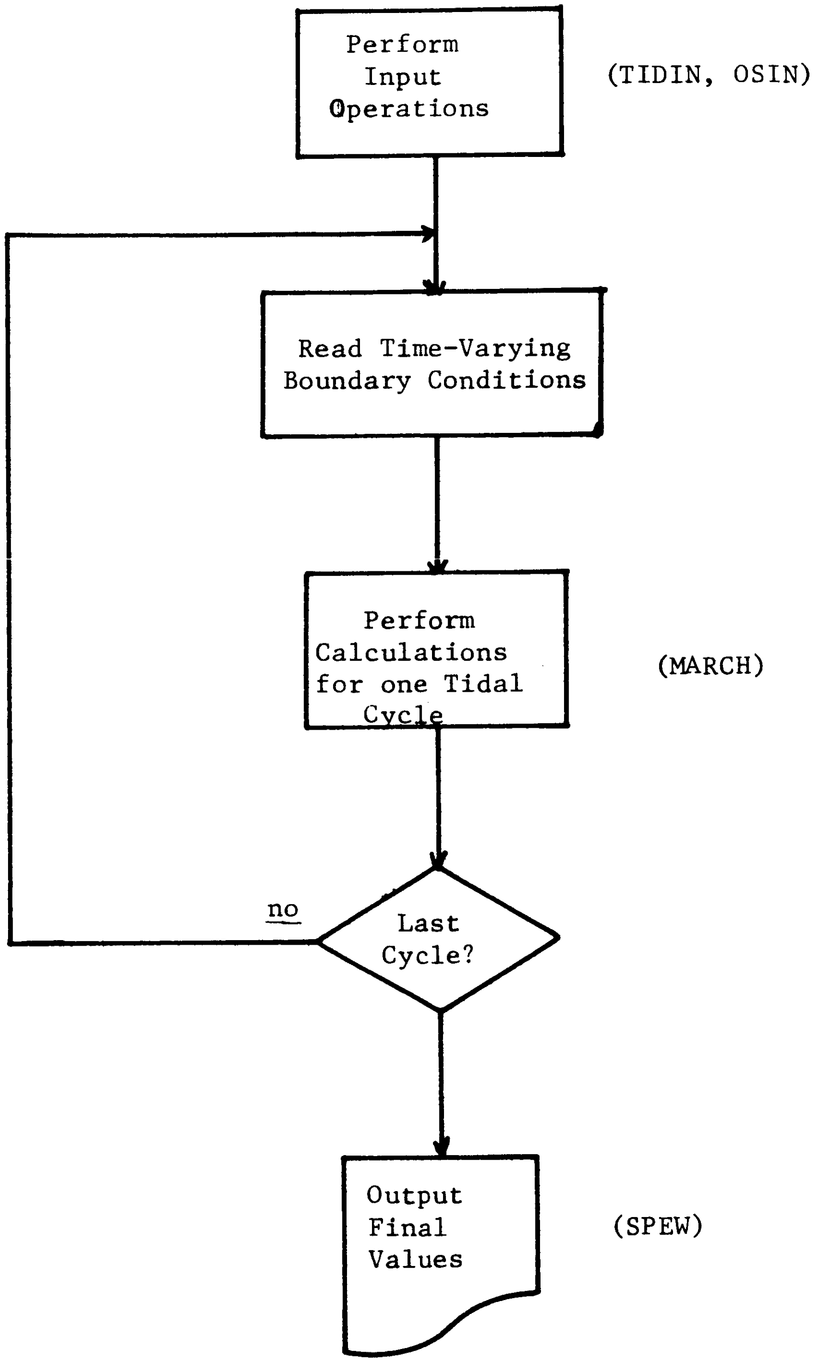
ESNOD: Calculates the tidal prism, $P_T$, the densimetric Froude number, the estuary number $\frac{P_T \mathrm{IF}_D^{\,2}}{Q_f T}$ and then uses the correlation of $\frac{K}{u_o L}$ vs. $\frac{P_T \mathrm{IF}_D^{\,2}}{Q_f T}$ to determine the value of dispersion parameter K to be used in the next tidal cycle of calculation.

SPEW: An output routine for the surface elevation, discharge, and salinities.

ERRL: An error handling routine to assist the user in preparing input decks and to understand what went wrong.

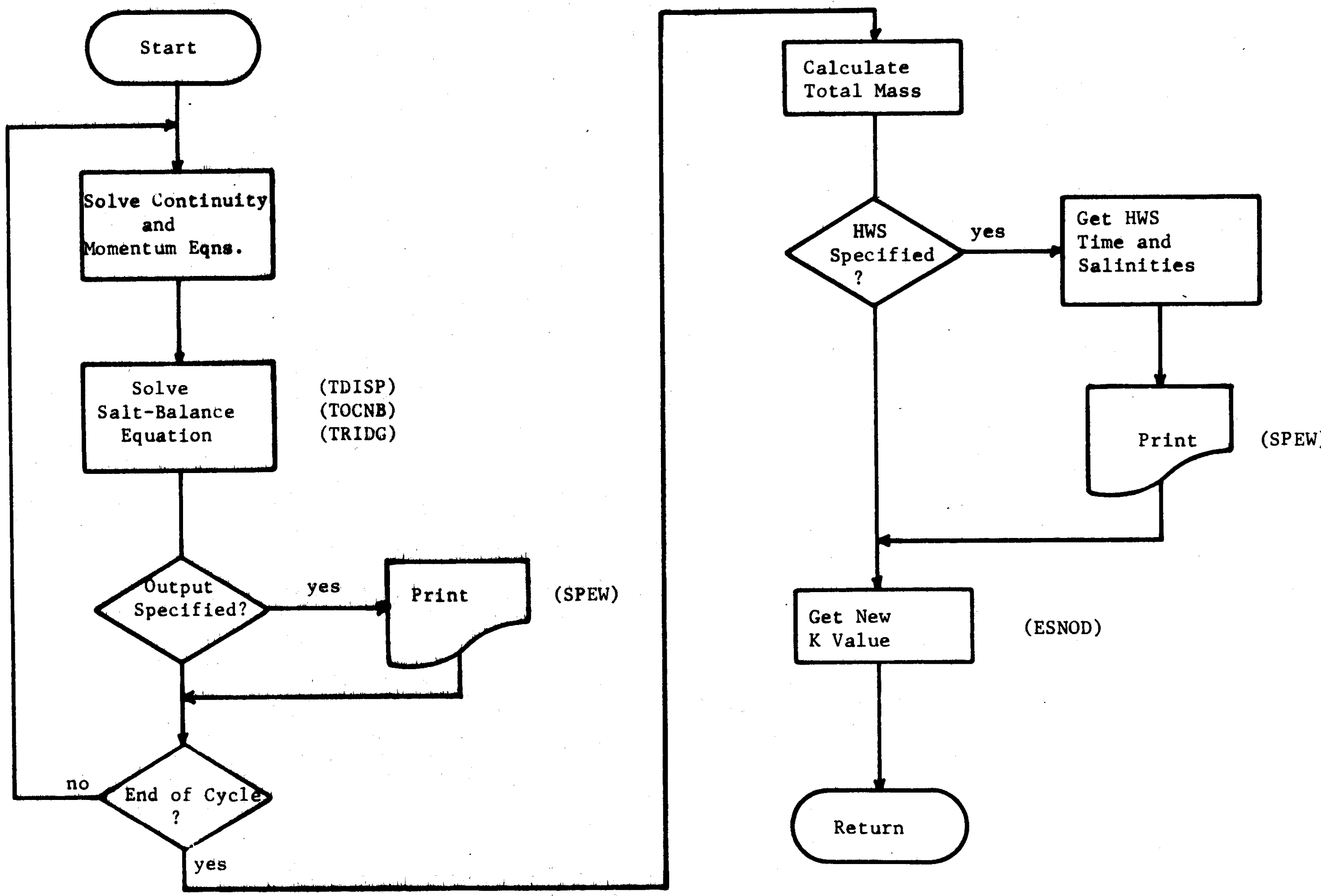
SEQTST: A sequence checking routine.

Figure 4.1 shows the basic structure of the program MAIN and Figure 4.2 shows the basic structure of subroutine MARCH. In both figures the single purpose routines used at the corresponding step are indicated in parenthesis.




Structural Diagram of Routine MAIN

Figure 4.1




Structural Diagram of Subroutine MARCH

Figure 4.2

## V. User Control Through Input Data

### 5.1 Introduction

This section presents the requirements and format for control of the computer program. There are six subsections, each one defining input requirements. The input is in the form of eighty column unit record cards and the perforation of these cards is according to specified FORTRAN formats. The card is divided according to the format instructions which specify the columns that correspond to each piece of input data. These columns constitute the "field" in the card for each item of data. A detailed explanation of FORTRAN formats can be found in many texts, the specific reference for this program is the IBM System/360, "FORTRAN IV Language", manual Form C28-6515, obtainable from local IBM branch offices (Ref. 3).

For the user who has had little experience with FORTRAN programming, a brief description of the format codes used in this section is included with explanation in Appendix II.

### 5.2 Input Description and Format

(Note: Punch decimal point in all "F" format fields.)

Section 1. Description of Schematized Estuary

| Card No. | | Format |
|---|---|---|
| A1 | Descriptive Information for a Heading | 20A4 |
| A2 | Descriptive Information for a Heading | " |
| A3 | Field 1 (right justified) Number of Sections (even) | I5 |
| | Field 2 Total Length in Feet | F10.d |
| A4 | Field 1 (right justified) Number of Time Intervals Per Cycle (even) | I5 |
| | Field 2 Tidal Period (cycle) in Seconds | F10.d |
| A5 | Field 1, Type of Schematization, Number 1,2,3,4 or 5 in Column 5 for: | I5 |
| | 1: Rectangular Cross-Section | |
| | 2: Irregular Cross-Section (storage) | |
| | 3: Trapezoidal Cross-Section | |
| | 4: Exponentially Varying Width, Rectangular Cross-Section | |
| | 5: Constant Rectangular Cross-Section | |
| | Field 2, for Closed End Estuary Blank or 0, for Open End Case = 1 | I5 |

For each case:

Case 1, Rectangular Cross-Section

For each section a card:

| Card No. | | | Format |
|---|---|---|---|
| A6(1) | 1: | Sequence Number[1] (right justified) | I5,5x |
| | 2: | Depth, d | F10.d |
| | 3: | Distance from Datum to Bottom of Section, $z_o$ | F10.d |
| | 4: | Width at Section, $b = b_{core}$ | F10.d |

Case 2, Irregular Cross Section (storage)

For each section a card:

| | | | |
|---|---|---|---|
| A6(2) | Field 1 | Sequence Number[1] (right justified) | I5,5x |
| etc. | Field 2 | Depth, $d_{core}$ | F10.d |
| | Field 3 | Distance from Datum to Bottom of Section, $z_o$ | " |
| | Field 4 | Total Width, $b_{total}$ | " |
| | Field 5 | Core Width, $b_{core}$ | " |
| | Field 6 | Storage Depth, d' | " |

Case 3, Trapezoidal Cross-Section

For each section a card:

| | | | |
|---|---|---|---|
| A6(3) | Field 1 | Sequence Number[1] (right justified) | I5,5x |
| etc. | Field 2 | Depth, d | F10.d |
| | Field 3 | Distance from Datum to Bottom of Section, $z_o$ | " |
| | Field 4 | Side Slope, Horizontal Distance Corresponding to a Unit Vertical Distance | " |
| | Field 5 | Bottom Width, $b_o$ | " |

Case 4, Exponentially Varying Width, Rectangular Cross-Section

Width is assumed to vary as

$$b(j) = b(1) \exp(-\delta x)$$

| | | | |
|---|---|---|---|
| A6(4) | Field 1 | Argument, $\delta$ | E10.d |
| | Field 2 | Width at Entrance, b(1) | F10.d |
| | then for each station a card: | | |
| A7(4) | Field 1 | Sequence Number[1] (right justified) | I5,5x |
| etc. | Field 2 | Depth, d | F10.d |
| | Field 3 | Distance from Datum to Bottom of Section, $z_o$ | F10.d |

[1]Note: Sequencing need not start at the number 1, but must be ascending with an increment of unity (i.e. j, j + 1, j + 2, . . .)

| Card No. | | Format |
|---|---|---|
| | Case 5, Constant Rectangular Cross-Section | |
| A6(5) | Field 1 Blank | 10x |
| | Field 2 Depth, d | F10.d |
| | Field 3 Distance from Datum to Bottom of Section, $z_o$ | F10.d |
| | Field 4 Width, $b = b_{core}$ | F10.d |
| | Section 2. Channel Roughness and Wind Effects | |
| B1 | Case 1 (Enter "1" in Column 5) | |
| | Constant Roughness and Constant Wind Effect | |
| | Case 2 (Enter "2" in Column 5) | |
| | Variation in Roughness, Wind, or both | I5 |
| | If Case 1 is specified only one card is necessary; for Case 2 a card for each section must be punched. | |
| B2 | Field 1 Sequence Number | I5, 5x |
| etc. | Field 2 Manning's "n" in ft-sec. units | F10.d, 10x |
| | Field 3 Wind Speed ft/sec, $V_j$ | F10.d |
| | Field 4 Angle of Wind in Radians Relative to Axis of Channel (blowing upstream is 0 angle) | F10.d |
| | Section 3. Surface Elevation at Entrance | |
| C1 | Type of Variation: Number 1, 2, or 3 in Column 5 | |
| | Case 1 Cosine Fit to HW, LW Series | |
| | Case 2 Repeating, Harmonically Defined in Terms of Amplitudes and Periods of each Component | |
| | Case 3 Repeating, Defined by a Table of Values | I5 |
| C2 | Distance MWL above MSL at Entrance | F10.d |
| | Case 1 Cosine Fit to HW, LW Series | |
| C3(1) | Field 1 Initial HW with Respect to MWL at the Entrance | F10.d |
| | Case 2 Repeating, Harmonically Determined | |
| C3(2) | Field 1 Number of Harmonics | I5 |
| C4(2) | Field 1 Amplitude in Feet, Field 2 Period in Seconds[1] | 2F10.d |
| | Case 3 Repeating Tabular | |
| C3(3) | Card A4 specified the number of time intervals per cycle and the specification was an even number. A series of elevations of length equal to 1/2 the number of time intervals is required. Thus every other interval is defined. The tabular information will be in five fields per card. | 5F10.d |

[1] Note: If only one harmonic, the period is taken as that of card A4.

| Card No. | | Format |
|---|---|---|
| | **Section 4. Definitions Concerning the Salt Balance Equation** | |
| D1 | Field 1 Initial Value of the Dispersion Parameter, K | F10.d |
| | Field 2 Multiplying Factor n in Equation 4-1, see below. If the field is set to zero or left blank n is automatically set to 1. Right justify to Column 15. $(E = K \left\| \frac{\partial s}{\partial x} \right\| + n E_T)$ | I5 |
| D2 | Field 1 Intercept of $K/u_oL$ vs. $\mathbb{E}_D$ relation; if blank or zero, intercept set at 0.00215, (this corresponds to Figure 1.2) | F10.d |
| | Field 2 Maximum limit of intrusion length for the calculation. If left blank or set to zero the total estuary length is taken. (This can be used to save computing time in cases where the maximum intrusion is well known and is significantly less than the total estuary length.) | F10.d |
| | Field 3 Fraction (0-0.5) of the tidal period during which the entrance salinity returns linearly to $s_o$ from its value at LWS. (Usually 0.05 if entrance is at the ocean but not more than 0.5.) | F10.d |
| | Field 4 Fraction (0-0.5) of the tidal period during which the entrance salinity remains at $s_o$ after HWS (usually 0.0). | F10.d |
| D3 | Source of Initial Conditions: Punch 1, 2 or 3 in Column 5 to define one of the following cases.<br>Case 1: Sequential dataset containing a complete tidal period of elevations, $\eta$, salinities, s, and discharges Q.<br>Case 2: Elevations, $\eta$, and discharges Q, from a sequential dataset as in Case 1, but salinities s from cards.<br>Case 3: Elevations, $\eta$, salinities, s, and discharges, Q, all from cards. | I5 |
| | For cases 1 and 2: The sequential dataset is assumed to have a FORTRAN dataset reference number of 3 unless the user wishes to override this by specifying another number in Columns 6-10, right justified. It is assumed that the dataset is organized in record lengths of "total number of sections /2" and that there are "total number of time intervals /2" sets of three | I5 |

Card No. Format

records, the records being in the sequence $\eta$, s, Q. (All elevations are assumed to be relative to MSL.) The last set of $\eta$, s, and Q will be taken as the initial conditions.

For Case 2:

D4(2) Initial salinities, s, at each odd section starting at the entrance, 5 per card — 5F10.d

For Case 3:

D4(3) Initial elevations, $\eta$ at each odd station starting at entrance, 5 per card — 5F10.d

Initial salinities s, at each odd station starting at the entrance, 5 per card, the first value beginning a new card — 5F10.d

Initial discharges Q, at each even station, starting at the seaward-most station, 5 per card, the first value beginning a new card — 5F10.d

Section 5. Output Selection

Options

E1 Four options are taken by punching keywords into any of the first four fields of 5 columns, always beginning on the first of the 5 columns.

Option 1: keyword = KEEP. This keyword will cause the program to store the calculated results of each time step on a sequential dataset, thereby enabling the user to keep the entire result for plotting or further processing. The unit number of this dataset, will be 15 unless the user specifies another number in Columns 26-30, right justified.

Option 2: keyword = HWS. This keyword will cause the calculation of High Water Slack salinities and these will be printed at the end of each tidal cycle.

Option 3: keyword = FC. This keyword will cause the program to punch out the final values of elevation, salinity and discharge in the format which permits these cards to be used as the initial conditions for a subsequent calculation. Elevations are relative to MSL.

Card No. — Format

Option 4: keyword = E. This keyword causes the program to output the dispersion coefficient calculated at each time step to a sequential dataset. The unit number of this dataset will be 11 unless the user specifies another number in Columns 31-35 right justified. 4(A4,1x),

Frequency of Basic Output — 2I5

Frequency is measured in time increments between outputting a calculated variable, η, s, or Q. "0" would be not at all, "2" would be at the end of each calculation, "m" would be at the beginning of each tidal cycle and every m intervals thereafter. (Each calculation is of 2Δt, therefore m must be even.)

E2 Surface elevation specification: H is punched in Column 1 and the frequency is punched, right justified, in Columns 6-10. (A1,4x,I5

E3 Salinity specification: S is punched in Column 1 and the frequency is punched, right justified, in Columns 6-10 (A1,4x,I5

E4 Discharge specification: Q is punched in Column 1 and the frequency is punched, right justified, in Columns 6-10.

Note: Cards E2, E3 and E4 can be in any order relative to each other.

## Section 6. Input of Time Varying Boundary Parameters at each Tidal Cycle

F1 Specification of Transient Fresh Water Input Locations

Field 1: Number of Transient Fresh Water Inputs

Field 2: The number of these which will be summed to compute the $Q_f$ used in calculating the estuary number.

Field 3,4,5,6, etc.: The section numbers of the inflows. These refer to an inflow between the section designated and the adjacent seaward section. The order given in fields 3,4,5,6 . . . is the order to be followed in the following specification cards for each tidal cycle. Those inflows to be summed into $Q_f$ as specified in field 2 must be given first. 16I5

F2 Number of tidal cycles of calculation in Columns 1-5, right justified I5

| Card No. | | | Format |
|---|---|---|---|
| F3 | Time varying boundary parameters for each cycle. | | |
| etc. | Field 1 | Number of the Tidal Cycle | I5,5x |
| | Field 2 | If surface elevation at the entrance is time varying (case 1), the LW or minimum elevation. | F10.d |
| | Field 3 | If surface elevation at the entrance is time varying (case 1), the HW or maximum elevation | F10.d |
| | Field 4 | The maximum salinity at the entrance during the cycle, $s_o$ | F10.d |
| | Fields 5,6,7,8,etc. | These fields are for specification of the fresh water inflows. In the case of an open end estuary field 5 contains the end discharge and 6,7,8, etc. the lateral inflows. Lateral inflows must be given in the order specified in fields 3,4,5,6, etc. of card F1. If more than four values are specified a second card can be included with fields of F10.d There will be a card similar to this F3 for each tidal cycle of calculation | 4F10.d |

End of Input to Program.

## VI. Test Case and Example

### 6.1 Introduction

A test case is developed in order to further document the use of the computer program and to furnish the user with a basis of comparison. The user should be able to reproduce the results of the test case by using the input decks described.

The test case is a study of the Potomac Estuary (Figure 6.1) with the geometry described by Tables 6.1, 6.2 and 6.3. (Reference 1 also discusses this case.) A step-by-step development of the input deck will be followed in accordance with Section 5.2

### 6.2 Input Preparation and Results (see Table 6.5 for listing)

#### Section 1

Cards A1 and A2 contain descriptive information and are as shown.

Card A3: (Field 1) number of sections is taken as 40, (Field 2) the total length is 603,768 ft.

Card A4: (Field 1) number of time intervals per cycle taken as 120, (Field 2) the tidal period is 44,640 seconds.

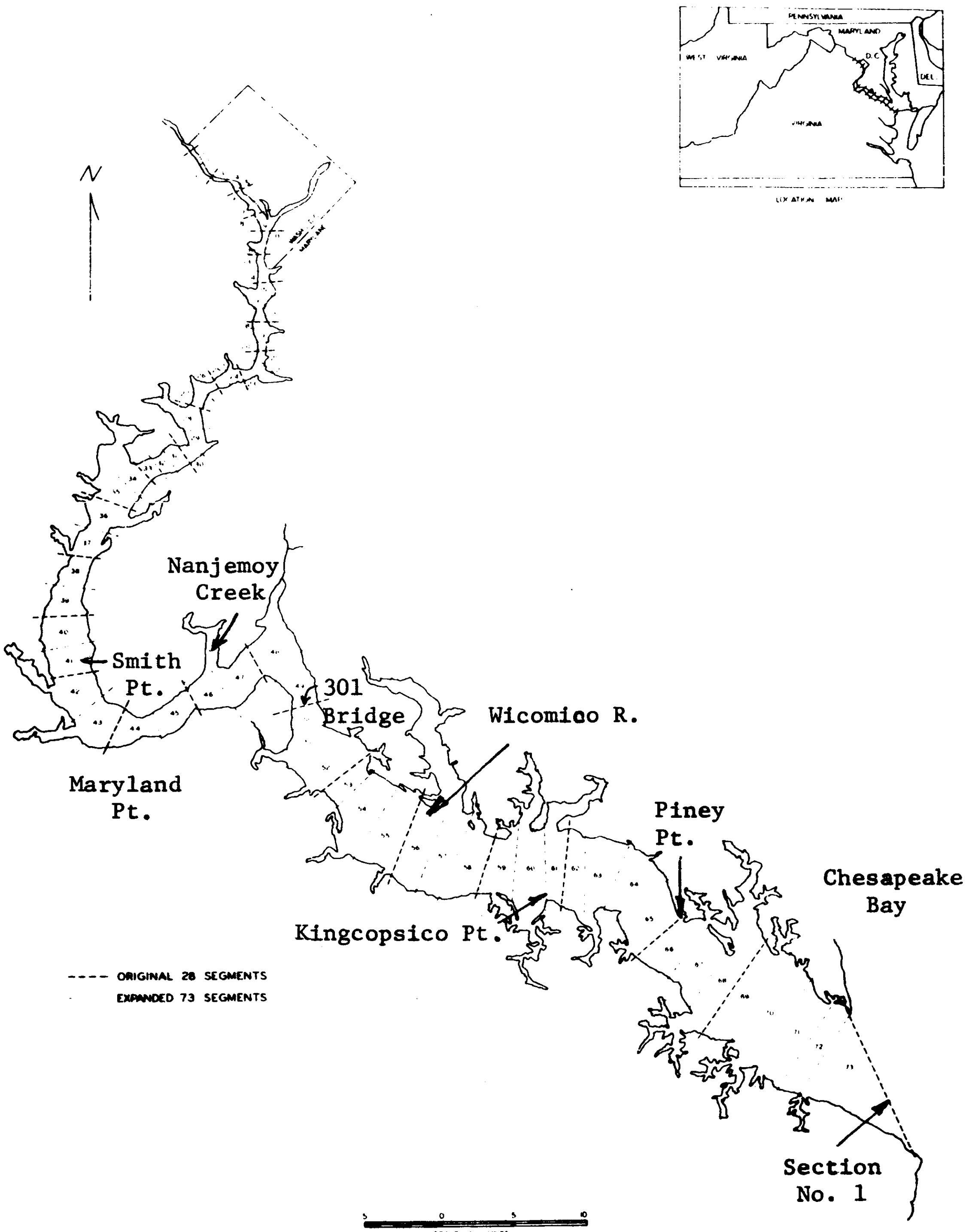
Card A5: The type of schematization for this case is that of the irregular cross-section with provisions for storage. This is type number 2. Field 2 is left blank for closed end case.

Cards A6(2), A7(2),, A45(2): These cards describe the forty cross-sections and are those shown in Table 6.3. (Note that the reference datum is 40 ft. below MWL at the entrance, and that as a horizontal water surface was assumed: $d + z_o = 40$ for all stations.)

#### Section 2

Card B1: As Manning's n is constant for the entire estuary and no wind effects are considered this is case number 1.

Card B2: (Field 1) no sequence number is necessary as only one card is required for case 1. (Field 2) Manning's n is taken at 0.018. (Field 3) wind speed is 0. (The field can be left blank.) (Field 4) no wind angle, leave blank.




POTOMAC ESTUARY

(from Data Source Reference 1)

Figure 6.1

Segment Geometry of Potomac Estuary
Excluding Embayments (Mean Water Data)
(from Jaworski and Clark, Data Source Reference 1)

| Segment Number | Length in ft (from Chain Bridge) | Average Width in ft | Average Depth in ft |
|---|---|---|---|
| 1 | 14,890 | 559 | 24.7 |
| 2 | 10,665 | 1,302 | 20.0 |
| 3 | 9,187 | 2,092 | 10.8 |
| 4 | 9,504 | 2,677 | 10.5 |
| 5 | 8,396 | 2,911 | 13.2 |
| 6 | 11,404 | 2,708 | 13.2 |
| 7 | 13,992 | 3,739 | 12.2 |
| 8 | 11,300 | 4,227 | 13.2 |
| 9 | 13,516 | 3,386 | 20.0 |
| 10 | 10,085 | 5,695 | 13.2 |
| 11 | 13,570 | 4,118 | 18.5 |
| 12 | 24,129 | 6,086 | 17.0 |
| 13 | 15,312 | 8,053 | 15.5 |
| 14 | 14,732 | 12,368 | 12.1 |
| 15 | 22,387 | 8,732 | 20.5 |
| 16 | 21,859 | 10,799 | 17.9 |
| 17 | 22,123 | 16,950 | 13.7 |
| 18 | 25,291 | 15,475 | 14.2 |
| 19 | 28,354 | 8,856 | 20.3 |
| 20 | 24,816 | 13,186 | 15.3 |
| 21 | 27,614 | 10,371 | 22.3 |
| 22 | 32,103 | 17,406 | 20.7 |
| 23 | 33,739 | 24,757 | 18.8 |
| 24 | 31,152 | 30,397 | 20.2 |
| 25 | 28,934 | 20,830 | 18.35 |
| 26 | 42,135 | 27,043 | 25.0 |
| 27 | 31,416 | 26,846 | 33.0 |
| 28 | 51,163 | 44,342 | 27.4 |

Table 6.1

Embayment Data for Potomac Estuary (Mean Water Data)
(from Jaworski and Clark, Data Source Reference 1)

| Name | Average Depth ft | Volume $ft^3 \times 10^8$ | Location (Miles below Chain Bridge) |
|---|---|---|---|
| Columbia Island Channel | 6.40 | 0.16 | 4.65 - 5.76 |
| Tidal Basin | 10.40 | 0.46 | 5.81 |
| Washington Channel | 24.45 | 1.98 | 7.60 - 8.20 |
| Anacostia River | 15.45 | 5.56 | 7.60 - 8.20 |
| Four Mile (Hunter Pt.) | 12.45 | 0.79 | 8.79 - 9.70 |
| Oxon Creek (Upper) | 9.40 | 1.28 | 10.55 - 12.13 |
| Oxon Creek (Lower) | 9.35 | 1.71 | 12.13 - 13.57 |
| Hunting Creek | 3.35 | 0.71 | 12.13 - 13.50 |
| Broad Creek | 4.30 | 0.70 | 14.90 - 15.92 |
| Piscataway Creek | 4.20 | 1.53 | 18.11 - 18.63 |
| Little Hunting Creek | 3.10 | 0.14 | 19.90 - 20.33 |
| Dogue Creek | 4.05 | 0.72 | 21.85 - 22.80 |
| Gunston Creek | 5.00 | 3.27 | 24.02 - 25.42 |
| Pomonkey Creek | 3.95 | 0.35 | 26.73 - 27.10 |
| Belmont Bay | 4.80 | 3.33 | 31.45 - 34.09 |
| Occoquan Bay | 5.80 | 8.63 | 31.45 - 34.09 |
| Powells Creek | 2.80 | 0.54 | 34.79 - 35.92 |
| Mattawoman Creek | 8.80 | 6.56 | 34.13 - 35.60 |
| Quantico Creek | 2.70 | 0.79 | 38.10 - 38.55 |
| Chicamuxen Creek | 3.70 | 0.84 | 36.91 - 37.75 |
| Chopawamsic Creek | 2.67 | 0.36 | 40.75 |
| Mallows Bay | 4.65 | 0.21 | 41.64 - 42.44 |
| Aquia Creek | 4.60 | 4.65 | 46.89 - 48.40 |
| Potomac Creek | 3.58 | 2.76 | 49.20 - 49.70 |
| Nanjemoy Creek | 3.55 | 4.44 | 58.18 - 59.20 |
| Port Tobacco River | 6.75 | 11.06 | 62.00 - 63.80 |

Table 6.2
(to be continued)

| Name | Average Depth ft | Volume $ft^3 \times 10^8$ | Location (Miles below Chain Bridge) |
|---|---|---|---|
| Upper Machodoc Creek | 5.80 | 4.16 | 69.45 - 71.32 |
| Rosier Creek | 3.80 | 0.55 | 72.60 - 73.27 |
| Cuckold Creek | 2.80 | 0.47 | 72.00 - 72.21 |
| Monroe Creek | 3.80 | 0.70 | 75.90 |
| Mattox Creek | 5.80 | 3.60 | 75.98 - 77.32 |
| Popes Creek | 1.85 | 0.23 | 79.15 |
| Wicomico River | 9.92 | 38.62 | 80.52 - 82.85 |
| St. Clement Bay | 9.90 | 15.25 | 86.05 - 88.35 |
| Breton Bay | 9.90 | 13.40 | 89.36 - 90.20 |
| Nomini Bay | 6.80 | 8.57 | 87.26 - 89.48 |
| Lower Machodoc Creek | 7.85 | 7.27 | 91.15 - 93.38 |
| Herring Creek | 4.80 | 0.88 | 96.10 |
| St. Georges Creek | 5.75 | 4.45 | 102.96 - 104.35 |
| St. Mary's River | 11.75 | 33.51 | 102.96 - 104.35 |
| Yeocomico River | 6.63 | 9.39 | 103.80 - 104.65 |
| Smith Creek | 7.75 | 3.77 | 105.15 - 106.65 |
| Coan River | 6.60 | 6.63 | 107.20 - 109.00 |
| Hull Creek | 6.60 | 1.34 | 113.00 |

Table 6.2
(continued)

| | Section no. | d feet | $z_0$ feet | $b_{total}$ feet | $b_{core}$ feet | d' feet |
|---|---|---|---|---|---|---|
| Chesapeake Bay | 1 | 30.00 | 10.00 | 58811. | 57500. | 6.60 |
| | 2 | 27.87 | 12.13 | 49325. | 49325. | 0.00 |
| | 3 | 27.65 | 12.35 | 48184. | 41695. | 6.60 |
| | 4 | 30.46 | 9.54 | 46673. | 34032. | 8.72 |
| | 5 | 32.97 | 7.03 | 48740. | 28043. | 10.63 |
| | 6 | 31.57 | 8.43 | 26016. | 26016. | 0.00 |
| | 7 | 27.63 | 12.37 | 28213. | 27029. | 4.80 |
| | 8 | 23.99 | 16.01 | 29123. | 26386. | 7.85 |
| | 9 | 20.49 | 19.50 | 33838. | 22519. | 9.37 |
| | 10 | 18.34 | 21.66 | 36988. | 20844. | 8.71 |
| | 11 | 19.10 | 20.90 | 27865. | 25918. | 9.90 |
| | 12 | 20.21 | 19.79 | 54428. | 30468. | 9.92 |
| | 13 | 19.49 | 20.51 | 30108. | 28637. | 9.02 |
| | 14 | 18.80 | 21.20 | 29914. | 24840. | 5.47 |
| | 15 | 19.45 | 20.55 | 23500. | 21527. | 3.34 |
| | 16 | 20.56 | 19.44 | 22586. | 17953. | 5.80 |
| | 17 | 21.96 | 18.04 | 13752. | 13752. | 0.00 |
| | 18 | 22.43 | 17.57 | 14927. | 10458. | 6.75 |
| | 19 | 18.15 | 21.85 | 18008. | 11893. | 6.75 |
| | 20 | 15.43 | 24.57 | 20975. | 12896. | 3.55 |
| | 21 | 19.31 | 20.69 | 9519. | 9519. | 0.00 |
| | 22 | 19.15 | 20.85 | 10146. | 10146. | 0.00 |
| | 23 | 14.79 | 25.21 | 19852. | 14793. | 3.60 |
| | 24 | 13.33 | 26.67 | 23450. | 17007. | 4.60 |
| | 25 | 14.18 | 25.82 | 16272. | 16272. | 0.00 |
| | 26 | 17.42 | 22.58 | 12503. | 11419. | 3.49 |
| | 27 | 20.45 | 19.55 | 12179. | 8905. | 3.22 |
| | 28 | 17.95 | 22.05 | 17187. | 9924. | 7.80 |
| | 29 | 12.23 | 27.77 | 23908. | 11878. | 5.52 |
| | 30 | 15.97 | 24.03 | 7456. | 7456. | 0.00 |
| | 31 | 16.94 | 23.06 | 8221. | 6160. | 4.76 |
| | 32 | 18.99 | 21.01 | 7849. | 4183. | 4.79 |
| | 33 | 13.19 | 26.81 | 6155. | 5702. | 3.51 |
| | 34 | 19.12 | 20.88 | 5751. | 3398. | 4.20 |
| | 35 | 12.20 | 27.80 | 5535. | 4103. | 5.92 |
| | 36 | 12.94 | 27.06 | 5311. | 2909. | 8.30 |
| | 37 | 12.71 | 27.29 | 6001. | 2892. | 17.30 |
| | 38 | 10.47 | 29.53 | 2577. | 2150. | 9.37 |
| | 39 | 23.03 | 16.97 | 1005. | 1005. | 0.00 |
| Chain Bridge | 40 | 20.00 | 20.00 | 110. | 110. | 0.00 |

**Potomac Estuary**
**Schematized Geometry after Including Embayments**

**Table 6.3**

Section 3

Card C1: The type of water surface variation at the entrance will be that typically defined by tide tables, a HW and LW series. This is case 1.

Card C2: The distance that MWL is above MSL at the entrance is assumed to be 0.0 ft.

Card C3(1): The initial HW value with respect to MWL at the entrance is 0.52 ft. (from Table 6.4).

Section 4

Card D1: (Field 1) The initial value of the dispersion parameter K is taken as 600 $ft^2$/sec. (Field 2) To use the dispersion relation $E = K\left|\frac{\partial \mathcal{S}_o}{\partial x}\right| + 3E_T$ the multiplying factor n = 3 must be punched in column 15.

Card D2: (Field 1) The $K/u_oL$ vs. $\mathbb{E}_D$ relations will be used with the standard intercept of 0.00215, therefore the field is left blank. (Field 2) It is assumed that reliable information exists which permits the specification of a limit for the salinity intrusion (and thus calculations) at a point 540,000 ft. above the entrance. (Without such justification the field would be left blank.)

(Field 3) The conditions at the entrance to the Potomac have been assumed to be those of a longshore current and thus the salinity is assumed to return to its maximum value in 0.05 of a tidal cycle after LWS. (Field 4) The salinity is not restricted to remain at its maximum value after HWS, therefore the field is either left blank or set to 0.

Card D3: Sequential datasets will not be used in this test case so as to accommodate those users without such facilities. Therefore the initial conditions will be all from cards - case 3.

Cards D4(3), D5(3), etc.: These are the initial conditions. Note that they are specified every other station due to the staggered mesh used in the finite difference calculations. Elevations and salinities are defined on the odd numbered sections starting at the entrance, whereas discharge is defined on the even numbered stations.

Maximum and Minimum Tidal Elevations
at the Entrance to the Potomac
(Relative to MWL at the Entrance)

Table 6.4

| Tidal Period | LW | HW | Tidal Period | LW | HW |
|---|---|---|---|---|---|
| 0 | | 2.20 | 16 | -2.00 | 2.80 |
| 1 | -1.30 | 1.80 | 17 | -2.60 | 1.90 |
| 2 | -1.40 | 2.60 | 18 | -1.80 | 2.60 |
| 3 | -1.20 | 2.10 | 19 | -2.30 | 2.00 |
| 4 | -1.70 | 2.70 | 20 | -1.70 | 2.60 |
| 5 | -1.70 | 2.10 | 21 | -2.20 | 2.10 |
| 6 | -1.70 | 3.00 | 22 | -1.50 | 2.60 |
| 7 | -1.80 | 2.50 | 23 | -2.20 | 2.30 |
| 8 | -1.80 | 3.00 | 24 | -1.60 | 2.50 |
| 9 | -2.20 | 2.10 | 25 | -2.10 | 2.50 |
| 10 | -2.20 | 3.10 | 26 | -1.80 | 2.30 |
| 11 | -2.40 | 2.00 | 27 | -2.40 | 2.70 |
| 12 | -2.20 | 3.20 | 28 | -2.20 | 2.10 |
| 13 | -2.50 | 2.20 | 29 | -2.50 | 3.00 |
| 14 | -2.00 | 3.20 | 30 | -2.20 | 2.30 |
| 15 | -2.50 | 2.00 | 31 | -2.60 | 3.10 |

For 40 stations this means 20 values, 5 per card for each variable or four cards per variable.

Section 5

Card E1: The output will not be put on a sequential data set so option 1 will not be taken. High water slack salinities will be requested, therefore the letters HWS will be punched in columns 1-3. As continuation after this run might be of interest, the third option of punching the final values will be taken. The letters FC are thus punched in columns 6-7. It is not desired to place the time and spatially varying dispersion coefficients on a sequential data set so option 4 will not be taken.

Card E2, E3, E4: For 120 time intervals per tidal cycle and a possible output every other interval due to the staggered finite difference mesh one could obtain 60 outputs per tidal cycle. 10 each cycle are to be specified which requires an output interval of 12. In this case all three variables will be assigned the same frequency. E2, E3 and E4 will contain the letters H, S, and Q in column one and 12 in columns 9 and 10.

Section 6

Card F1: (Field 1) Only one transient input is assumed. (Field 2) Again one input is involved. (Field 3) The input is at the head of the estuary and so it is identified as entering between section 39 and 40 by designating section 40.

Card F2: Only two tidal cycles are specified as this is a test case.

Cards F3, F4: (Field 1) cycle no. (Field 2,3) The LW, HW from Table 6.4. (Field 4) The maximum salinity at the entrance which is taken to be ~16.5 ppt for both cycles. (Field 5) The fresh water discharge for these cycles which are 2730 and 2626 cfs.

The resulting input listing for this test case is in Table 6.5 and the output for two tidal cycle's calculation is in Table 6.6.

Input Listing for Test Case

Table 6.5

| | | | | | | | Card No. |
|---|---|---|---|---|---|---|---|
| * * * * * TEST CASE POTOMAC ESTUARY * * * * * | | | | | | | 0001 |
| (DEMONSTRATION OF INPUT-OUTPUT RELATIONSHIPS) | | | | | | | 0002 |
| 40 603768. | | | | | | | 0003 |
| 120 44640. | | | | | | | 0004 |
| 2 | | | | | | | 0005 |
| 1 | 30.00 | 10.00 | 58811.4 | 57499.9 | 6.60 | 0. | 0006 |
| 2 | 27.87 | 12.13 | 49324.7 | 49324.7 | 0.0 | 15481. | 0007 |
| 3 | 27.65 | 12.35 | 48183.8 | 41694.9 | 6.60 | 30962. | 0008 |
| 4 | 30.46 | 9.54 | 46672.8 | 34032.1 | 8.72 | 46444. | 0009 |
| 5 | 32.97 | 7.03 | 48739.8 | 28042.9 | 10.63 | 61925. | 0010 |
| 6 | 31.57 | 8.43 | 26015.6 | 26015.6 | 0.0 | 77406. | 0011 |
| 7 | 27.63 | 12.37 | 28212.9 | 27028.7 | 4.80 | 92887. | 0012 |
| 8 | 23.99 | 16.01 | 29122.6 | 26386.3 | 7.85 | 108369. | 0013 |
| 9 | 20.49 | 19.50 | 33837.9 | 22518.9 | 9.37 | 123850. | 0014 |
| 10 | 18.34 | 21.66 | 36988.4 | 20844.4 | 8.71 | 139331. | 0015 |
| 11 | 19.10 | 20.90 | 27864.9 | 25918.1 | 9.90 | 154812. | 0016 |
| 12 | 20.21 | 19.79 | 54428.1 | 30467.5 | 9.92 | 170293. | 0017 |
| 13 | 19.49 | 20.51 | 30107.9 | 28636.8 | 9.02 | 185774. | 0018 |
| 14 | 18.80 | 21.20 | 29913.9 | 24840.1 | 5.47 | 201256. | 0019 |
| 15 | 19.45 | 20.55 | 23500.1 | 21527.0 | 3.34 | 216737. | 0020 |
| 16 | 20.56 | 19.44 | 22585.8 | 17952.8 | 5.80 | 232218. | 0021 |
| 17 | 21.96 | 18.04 | 13751.9 | 13751.9 | 0.0 | 247699. | 0022 |
| 18 | 22.43 | 17.57 | 14926.6 | 10457.8 | 6.75 | 263180. | 0023 |
| 19 | 18.15 | 21.85 | 18008.0 | 11892.8 | 6.75 | 278662. | 0024 |
| 20 | 15.43 | 24.57 | 20975.3 | 12896.3 | 3.55 | 294143. | 0025 |
| 21 | 19.31 | 20.69 | 9519.3 | 9519.3 | 0.0 | 309624. | 0026 |
| 22 | 19.15 | 20.85 | 10146.0 | 10146.0 | 0.0 | 325105. | 0027 |
| 23 | 14.79 | 25.21 | 19852.1 | 14792.5 | 3.60 | 340586. | 0028 |
| 24 | 13.33 | 26.67 | 23450.0 | 17006.8 | 4.60 | 356068. | 0029 |
| 25 | 14.18 | 25.82 | 16271.5 | 16271.5 | 0.0 | 371549. | 0030 |
| 26 | 17.42 | 22.58 | 12502.5 | 11419.4 | 3.40 | 387030. | 0031 |
| 27 | 20.45 | 19.55 | 12179.4 | 8904.8 | 3.22 | 402511. | 0032 |
| 28 | 17.95 | 22.05 | 17187.3 | 9923.6 | 7.80 | 417992. | 0033 |
| 29 | 12.23 | 27.77 | 23908.2 | 11877.5 | 5.52 | 433473. | 0034 |
| 30 | 15.97 | 24.03 | 7455.8 | 7455.8 | 0.0 | 448955. | 0035 |
| 31 | 16.94 | 23.06 | 8221.0 | 6160.3 | 4.76 | 464436. | 0036 |

Table 6.5 (cont'd)

| | | | | | | | Card No. |
|---|---|---|---|---|---|---|---|
| 32 | 18.99 | 21.01 | 7849.0 | 4182.7 | 4.79 | 479917. | 0037 |
| 33 | 13.19 | 26.81 | 6155.0 | 5702.0 | 3.51 | 495358. | 0038 |
| 34 | 19.12 | 20.88 | 5750.8 | 3397.7 | 4.20 | 510879. | 0039 |
| 35 | 12.20 | 27.80 | 5534.7 | 4103.4 | 5.92 | 526361. | 0040 |
| 36 | 12.94 | 27.06 | 5311.2 | 2908.8 | 8.30 | 541842. | 0041 |
| 37 | 12.71 | 27.29 | 6001.0 | 2891.6 | 17.30 | 557323. | 0042 |
| 38 | 10.47 | 29.53 | 2577.3 | 2149.8 | 9.37 | 572804. | 0043 |
| 39 | 23.03 | 16.97 | 1005.2 | 1005.2 | 0.0 | 588285. | 0044 |
| 40 | 20.00 | 20.00 | 110.1 | 110.1 | 0.0 | 603767. | 0045 |
| 1 | | | | | | | 0046 |
| 1 0.018 | 0. | | | | | | 0047 |
| 1 | | | | | | | 0048 |
| 0. | | | | | | | 0049 |
| 0.52 | | | | | | | 0050 |
| 600. | 3 | | | | | | 0051 |
| 540000. | 0.05 | 0. | | | | | 0052 |
| 3 | | | | | | | 0053 |
| 0.52000 | 0.56230 | 0.59893 | 0.63069 | 0.65786 | | | 0054 |
| 0.62022 | 0.60293 | 0.55940 | 0.49907 | 0.38124 | | | 0055 |
| 0.20194 | -0.00952 | -0.18197 | -0.32467 | -0.44268 | | | 0056 |
| -0.51065 | -0.56445 | -0.59675 | -0.59867 | -0.59297 | | | 0057 |
| 16.89 | 16.46 | 16.23 | 15.25 | 13.50 | | | 0058 |
| 12.43 | 11.70 | 11.10 | 10.50 | 7.78 | | | 0059 |
| 5.36 | 3.38 | 1.52 | 0.25 | 0.0 | | | 0060 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | | 0061 |
| 338446. | 333211. | 315704. | 296609. | 262419. | | | 0062 |
| 223690. | 174974. | 133834. | 109044. | 82771. | | | 0063 |
| 66325. | 19291. | -12435. | -25034. | -27824. | | | 0064 |
| -24682. | -19499. | -12941. | -4572. | 0. | | | 0065 |
| HWS FC | | | | | | | 0066 |
| H | 12 | | | | | | 0067 |
| S | 12 | | | | | | 0068 |
| Q | 12 | | | | | | 0069 |
| 1 | 1 | 40 | | | | | 0070 |
| 2 | | | | | | | 0071 |
| 1 | -0.47 | 0.88 | 16.57 | 2730. | | | 0072 |
| 2 | -0.52 | 0.52 | 16.56 | 2626. | | | 0073 |

Output Listing from Test Case

Table 6.6

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
*                                                                          *
*   M.I.T. SALINITY INTRUSION PROGRAM, ONE-DIMENSIONAL SCHEMATIZATION      *
*                                                                          *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

SECTION 1, DESCRIPTION OF THE SCHEMATIZED ESTUARY

* * * *     TEST CASE     POTOMAC ESTUARY     * * * * *
(DEMONSTRATION OF INPUT-OUTPUT RELATIONSHIPS)

GEOMETRIC DATA     *** CLOSED END ESTUARY ***

NUMBER OF STATIONS = 40     ESTUARY LENGTH= 603768. FT.
NUMBER OF TIME INCREMENTS PER PERIOD= 120     PERIOD= 44640.SECONDS

CASE 2, IRREGULAR CROSS-SECTION (STORAGE)

| MILES | D | ZO | B | B(CORE) | D' | FEET | SECTION |
|---|---|---|---|---|---|---|---|
| 0.0 | 30.00000 | 10.00000 | 58811.4 | 57499.9 | 6.6 | 0. | 1 |
| 2.93205 | 27.87000 | 12.13000 | 49324.7 | 49324.7 | 0.0 | 15481. | 2 |
| 5.86410 | 27.64999 | 12.35000 | 48183.8 | 41694.9 | 6.6 | 30962. | 3 |
| 8.79615 | 30.45999 | 9.54000 | 46672.8 | 34032.1 | 8.7 | 46444. | 4 |
| 11.72820 | 32.96999 | 7.03000 | 48739.8 | 28042.9 | 10.6 | 61925. | 5 |
| 14.66025 | 31.56999 | 8.43000 | 26015.6 | 26015.6 | 0.0 | 77406. | 6 |
| 17.59230 | 27.62999 | 12.37000 | 28212.9 | 27028.7 | 4.8 | 92887. | 7 |
| 20.52434 | 23.98999 | 16.00999 | 29122.6 | 26386.3 | 7.8 | 108369. | 8 |
| 23.45639 | 20.48999 | 19.50000 | 33837.9 | 22518.9 | 9.4 | 123850. | 9 |
| 26.38846 | 18.34000 | 21.65999 | 36988.4 | 20844.4 | 8.7 | 139331. | 10 |
| 29.32050 | 19.09999 | 20.89999 | 27864.9 | 25918.1 | 9.9 | 154812. | 11 |
| 32.25255 | 20.20999 | 19.78999 | 54428.1 | 30467.5 | 9.9 | 170294. | 12 |
| 35.18460 | 19.48999 | 20.50999 | 30107.9 | 28636.8 | 9.0 | 185775. | 13 |
| 38.11665 | 18.79999 | 21.20000 | 29913.9 | 24840.1 | 5.5 | 201256. | 14 |
| 41.04871 | 19.45000 | 20.54999 | 23500.1 | 21527.0 | 3.3 | 216737. | 15 |
| 43.98076 | 20.56000 | 19.43999 | 22585.8 | 17952.8 | 5.8 | 232218. | 16 |
| 46.91281 | 21.95999 | 18.03999 | 13751.9 | 13751.9 | 0.0 | 247700. | 17 |
| 49.84485 | 22.42999 | 17.56999 | 14926.6 | 10457.8 | 6.8 | 263181. | 18 |
| 52.77692 | 18.14999 | 21.84999 | 18008.0 | 11892.8 | 6.8 | 278662. | 19 |
| 55.70897 | 15.43000 | 24.56999 | 20975.3 | 12896.3 | 3.5 | 294143. | 20 |
| 58.64101 | 19.31000 | 20.68999 | 9519.3 | 9519.3 | 0.0 | 309625. | 21 |
| 61.57306 | 19.14999 | 20.84999 | 10146.0 | 10146.0 | 0.0 | 325106. | 22 |
| 64.50511 | 14.79000 | 25.20999 | 19852.1 | 14792.5 | 3.6 | 340587. | 23 |
| 67.43716 | 13.33000 | 26.67000 | 23450.0 | 17006.8 | 4.6 | 356068. | 24 |
| 70.36922 | 14.18000 | 25.81999 | 16271.5 | 16271.5 | 0.0 | 371550. | 25 |
| 73.30127 | 17.42000 | 22.57999 | 12502.5 | 11419.4 | 3.4 | 387031. | 26 |
| 76.23331 | 20.45000 | 19.54999 | 12179.4 | 8904.8 | 3.2 | 402512. | 27 |
| 79.16537 | 17.95000 | 22.04999 | 17187.3 | 9923.6 | 7.8 | 417993. | 28 |
| 82.09743 | 12.23000 | 27.76999 | 23908.2 | 11877.5 | 5.5 | 433474. | 29 |
| 85.02946 | 15.97000 | 24.03000 | 7455.8 | 7455.8 | 0.0 | 448956. | 30 |
| 87.96152 | 16.93999 | 23.06000 | 8221.0 | 6160.3 | 4.8 | 464437. | 31 |
| 90.89357 | 18.98999 | 21.00999 | 7849.0 | 4182.7 | 4.8 | 479918. | 32 |
| 93.82564 | 13.19000 | 26.81000 | 6155.0 | 5702.0 | 3.5 | 495399. | 33 |
| 96.75768 | 19.12000 | 20.87999 | 5750.8 | 3397.7 | 4.2 | 510881. | 34 |
| 99.68973 | 12.20000 | 27.79999 | 5534.7 | 4103.4 | 5.9 | 526362. | 35 |
| 102.62178 | 12.94000 | 27.06000 | 5311.2 | 2908.8 | 8.3 | 541843. | 36 |
| 105.55383 | 12.71000 | 27.28999 | 6001.0 | 2891.6 | 17.3 | 557324. | 37 |
| 108.48589 | 10.47000 | 29.53000 | 2577.3 | 2149.8 | 9.4 | 572806. | 38 |
| 111.41794 | 23.03000 | 16.96999 | 1005.2 | 1005.2 | 0.0 | 588287. | 39 |
| 114.34998 | 20.00000 | 20.00000 | 110.1 | 110.1 | 0.0 | 603768. | 40 |

NOTE, D' DEEPER THAN D FOR SECTION 37

Table 6.6 (cont'd)

SECTION 2 CHANNEL ROUGHNESS AND WIND EFFECTS

CASE 1 CCNSTANT ROUGHNESS AND CONSTANT WIND

NO WIND

| MILES | MANCC | FQ | V | PHI | FEET | SECTION |
|---|---|---|---|---|---|---|
| 0.0 | 0.0180000 | 0.0 | C.0 | 0.0 | 0. | 1 |
| 2.93205 | 0.C180000 | C.0 | C.0 | C.0 | 15481. | 2 |
| 5.86410 | 0.0180000 | 0.0 | 0.0 | 0.0 | 30962. | 3 |
| 8.79615 | 0.0180000 | C.0 | C.0 | 0.0 | 46444. | 4 |
| 11.72820 | 0.0180000 | 0.0 | 0.0 | 0.0 | 61925. | 5 |
| 14.66025 | 0.C18C000 | 0.0 | C.0 | 0.0 | 77406. | 6 |
| 17.59230 | 0.C180000 | C.0 | 0.0 | 0.0 | 92887. | 7 |
| 20.52434 | 0.0180000 | C.0 | C.0 | C.0 | 108369. | 8 |
| 23.45639 | 0.C180000 | C.0 | 0.0 | C.0 | 123850. | 9 |
| 26.38846 | 0.0180000 | 0.0 | C.0 | C.0 | 139331. | 10 |
| 29.32050 | 0.0180000 | 0.0 | 0.0 | C.0 | 154812. | 11 |
| 32.25255 | 0.0180000 | 0.0 | C.0 | 0.0 | 170294. | 12 |
| 35.18460 | 0.0180000 | 0.0 | C.0 | 0.0 | 185775. | 13 |
| 38.11665 | 0.0180000 | 0.0 | C.0 | C.0 | 201256. | 14 |
| 41.04871 | 0.0180000 | 0.C | 0.0 | 0.0 | 216737. | 15 |
| 43.98076 | 0.0180000 | 0.0 | C.0 | C.0 | 232218. | 16 |
| 46.91281 | 0.C180000 | C.0 | 0.0 | C.0 | 247700. | 17 |
| 49.84485 | 0.0180000 | C.0 | C.0 | C.0 | 263181. | 18 |
| 52.77692 | 0.0180000 | C.0 | 0.0 | C.0 | 278662. | 19 |
| 55.7C897 | 0.0180000 | C.0 | C.0 | C.0 | 294143. | 20 |
| 58.64101 | 0.C180000 | 0.0 | 0.0 | C.0 | 309625. | 21 |
| 61.57306 | 0.0180000 | C.0 | 0.0 | 0.0 | 325106. | 22 |
| 64.50511 | 0.0180000 | 0.0 | 0.0 | 0.0 | 340587. | 23 |
| 67.43716 | 0.0180000 | 0.0 | C.0 | 0.0 | 356068. | 24 |
| 7C.36922 | 0.C180000 | C.0 | 0.0 | 0.0 | 371550. | 25 |
| 73.30127 | 0.C180000 | 0.0 | C.0 | C.0 | 387031. | 26 |
| 76.23331 | 0.0180000 | 0.0 | C.0 | C.0 | 402512. | 27 |
| 79.16537 | 0.0180000 | C.0 | C.0 | 0.0 | 417993. | 28 |
| 82.09743 | 0.0180000 | C.0 | C.0 | C.0 | 433474. | 29 |
| 85.02946 | 0.0180000 | 0.0 | C.0 | C.0 | 448956. | 30 |
| 87.96152 | 0.C180000 | C.C | 0.0 | 0.0 | 464437. | 31 |
| 90.89357 | 0.0180000 | 0.0 | C.0 | C.0 | 479918. | 32 |
| 93.82564 | 0.C180000 | 0.0 | C.0 | C.0 | 495399. | 33 |
| 96.75768 | 0.0180000 | 0.0 | C.0 | C.0 | 510881. | 34 |
| 99.68973 | 0.0180000 | C.0 | 0.0 | 0.0 | 526362. | 35 |
| 102.62178 | 0.0180000 | C.0 | C.0 | 0.0 | 541843. | 36 |
| 105.55383 | 0.C180000 | 0.0 | C.0 | 0.0 | 557324. | 37 |
| 108.48589 | 0.0180000 | C.0 | C.0 | 0.0 | 572806. | 38 |
| 111.41794 | 0.C180000 | 0.0 | 0.0 | 0.0 | 588287. | 39 |
| 114.34998 | 0.0180000 | 0.0 | C.0 | C.0 | 603768. | 40 |

SECTICN 3, SURFACE ELEVATION AT THE ENTRANCE

MWL 0.0 FT ABCVE MSL AT OCEAN
MSL 40.00 FT ABOVE THE HORIZONTAL CATUM

CASE 1, COSINE FIT TO HW-LW SERIES
FIRST HW VALUE RELATIVE TC MWL = C.52

DT= 372.00 SEC. DX= 15481.2 FT.
DELTAX/DELTAT= 41.62 FT./SEC.

Table 6.6 (cont'd)

CELERITY WITH RESPECT TO DEPTH ONLY

| SECTION | CELERITY (FT/SEC) | WAVE LENGTH (MILES) |
|---|---|---|
| 1 | 31.08 | 262.77 |
| 2 | 29.96 | 253.27 |
| 3 | 29.84 | 252.27 |
| 4 | 31.32 | 264.78 |
| 5 | 32.58 | 275.47 |
| 6 | 31.88 | 269.56 |
| 7 | 29.83 | 252.18 |
| 8 | 27.79 | 234.98 |
| 9 | 25.69 | 217.16 |
| 10 | 24.30 | 205.46 |
| 11 | 24.80 | 209.67 |
| 12 | 25.51 | 215.68 |
| 13 | 25.05 | 211.80 |
| 14 | 24.60 | 208.02 |
| 15 | 25.03 | 211.58 |
| 16 | 25.73 | 217.54 |
| 17 | 26.59 | 224.82 |
| 18 | 26.87 | 227.21 |
| 19 | 24.17 | 204.39 |
| 20 | 22.29 | 188.45 |
| 21 | 24.94 | 210.82 |
| 22 | 24.83 | 209.94 |
| 23 | 21.82 | 184.50 |
| 24 | 20.72 | 175.16 |
| 25 | 21.37 | 180.66 |
| 26 | 23.68 | 200.24 |
| 27 | 25.66 | 216.95 |
| 28 | 24.04 | 203.26 |
| 29 | 19.84 | 167.78 |
| 30 | 22.68 | 191.72 |
| 31 | 23.36 | 197.46 |
| 32 | 24.73 | 209.06 |
| 33 | 20.61 | 174.24 |
| 34 | 24.81 | 209.78 |
| 35 | 19.82 | 167.57 |
| 36 | 20.41 | 172.58 |
| 37 | 20.23 | 171.04 |
| 38 | 18.36 | 155.24 |
| 39 | 27.23 | 230.23 |
| 40 | 25.38 | 214.55 |

Table 6.6 (cont'd)

```
SECTION 4,  DEFINITIONS RELATIVE TO THE SALT BALANCE EQUATION, AND TO INITIAL SALINITIES


E=K(DS/DX)+ 3*E(TAYLOR)      K FOR THE NEXT TIDAL CYCLE IS    600.00

K VS. ED GIVEN BY K/(UZ*L)= 0.215E-02ED**(-1/4)

SALINITY EXCURSION LIMIT = 540000.00 FT

SALINITY RETURNS TO SZERO AFTER LWS IN 0.05 OF A TIDAL PERIOD
EXTENTION OF SZERO AFTER HWS FOR 0.0  OF A TIDAL PERIOD                                  3        0

CASE 3, INITIAL CONDITIONS ALL FROM CARDS

TIDAL CYCLE    1     0.0    HOURS      DAY   0     0.0    HOURS      INSTANTANEOUS SURFACE ELEVATION WITH RESPECT TO MSL, FT
STATIONS      1        3        5        7        9       11       13       15       17       19       21       23       25       27
ELEV.      0.520    0.562    0.599    0.631    0.658    0.620    0.603    0.559    0.499    0.381    0.202   -0.010   -0.182   -0.325
STATIONS    29       31       33       35       37       39
ELEV.     -0.443   -0.511   -0.564   -0.597   -0.599   -0.593

TIDAL CYCLE    1     0.0    HOURS      DAY   0     0.0    HOURS      INSTANTANEOUS SALINITIES IN PPT
STATIONS      1        3        5        7        9       11       13       15       17       19       21       23       25       27
SALINITY  16.890   16.460   16.230   15.250   13.500   12.430   11.700   11.100   10.500    7.780    5.360    3.380    1.520    0.250
STATIONS    29       31       33       35       37       39
SALINITY   0.0      0.0      0.0      0.0      0.0      0.0

TIDAL CYCLE    1     0.103 HOURS      DAY   0     0.103 HOURS      INSTANTANEOUS DISCHARGES IN CFS
STATIONS        2          4          6          8         10         12         14         16         18         20
DISCHARGE    338446.    333211.    315704.    296609.    262419.    223690.    174974.    133834.    109044.     82771.
STATIONS       22         24         26         28         30         32         34         36         38         40
DISCHARGE     66325.     19291.    -12435.    -25034.    -27824.    -24682.    -19499.    -12941.     -4572.         0.


SECTION 5,   OUTPUT SELECTION

OPTION HWS   SPECIFIED

OPTION FC    SPECIFIED

 BASIC OUTPUT      FREQUENCY
      H               12
      S               12
      Q               12
```

Table 6.6 (cont'd)

```
CALCULATION BEGINS

TRANSIENT FRESH WATER INPUTS AT SEGMENTS   40
TRANSIENT MIN-MAX OCEAN ELEVATIONS WRT MWL
                                                  CALCULATION FOR    2 CYCLES

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

CYCLE   1      HMIN=  -0.47   HMAX=   0.88    SZERC=  16.57     QF'S AND STATIONS ARE  2730.000  40
               K=    600.00

TIDAL CYCLE    1     1.240 HCURS       DAY   C     1.240 HOURS       INSTANTANEOUS SURFACE ELEVATION WITH RESPECT TO MSL, FT
STATIONS       1       3       5       7       9      11      13      15      17      19      21      23      25      27
ELEV.      0.425   0.482   0.541   0.608   0.679   0.719   0.731   0.702   0.655   0.557   0.401   0.253   0.135  -0.029
STATIONS      29      31      33      35      37      39
ELEV.     -0.221  -0.390  -0.546  -0.653  -0.745  -0.750

TIDAL CYCLE    1     1.240 HOURS       CAY   0     1.240 HOURS       INSTANTANEOUS SALINITIES IN PPT
STATIONS       1       3       5       7       9      11      13      15      17      19      21      23      25      27
SALINITY  16.570  16.591  16.204  15.331  13.600  12.490  11.742  11.134  10.567   8.071   5.541   3.538   1.598   0.275
STATICNS      29      31      33      35      37
SALINITY  -0.CC2   0.001  -0.000   0.000  -0.000

TIDAL CYCLE    1     1.343 HOURS       DAY   0     1.343 HOURS       INSTANTANEOUS DISCHARGES IN CFS
STATIONS         2          4          6          8          10          12          14          16          18          20
DISCHARGE    -1426.     63869.    133329.    167368.     200036.     214679.     230351.     227056.     221937.     202412.
STATIONS        22         24         26         28          30          32          34          36          38          40
DISCHARGE   152516.    164790.    144693.    119829.      38913.      14163.       2015.      -3219.      -3027.          0.

TIDAL CYCLE    1     2.480 HOURS       DAY   0     2.480 HOURS       INSTANTANEOUS SURFACE ELEVATION WITH RESPECT TO MSL, FT
STATIONS       1       3       5       7       9      11      13      15      17      19      21      23      25      27
ELEV.      0.178   0.229   0.281   0.346   0.426   0.524   0.575   0.616   0.634   0.632   0.517   0.417   0.322   0.269
STATICNS      29      31      33      35      37      39
ELEV.      0.216   0.110  -0.062  -0.270  -C.531  -0.605

TIDAL CYCLE    1     2.480 HOURS       DAY   0     2.480 HOURS       INSTANTANEOUS SALINITIES IN PPT
STATICNS       1       3       5       7       9      11      13      15      17      19      21      23      25      27
SALINITY  16.577  16.603  16.170  15.389  13.61C  12.562  11.759  11.177  10.683   8.441   5.904   3.792   1.930   0.375
STATIONS      29      31      33      35      37
SALINITY  -0.002   0.001  -0.000   0.000  -C.CCC

TIDAL CYCLE    1     2.583 HOURS       CAY   0     2.583 HOURS       INSTANTANEOUS DISCHARGES IN CFS
STATIONS         2          4          6          8          10          12          14          16          18          20
DISCHARGE  -318786.  -209822.    -99904.    -27698.      53554.     109547.     168362.     203614.     220774.     229557.
STATIONS        22         24         26         28          30          32          34          36          38          40
DISCHARGE   228956.    208890.    180162.    152426.      99394.      77359.      53393.      26344.       1536.          0.

TIDAL CYCLE    1     3.720 HOURS       CAY   0     3.720 HOURS       INSTANTANEOUS SURFACE ELEVATION WITH RESPECT TO MSL, FT
STATIONS       1       3       5       7       9      11      13      15      17      19      21      23      25      27
ELEV.     -0.128  -0.104  -0.065  -0.012   0.076   0.180   0.236   0.307   0.366   0.459   0.493   0.547   0.530   0.521
STATIONS      29      31      33      35      37      39
ELEV.      0.503   0.455   0.406   0.381   0.293   0.318

TIDAL CYCLE    1     3.720 HOURS       DAY   0     3.720 HOURS       INSTANTANEOUS SALINITIES IN PPT
STATIONS       1       3       5       7       9      11      13      15      17      19      21      23      25      27
SALINITY  16.566  16.609  16.113  15.406  13.548  12.604  11.751  11.195  10.792   8.699   6.320   4.052   2.014   0.499
STATICNS      29      31      33      35      37
SALINITY   0.0C4  -0.002   0.001  -0.000   0.000
```

Table 6.6 (cont'd)

TIDAL CYCLE 1 3.823 HOURS DAY 0 3.823 HOURS INSTANTANEOUS DISCHARGES IN CFS

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| STATIONS | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 |
| DISCHARGE | -486704. | -385263. | -280823. | -212671. | -125047. | -52339. | 31586. | 98712. | 131700. | 163726. |
| STATIONS | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 | 38 | 40 |
| DISCHARGE | 170326. | 167014. | 156227. | 140960. | 101240. | 82198. | 63565. | 43052. | 4432. | 0. |

TIDAL CYCLE 1 4.960 HOURS DAY 0 4.960 HOURS INSTANTANEOUS SURFACE ELEVATION WITH RESPECT TO MSL, FT

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STATIONS | 1 | 3 | 5 | 7 | 9 | 11 | 13 | 15 | 17 | 19 | 21 | 23 | 25 | 27 |
| ELEV. | -0.375 | -0.372 | -0.356 | -0.335 | -0.280 | -0.198 | -0.151 | -0.080 | 0.003 | 0.156 | 0.310 | 0.461 | 0.551 | 0.645 |
| STATIONS | 29 | 31 | 33 | 35 | 37 | 39 | | | | | | | | |
| ELEV. | 0.704 | 0.755 | 0.833 | 0.935 | 1.038 | 1.060 | | | | | | | | |

TIDAL CYCLE 1 4.960 HOURS DAY 0 4.960 HOURS INSTANTANEOUS SALINITIES IN PPT

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STATIONS | 1 | 3 | 5 | 7 | 9 | 11 | 13 | 15 | 17 | 19 | 21 | 23 | 25 | 27 |
| SALINITY | 16.594 | 16.607 | 16.054 | 15.370 | 13.428 | 12.612 | 11.715 | 11.190 | 10.853 | 8.772 | 6.601 | 4.305 | 2.130 | 0.595 |
| STATIONS | 29 | 31 | 33 | 35 | 37 | | | | | | | | | |
| SALINITY | 0.014 | -0.006 | 0.002 | -0.001 | 0.000 | | | | | | | | | |

TIDAL CYCLE 1 5.063 HOURS DAY 0 5.063 HOURS INSTANTANEOUS DISCHARGES IN CFS

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| STATIONS | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 |
| DISCHARGE | -518154. | -446900. | -356109. | -303169. | -229656. | -168031. | -99209. | -41968. | -11668. | 36293. |
| STATIONS | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 | 38 | 40 |
| DISCHARGE | 53083. | 78679. | 89649. | 87992. | 67465. | 53417. | 36718. | 18815. | 136. | 0. |

TIDAL CYCLE 1 6.200 HOURS DAY 0 6.200 HOURS INSTANTANEOUS SURFACE ELEVATION WITH RESPECT TO MSL, FT

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STATIONS | 1 | 3 | 5 | 7 | 9 | 11 | 13 | 15 | 17 | 19 | 21 | 23 | 25 | 27 |
| ELEV. | -0.470 | -0.507 | -0.539 | -0.549 | -0.528 | -0.458 | -0.422 | -0.370 | -0.297 | -0.152 | 0.036 | 0.225 | 0.392 | 0.572 |
| STATIONS | 29 | 31 | 33 | 35 | 37 | 39 | | | | | | | | |
| ELEV. | 0.743 | 0.908 | 1.073 | 1.194 | 1.304 | 1.337 | | | | | | | | |

TIDAL CYCLE 1 6.200 HOURS DAY 0 6.200 HOURS INSTANTANEOUS SALINITIES IN PPT

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STATIONS | 1 | 3 | 5 | 7 | 9 | 11 | 13 | 15 | 17 | 19 | 21 | 23 | 25 | 27 |
| SALINITY | 16.557 | 16.599 | 16.002 | 15.299 | 13.303 | 12.592 | 11.666 | 11.178 | 10.827 | 8.661 | 6.636 | 4.181 | 2.253 | 0.543 |
| STATIONS | 29 | 31 | 33 | 35 | 37 | | | | | | | | | |
| SALINITY | 0.019 | -0.009 | 0.003 | -0.001 | 0.000 | | | | | | | | | |

TIDAL CYCLE 1 6.303 HOURS DAY 0 6.303 HOURS INSTANTANEOUS DISCHARGES IN CFS

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| STATIONS | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 |
| DISCHARGE | -327523. | -324867. | -311523. | -298408. | -268138. | -232762. | -190439. | -155744. | -138931. | -111420. |
| STATIONS | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 | 38 | 40 |
| DISCHARGE | -98039. | -67317. | -41104. | -26861. | -9723. | -5076. | -2157. | -1514. | -2650. | 0. |

TIDAL CYCLE 1 7.440 HOURS DAY 0 7.440 HOURS INSTANTANEOUS SURFACE ELEVATION WITH RESPECT TO MSL, FT

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STATIONS | 1 | 3 | 5 | 7 | 9 | 11 | 13 | 15 | 17 | 19 | 21 | 23 | 25 | 27 |
| ELEV. | -0.341 | -0.400 | -0.463 | -0.509 | -0.540 | -0.552 | -0.546 | -0.514 | -0.450 | -0.319 | -0.114 | 0.059 | 0.222 | 0.367 |
| STATIONS | 29 | 31 | 33 | 35 | 37 | 39 | | | | | | | | |
| ELEV. | 0.507 | 0.647 | 0.816 | 0.964 | 1.129 | 1.172 | | | | | | | | |

TIDAL CYCLE 1 7.440 HOURS DAY 0 7.440 HOURS INSTANTANEOUS SALINITIES IN PPT

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STATIONS | 1 | 3 | 5 | 7 | 9 | 11 | 13 | 15 | 17 | 19 | 21 | 23 | 25 | 27 |
| SALINITY | 16.593 | 16.585 | 15.995 | 15.190 | 13.240 | 12.525 | 11.617 | 11.165 | 10.704 | 8.425 | 6.407 | 3.986 | 2.136 | 0.576 |
| STATIONS | 29 | 31 | 33 | 35 | 37 | | | | | | | | | |
| SALINITY | 0.012 | -0.006 | 0.002 | -0.000 | 0.000 | | | | | | | | | |

TIDAL CYCLE 1 7.543 HOURS DAY 0 7.543 HOURS INSTANTANEOUS DISCHARGES IN CFS

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| STATIONS | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 |
| DISCHARGE | 19754. | -62791. | -147342. | -185055. | -220023. | -232519. | -233060. | -224278. | -216032. | -200944. |
| STATIONS | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 | 38 | 40 |
| DISCHARGE | -193988. | -180091. | -164620. | -145672. | -85256. | -62698. | -43537. | -24511. | -5718. | 0. |

TIDAL CYCLE 1 8.680 HOURS DAY 0 8.680 HOURS INSTANTANEOUS SURFACE ELEVATION WITH RESPECT TO MSL, FT

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STATIONS | 1 | 3 | 5 | 7 | 9 | 11 | 13 | 15 | 17 | 19 | 21 | 23 | 25 | 27 |
| ELEV. | -0.004 | -0.062 | -0.127 | -0.195 | -0.266 | -0.388 | -0.436 | -0.463 | -0.456 | -0.390 | -0.209 | -0.073 | 0.061 | 0.111 |
| STATIONS | 29 | 31 | 33 | 35 | 37 | 39 | | | | | | | | |
| ELEV. | 0.172 | 0.237 | 0.327 | 0.408 | 0.558 | 0.583 | | | | | | | | |

Table 6.6 (cont'd)

```
TIDAL CYCLE   1    8.680 HOURS      DAY   0    8.680 HOURS      INSTANTANEOUS SALINITIES IN PPT
STATIONS    1       3       5       7       9      11      13      15      17      19      21      23      25      27
SALINITY  16.570  16.573  16.042  15.082  13.278  12.432  11.595  11.143  10.510   8.129   6.040   3.714   1.959   0.660
STATICNS   29      31      33      35      37
SALINITY   0.0C2  -0.001   0.000  -0.000  -0.0C0

TIDAL CYCLE   1    8.783 HOURS      DAY   0    8.783 HOURS      INSTANTANEOUS DISCHARGES IN CFS
STATIONS      2         4         6         8        10        12        14        16        18        20
DISCHARGE   412949.   272904.   122896.    38515.   -58183.  -124955.  -180420.  -213922.  -226148.  -229459.
STATIONS     22        24        26        28        30        32        34        36        38        40
DISCHARGE  -222642.  -196606.  -170161.  -148994.   -98900.   -77607.   -56898.   -34763.    -7387.        0.

TIDAL CYCLE   1    9.920 HOURS      DAY   0    9.920 HOURS      INSTANTANEOUS SURFACE ELEVATION WITH RESPECT TO MSL, FT
STATIONS    1       3       5       7       9      11      13      15      17      19      21      23      25      27
ELEV.      0.414   0.373   0.324   0.262   0.187   0.049  -0.028  -0.124  -0.212  -0.298  -0.265  -0.241  -0.133  -0.148
STATICNS   29      31      33      35      37      39
ELEV.     -0.119  -0.108  -0.104  -0.111  -0.056  -0.044

TIDAL CYCLE   1    9.920 HOURS      DAY   0    9.920 HOURS      INSTANTANEOUS SALINITIES IN PPT
STATIONS    1       3       5       7       9      11      13      15      17      19      21      23      25      27
SALINITY  16.570  16.555  16.129  15.036  13.407  12.372  11.617  11.124  10.297   7.847   6.463   3.660   1.737   0.365
STATICNS   29      31      33      35      37
SALINITY  -0.004   0.002  -0.001   0.000  -0.000

TIDAL CYCLE   1   10.023 HOURS      DAY   0   10.023 HOURS      INSTANTANEOUS DISCHARGES IN CFS
STATIONS      2         4         6         8        10        12        14        16        18        20
DISCHARGE   688488.   548652.   402995.   309773.   197222.    96963.   -13977.  -100439.  -142635.  -174995.
STATICNS     22        24        26        28        30        32        34        36        38        40
DISCHARGE  -178079.  -166050.  -144276.  -123882.   -76664.   -58689.   -43186.   -27758.    -6448.        0.

TIDAL CYCLE   1   11.160 HOURS      DAY   0   11.160 HOURS      INSTANTANEOUS SURFACE ELEVATION WITH RESPECT TO MSL, FT
STATIONS    1       3       5       7       9      11      13      15      17      19      21      23      25      27
ELEV.      0.751   0.746   0.730   0.712   0.667   0.552   0.499   0.423   0.321   0.152  -0.054  -0.225  -0.296  -0.343
STATICNS   29      31      33      35      37      39
ELEV.     -0.379  -0.401  -0.423  -0.450  -0.466  -0.468

TIDAL CYCLE   1   11.160 HOURS      DAY   0   11.160 HOURS      INSTANTANEOUS SALINITIES IN PPT
STATIONS    1       3       5       7       9      11      13      15      17      19      21      23      25      27
SALINITY  16.570  16.541  16.226  15.068  13.608  12.372  11.668  11.150  10.168   7.817   5.317   3.314   1.662   0.301
STATICNS   29      31      33      35      37
SALINITY  -0.007   0.004  -0.002   0.001  -0.000

TIDAL CYCLE   1   11.263 HOURS      DAY   0   11.263 HOURS      INSTANTANEOUS DISCHARGES IN CFS
STATIONS      2         4         6         8        10        12        14        16        18        20
DISCHARGE   766371.   669640.   553001.   474564.   373070.   282921.   180847.   100427.    50092.   -24630.
STATIONS     22        24        26        28        30        32        34        36        38        40
DISCHARGE   -55003.   -87037.   -90490.   -82573.   -50925.   -37486.   -26358.   -16063.    -4614.        0.

TIDAL CYCLE   1   12.400 HOURS      DAY   0   12.400 HOURS      INSTANTANEOUS SURFACE ELEVATION WITH RESPECT TO MSL, FT
STATIONS    1       3       5       7       9      11      13      15      17      19      21      23      25      27
ELEV.      0.880   0.928   0.972   1.012   1.022   0.949   0.920   0.862   0.772   0.608   0.386   0.170  -0.067  -0.266
STATICNS   29      31      33      35      37      39
ELEV.     -0.453  -0.547  -0.617  -0.657  -0.674  -0.673

TIDAL CYCLE   1   12.400 HOURS      DAY   0   12.400 HOURS      INSTANTANEOUS SALINITIES IN PPT
STATIONS    1       3       5       7       9      11      13      15      17      19      21      23      25      27
SALINITY  16.570  16.533  16.306  15.148  13.815  12.441  11.727  11.205  10.197   8.037   5.325   3.381   1.583   0.279
STATICNS   29      31      33      35      37
SALINITY  -0.009   0.005  -0.003   0.001  -0.000

TIDAL CYCLE   1   12.503 HOURS      DAY   0   12.503 HOURS      INSTANTANEOUS DISCHARGES IN CFS
STATIONS      2         4         6         8        10        12        14        16        18        20
DISCHARGE   520756.   516950.   492433.   470213.   424118.   371314.   304517.   252924.   223152.   183727.
STATIONS     22        24        26        28        30        32        34        36        38        40
DISCHARGE   164241.   109854.    51525.    16278.   -13132.   -15348.   -13120.    -9212.    -3684.        0.
                                                                                      AVE MASS =    0.303371E 13
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Table 6.6 (cont'd)

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TIDAL CYCLE   1    0.0   HOURS      DAY   0    0.0   HOURS      HIGH WATER SLACK SALINITIES IN PPT
STATIONS     1       3       5       7       9      11      13      15      17      19      21      23      25      27
TIME HRS   1.240   1.653   2.067   2.480   2.893   3.307   4.133   4.753   4.960   5.373   5.580   5.787   5.993   5.993
SALINITY  16.570  16.593  16.189  15.389  13.596  12.593  11.743  11.191  10.853   8.748   6.655   4.212   2.254   0.641
STATIONS    29      31      33      35      37
TIME HRS   6.200   6.200   6.200   6.200   5.167
SALINITY   0.019  -0.009   0.003  -0.001   0.000

PRISM=   0.1037522E 11 CUFT                 VMAX=    0.5491 FT/SEC    AT  10.95 HRS FROM BEGINNING OF CYCLE
DENSIMETRIC FROUDE NO.=  0.164409           SUM OF QF'S=  2730.000 CU.FT/SEC
DENSIMETRIC ESTUARY NO.=     2.301          K FOR THE NEXT CYCLE IS     578.67 SQFT/SEC

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CYCLE   2      HMIN=  -0.52    HMAX=   0.52    SZERO=  16.56      QF'S AND STATIONS ARE  2626.000  40
               K=     578.67

TIDAL CYCLE   2     1.240 HOURS      DAY   0   13.640 HOURS      INSTANTANEOUS SURFACE ELEVATION WITH RESPECT TO MSL, FT
STATIONS     1       3       5       7       9      11      13      15      17      19      21      23      25      27
ELEV.      0.746   0.820   0.903   0.986   1.064   1.089   1.101   1.075   1.025   0.907   0.692   0.493   0.326   0.149
STATIONS    29      31      33      35      37      39
ELEV.     -0.005  -0.221  -0.455  -0.618  -0.739  -0.757

TIDAL CYCLE   2     1.240 HOURS      DAY   0   13.640 HOURS      INSTANTANEOUS SALINITIES IN PPT
STATIONS     1       3       5       7       9      11      13      15      17      19      21      23      25      27
SALINITY  16.560  16.541  16.327  15.255  13.947  12.568  11.775  11.280  10.336   8.434   5.692   3.625   1.735   0.351
STATIONS    29      31      33      35      37
SALINITY  -0.012   0.006  -0.003   0.001  -0.000

TIDAL CYCLE   2     1.343 HOURS      DAY   0   13.743 HOURS      INSTANTANEOUS DISCHARGES IN CFS
STATIONS       2         4         6         8        10        12        14        16        18        20
DISCHARGE    66089.   156965.   242624.   285544.   326061.   340772.   342345.   329674.   314403.   283865.
STATIONS      22        24        26        28        30        32        34        36        38        40
DISCHARGE   267352.   232346.   205129.   178225.    79423.    39825.    15210.     1955.    -2320.       0.

TIDAL CYCLE   2     2.480 HOURS      DAY   0   14.880 HOURS      INSTANTANEOUS SURFACE ELEVATION WITH RESPECT TO MSL, FT
STATIONS     1       3       5       7       9      11      13      15      17      19      21      23      25      27
ELEV.      0.396   0.464   0.546   0.644   0.761   0.906   0.978   1.025   1.048   1.026   0.854   0.727   0.619   0.550
STATIONS    29      31      33      35      37      39
ELEV.      0.470   0.358   0.218   0.032  -0.327  -0.422

TIDAL CYCLE   2     2.480 HOURS      DAY   0   14.880 HOURS      INSTANTANEOUS SALINITIES IN PPT
STATIONS     1       3       5       7       9      11      13      15      17      19      21      23      25      27
SALINITY  16.567  16.560  16.282  15.359  13.954  12.703  11.798  11.350  10.501   8.830   6.233   3.957   1.990   0.490
STATIONS    29      31      33      35      37
SALINITY  -0.006   0.003  -0.001   0.001  -0.000

TIDAL CYCLE   2     2.583 HOURS      DAY   0   14.983 HOURS      INSTANTANEOUS DISCHARGES IN CFS
STATIONS       2         4         6         8        10        12        14        16        18        20
DISCHARGE  -356029.  -247051.   -99583.    -1585.   100695.   166310.   227877.   266704.   294194.   295194.
STATIONS      22        24        26        28        30        32        34        36        38        40
DISCHARGE   288826.   254256.   214157.   185274.   119537.    96043.    73572.    42287.     4263.       0.

TIDAL CYCLE   2     3.720 HOURS      DAY   0   16.120 HOURS      INSTANTANEOUS SURFACE ELEVATION WITH RESPECT TO MSL, FT
STATIONS     1       3       5       7       9      11      13      15      17      19      21      23      25      27
ELEV.     -0.036   0.016   0.086   0.176   0.293   0.459   0.551   0.649   0.744   0.856   0.876   0.909   0.980   0.961
STATIONS    29      31      33      35      37      39
ELEV.      0.832   0.779   0.731   0.705   0.705   0.787
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Table 6.6 (cont'd)

```
TIDAL CYCLE   2    3.720 HOURS      DAY   0   16.120 HOURS      INSTANTANEOUS SALINITIES IN PPT
STATIONS     1       3       5       7       9      11      13      15      17      19      21      23      25      27
SALINITY 16.578  16.578  16.201  15.407  13.853  12.769  11.784  11.380  10.652   9.078   6.774   4.289   2.236   0.446
STATIONS    29      31      33      35      37
SALINITY   0.008  -0.005   0.002  -0.000  -0.000

TIDAL CYCLE   2    3.823 HOURS      DAY   0   16.223 HOURS      INSTANTANEOUS DISCHARGES IN CFS
STATIONS       2          4          6          8         10         12         14         16         18         20
DISCHARGE  -688281.   -545261.   -397519.   -305717.   -187198.   -85460.    32140.    120023.    163465.    202545.
STATIONS      22         24         26         28         30         32         34         36         38         40
DISCHARGE   206366.    205555.    188180.    168784.    115341.    92002.     69375.     43435.     3660.         0.

TIDAL CYCLE   2    4.960 HOURS      DAY   0   17.360 HOURS      INSTANTANEOUS SURFACE ELEVATION WITH RESPECT TO MSL, FT
STATIONS     1       3       5       7       9      11      13      15      17      19      21      23      25      27
ELEV.     -0.386  -0.373  -0.343  -0.295  -0.212  -0.052   0.022   0.111   0.223   0.419   0.676   0.773   0.925   1.022
STATIONS    29      31      33      35      37      39
ELEV.      1.103   1.163   1.262   1.364   1.435   1.445

TIDAL CYCLE   2    4.960 HOURS      DAY   0   17.360 HOURS      INSTANTANEOUS SALINITIES IN PPT
STATIONS     1       3       5       7       9      11      13      15      17      19      21      23      25      27
SALINITY 16.587  16.584  16.108  15.382  13.665  12.773  11.734  11.367  10.746   9.105   7.137   4.491   2.439   0.792
STATIONS    29      31      33      35      37
SALINITY   0.029  -0.014   0.004  -0.001   0.000

TIDAL CYCLE   2    5.063 HOURS      DAY   0   17.463 HOURS      INSTANTANEOUS DISCHARGES IN CFS
STATIONS       2          4          6          8         10         12         14         16         18         20
DISCHARGE  -776741.   -670128.   -541841.   -455601.   -346257.   -258648.   -160863.   -83139.    -35426.     33827.
STATIONS      22         24         26         28         30         32         34         36         38         40
DISCHARGE    61295.     96735.    106950.    104298.     75659.     56658.     36621.     19441.     1436.         0.

TIDAL CYCLE   2    6.200 HOURS      DAY   0   18.600 HOURS      INSTANTANEOUS SURFACE ELEVATION WITH RESPECT TO MSL, FT
STATIONS     1       3       5       7       9      11      13      15      17      19      21      23      25      27
ELEV.     -0.520  -0.572  -0.609  -0.623  -0.590  -0.452  -0.392  -0.310  -0.203  -0.008   0.240   0.480   0.703   0.965
STATIONS    29      31      33      35      37      39
ELEV.      1.165   1.332   1.492   1.623   1.743   1.739

TIDAL CYCLE   2    6.200 HOURS      DAY   0   18.600 HOURS      INSTANTANEOUS SALINITIES IN PPT
STATIONS     1       3       5       7       9      11      13      15      17      19      21      23      25      27
SALINITY 16.589  16.575  16.030  15.293  13.470  12.729  11.661  11.343  10.726   8.945   7.155   4.441   2.512   0.838
STATIONS    29      31      33      35      37
SALINITY   0.040  -0.018   0.005  -0.001   0.000

TIDAL CYCLE   2    6.303 HOURS      DAY   0   18.703 HOURS      INSTANTANEOUS DISCHARGES IN CFS
STATIONS       2          4          6          8         10         12         14         16         18         20
DISCHARGE  -503758.   -498814.   -477031.   -452245.   -402553.   -345241.   -276946.   -223010.   -194984.   -159505.
STATIONS      22         24         26         28         30         32         34         36         38         40
DISCHARGE  -143636.   -101436.    -63753.    -35852.    -13114.    -3646.      239.       362.      -2052.        0.

TIDAL CYCLE   2    7.440 HOURS      DAY   0   19.840 HOURS      INSTANTANEOUS SURFACE ELEVATION WITH RESPECT TO MSL, FT
STATIONS     1       3       5       7       9      11      13      15      17      19      21      23      25      27
ELEV.     -0.421  -0.482  -0.542  -0.597  -0.637  -0.622  -0.606  -0.550  -0.458  -0.273   0.027   0.265   0.471   0.639
STATIONS    29      31      33      35      37      39
ELEV.      0.757   0.990   1.202   1.374   1.566   1.621

TIDAL CYCLE   2    7.440 HOURS      DAY   0   19.840 HOURS      INSTANTANEOUS SALINITIES IN PPT
STATIONS     1       3       5       7       9      11      13      15      17      19      21      23      25      27
SALINITY 16.587  16.558  16.012  15.156  13.362  12.621  11.595  11.310  10.583   8.667   6.835   4.169   2.370   0.732
STATIONS    29      31      33      35      37
SALINITY   0.027  -0.013   0.004  -0.001   0.000

TIDAL CYCLE   2    7.543 HOURS      DAY   0   19.543 HOURS      INSTANTANEOUS DISCHARGES IN CFS
STATIONS       2          4          6          8         10         12         14         16         18         20
DISCHARGE  -105776.   -177563.   -247545.   -289080.   -328982.   -336349.   -327864.   -307052.   -289879.   -261941.
STATIONS      22         24         26         28         30         32         34         36         38         40
DISCHARGE  -250591.   -227783.   -205853.   -179511.   -102113.   -71200.    -47887.    -26812.    -6818.        0.
```

Table 6.6 (cont'd)

TIDAL CYCLE 2 8.680 HOURS DAY 0 21.080 HOURS INSTANTANEOUS SURFACE ELEVATION WITH RESPECT TO MSL, FT

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STATIONS | 1 | 3 | 5 | 7 | 9 | 11 | 13 | 15 | 17 | 19 | 21 | 23 | 25 | 27 |
| ELEV. | -0.161 | -0.207 | -0.257 | -0.311 | -0.378 | -0.479 | -0.525 | -0.547 | -0.527 | -0.421 | -0.147 | 0.047 | 0.209 | 0.310 |
| STATIONS | 29 | 31 | 33 | 35 | 37 | 39 | | | | | | | | |
| ELEV. | 0.356 | 0.482 | 0.599 | 0.713 | 0.910 | 0.961 | | | | | | | | |

TIDAL CYCLE 2 8.680 HOURS DAY 0 21.080 HOURS INSTANTANEOUS SALINITIES IN PPT

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STATIONS | 1 | 3 | 5 | 7 | 9 | 11 | 13 | 15 | 17 | 19 | 21 | 23 | 25 | 27 |
| SALINITY | 16.560 | 16.549 | 16.040 | 15.035 | 13.364 | 12.498 | 11.566 | 11.259 | 10.355 | 8.319 | 6.350 | 3.913 | 2.154 | 0.573 |
| STATIONS | 29 | 31 | 33 | 35 | 37 | | | | | | | | | |
| SALINITY | 0.009 | -0.005 | 0.002 | -0.000 | -0.000 | | | | | | | | | |

TIDAL CYCLE 2 8.783 HOURS DAY 0 21.183 HOURS INSTANTANEOUS DISCHARGES IN CFS

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| STATIONS | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 |
| DISCHARGE | 235361. | 121931. | 933. | -68930. | -147839. | -200811. | -251696. | -282804. | -292935. | -289321. |
| STATIONS | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 | 38 | 40 |
| DISCHARGE | -276200. | -237407. | -202419. | -175041. | -115655. | -92143. | -68146. | -40167. | -8119. | 0. |

TIDAL CYCLE 2 9.920 HOURS DAY 0 22.320 HOURS INSTANTANEOUS SURFACE ELEVATION WITH RESPECT TO MSL, FT

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STATIONS | 1 | 3 | 5 | 7 | 9 | 11 | 13 | 15 | 17 | 19 | 21 | 23 | 25 | 27 |
| ELEV. | 0.161 | 0.129 | 0.091 | 0.051 | -0.006 | -0.119 | -0.186 | -0.264 | -0.325 | -0.364 | -0.269 | -0.193 | -0.087 | -0.018 |
| STATIONS | 29 | 31 | 33 | 35 | 37 | 39 | | | | | | | | |
| ELEV. | 0.040 | 0.070 | 0.095 | 0.104 | 0.177 | 0.183 | | | | | | | | |

TIDAL CYCLE 2 9.920 HOURS DAY 0 22.320 HOURS INSTANTANEOUS SALINITIES IN PPT

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STATIONS | 1 | 3 | 5 | 7 | 9 | 11 | 13 | 15 | 17 | 19 | 21 | 23 | 25 | 27 |
| SALINITY | 16.560 | 16.533 | 16.098 | 14.973 | 13.438 | 12.422 | 11.576 | 11.218 | 10.112 | 8.011 | 5.836 | 3.499 | 1.954 | 0.441 |
| STATIONS | 29 | 31 | 33 | 35 | 37 | | | | | | | | | |
| SALINITY | -0.000 | -0.001 | 0.000 | -0.000 | -0.000 | | | | | | | | | |

TIDAL CYCLE 2 10.023 HOURS DAY 0 22.423 HOURS INSTANTANEOUS DISCHARGES IN CFS

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| STATIONS | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 |
| DISCHARGE | 451061. | 346200. | 232835. | 163888. | 73635. | -10787. | -103228. | -168812. | -200624. | -226992. |
| STATIONS | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 | 38 | 40 |
| DISCHARGE | -227106. | -206899. | -178545. | -152316. | -92158. | -69393. | -50788. | -32765. | -6932. | 0. |

TIDAL CYCLE 2 11.160 HOURS DAY 0 23.560 HOURS INSTANTANEOUS SURFACE ELEVATION WITH RESPECT TO MSL, FT

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STATIONS | 1 | 3 | 5 | 7 | 9 | 11 | 13 | 15 | 17 | 19 | 21 | 23 | 25 | 27 |
| ELEV. | 0.421 | 0.417 | 0.409 | 0.395 | 0.364 | 0.289 | 0.252 | 0.193 | 0.104 | -0.039 | -0.157 | -0.249 | -0.270 | -0.297 |
| STATIONS | 29 | 31 | 33 | 35 | 37 | 39 | | | | | | | | |
| ELEV. | -0.295 | -0.299 | -0.306 | -0.324 | -0.316 | -0.317 | | | | | | | | |

TIDAL CYCLE 2 11.160 HOURS DAY 0 23.560 HOURS INSTANTANEOUS SALINITIES IN PPT

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STATIONS | 1 | 3 | 5 | 7 | 9 | 11 | 13 | 15 | 17 | 19 | 21 | 23 | 25 | 27 |
| SALINITY | 16.560 | 16.522 | 16.171 | 14.977 | 13.564 | 12.406 | 11.610 | 11.216 | 9.944 | 7.861 | 5.413 | 3.302 | 1.776 | 0.346 |
| STATIONS | 29 | 31 | 33 | 35 | 37 | | | | | | | | | |
| SALINITY | -0.004 | 0.001 | -0.001 | 0.000 | -0.000 | | | | | | | | | |

TIDAL CYCLE 2 11.263 HOURS DAY 0 23.663 HOURS INSTANTANEOUS DISCHARGES IN CFS

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| STATIONS | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 |
| DISCHARGE | 531712. | 458771. | 369015. | 308341. | 226475. | 154112. | 71076. | 448. | -45190. | -103095. |
| STATIONS | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 | 38 | 40 |
| DISCHARGE | -121481. | -133872. | -125775. | -110753. | -66434. | -47998. | -32840. | -19551. | -5004. | 0. |

TIDAL CYCLE 2 12.400 HOURS DAY 1 0.800 HOURS INSTANTANEOUS SURFACE ELEVATION WITH RESPECT TO MSL, FT

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STATIONS | 1 | 3 | 5 | 7 | 9 | 11 | 13 | 15 | 17 | 19 | 21 | 23 | 25 | 27 |
| ELEV. | 0.520 | 0.557 | 0.595 | 0.631 | 0.650 | 0.623 | 0.604 | 0.555 | 0.489 | 0.372 | 0.189 | -0.033 | -0.206 | -0.351 |
| STATIONS | 29 | 31 | 33 | 35 | 37 | 39 | | | | | | | | |
| ELEV. | -0.472 | -0.538 | -0.585 | -0.611 | -0.607 | -0.599 | | | | | | | | |

TIDAL CYCLE 2 12.400 HOURS DAY 1 0.800 HOURS INSTANTANEOUS SALINITIES IN PPT

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STATIONS | 1 | 3 | 5 | 7 | 9 | 11 | 13 | 15 | 17 | 19 | 21 | 23 | 25 | 27 |
| SALINITY | 16.560 | 16.517 | 16.230 | 15.028 | 13.703 | 12.444 | 11.652 | 11.241 | 9.918 | 7.926 | 5.264 | 3.263 | 1.568 | 0.300 |
| STATIONS | 29 | 31 | 33 | 35 | 37 | | | | | | | | | |
| SALINITY | -0.007 | 0.003 | -0.001 | 0.001 | -0.000 | | | | | | | | | |

Table 6.6 (cont'd)

```
TIDAL CYCLE   2   12.503 HOURS      DAY   1     0.903 HOURS      INSTANTANEOUS DISCHARGES IN CFS
STATIONS      2          4          6          8          10         12         14         16         18         20
DISCHARGE    362601.    355858.    336673.    315037.    277675.    235973.    182830.    138204.    111027.    82664.
STATIONS      22         24         26         28         30         32         34         36         38         40
DISCHARGE     64635.     13949.    -19194.    -31512.    -31570.    -27338.    -21121.    -13598.     -4290.        0.
                                                                                                 AVE MASS =    0.304719E 1

TIDAL CYCLE   2    0.0    HOURS      DAY   0   12.400 HOURS      HIGH WATER SLACK SALINITIES IN PPT
STATIONS      1       3       5       7       9       11      13      15      17      19      21      23      25      27
TIME HRS   1.447   1.860   2.273   2.480   3.100   3.307   3.927   4.547   4.753   5.167   5.373   5.787   5.993   5.993
SALINITY  16.560  16.550  16.294  15.359  13.915  12.756  11.777  11.372  10.737   9.085   7.194   4.493   2.515   0.839
STATIONS     29      31      33      35      37
TIME HRS   6.200   6.200   6.407   6.407   5.373
SALINITY   0.040  -0.018   0.005  -0.001   0.000

PRISM=   0.7327736E 10 CUFT                   VMAX=    0.5787 FT/SEC    AT    4.75 HRS FROM BEGINNING OF CYCLE
DENSIMETRIC FROUDE NO.=  0.173325             SUM OF QF'S=  2626.000 CU.FT/SEC
DENSIMETRIC ESTUARY NO.=     1.878            K FOR THE NEXT CYCLE IS     641.66 SQFT/SEC

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

TIDAL CYCLE   2    0.0    HOURS      DAY   0   12.400 HOURS      INSTANTANEOUS SURFACE ELEVATION WITH RESPECT TO MSL, FT
STATIONS      1       3       5       7       9       11      13      15      17      19      21      23      25      27
ELEV.      0.520   0.557   0.595   0.631   0.650   0.623   0.604   0.555   0.489   0.372   0.189  -0.090  -0.206  -0.351
STATIONS     29      31      33      35      37      39
ELEV.     -0.472  -0.538  -0.585  -0.611  -0.607  -0.599

TIDAL CYCLE   2    0.0    HOURS      DAY   0   12.400 HOURS      INSTANTANEOUS SALINITIES IN PPT
STATIONS      1       3       5       7       9       11      13      15      17      19      21      23      25      27
SALINITY  16.560  16.517  16.230  15.028  13.703  12.444  11.652  11.241   9.918   7.926   5.264   3.269   1.668   0.300
STATIONS     29      31      33      35      37
SALINITY  -0.007   0.003  -0.001   0.001  -0.000

TIDAL CYCLE   2    0.103 HOURS      DAY   0   12.503 HOURS      INSTANTANEOUS DISCHARGES IN CFS
STATIONS      2          4          6          8          10         12         14         16         18         20
DISCHARGE    362601.    355858.    336673.    315037.    277675.    235973.    182830.    138204.    111027.    92664.
STATIONS      22         24         26         28         30         32         34         36         38         40
DISCHARGE     64635.     13949.    -19194.    -31512.    -31570.    -27338.    -21121.    -13598.     -4290.        0.

END OF ALL CALCULATIONS
```

VII. Possible Error Messages

There are a variety of error messages which may result from an inadvertent omission, a badly punched card or a misunderstanding in the preparation of input data. The program has built-in checks on certain logic conditions, and when these conditions occur a message is printed out to aid the user in correcting the condition. The following messages are produced by the computer program. All but the last are preceeded by

"* * * SALINITY INTRUSION PROGRAM ERROR * * *"

1) NUMBER OF SECTIONS MUST BE EVEN - This refers to card A3, field 1.
2) NUMBER OF TIME INTERVALS MUST BE EVEN - This refers to card A4, field 1.
3) CASE NOT 1 THRU 5 - This refers to card A5.
4) NEGATIVE INTRUSION LENGTH IN INPUT - This refers to card D2, field 2.
5) COLUMN 1 DOES NOT CONTAIN H, Q, OR S - in cards E2, E3 or E4 the first column is not correctly punched.
6) SEQUENCING ERROR IN INPUT STREAM - In the input of geometry, Manning's n or wind data, the first sequence field shows that the cards are not sequentially identified. The sequence number of each card must be 1 greater than the preceding card.
7) INTERVAL FOR OUTPUT MUST BE EVEN - This refers to the interval for outputing $\eta$ (H), S, or Q as specified in cards E2, E3 or E4.
8) WATER SURFACE BELOW THE BOTTOM WHICH INDICATES A PROBABLE NUMERICAL INSTABILIITY. THE REMEDY MAY WELL BE A SMALLER DELTA-T. This message speaks for itself and results from a probable instability. A check of the stability criteria and of the calculated wave speeds printed by the program may be of use to the user in specifying a smaller $\Delta t$.
9) THE WATER SURFACE IN THE STORAGE AREA HAS FALLEN BELOW THE BOTTOM. THIS IS NOT NECESSARILY AN INSTABILITY, BUT IS PROBABLY A PROBLEM IN SCHEMATIZATION - This message indicates that a deeper depth of storage area is necessary to continue the calculations. Often the depth of storage area is calculated by dividing a total volume by a planar or surface area. This may result in a depth which is less than the expected lowering of the water surface during tidal action. The program is not designed to account for schematizations which contain bottom sections which become dry. To correct for this

situation it is recommended that the volume of storage be maintained, but that a deeper depth of storage be taken with a correspondingly narrower storage width.

10) CARDS NOT IN SEQUENCE, EXIT TAKEN AFTER LAST CYCLE'S CALCULATION - The cards not in sequence are F3, F4, . . . etc. which specify the time varying boundary conditions from tidal cycle to tidal cycle. It should be possible to restart the calculation from the last cycle's calculation if the user so desires.

## VIII. Implementation on Different Computer Systems

### 8.1 Memory Size

This program has been implemented on IBM 360/65 and 370/155 computers running in a MVT/OS environment. The G-level FORTRAN compiler has been used for compilation of the FORTRAN program. The memory requirements corresponding to the program as listed in this report are about 120 K bytes. This permits discretizations of up to 200 sections by 449 time intervals.

Should the user find it necessary to reduce the memory used by the program he may do so by two different procedures. First of all he can overlay the subroutines TIDIN and OSIN which are required for input operations only. Secondly he can reduce the dimensioned variables used in the program, if such a reduction is permitted by the size of his particular mesh of $\Delta x$ and $\Delta t$.

### 8.2 FORTRAN IV Restrictions

Some FORTRAN IV compilers are not always compatible with others. Possible sources of incompatibility in this program's FORTRAN IV language are the use of mixed-mode expressions, T format codes and literals enclosed in apostrophes. If the user has available to him a computer whose FORTRAN IV language does not accept one or more of these conventions some minor reprogramming will be necessary.

### 8.3 Hints for Modifying the Program

It may be desirable for some users to modify or extend the program in accordance with their specific needs. This section will give some details of the program's construction which should prove helpful to those users.

The program's COMMON area is based on that contained in the program of Harleman and Lee, 1969 (Ref. 2). This was modified to form the Tidal Dynamics part of this model. The modification consists of including a density gradient term, and also eliminating the storage of the elevations and discharges at every time step of a tidal cycle. This eliminated a huge matrix which was always only one half full due to the use of subscripts which represented the full staggered $\Delta x$, $\Delta t$ mesh. Harleman and Lee's input routines have been slightly modified and form the subroutine TIDIN. The use of subscripting which includes each cross-section, rather than every other one still exists, and most arrays such as H, S, and Q are only one half full as a result.

The computations proceed from time step to time step in the following manner. First the Tidal Dynamics section is executed which produces elevation,

$\eta$, and discharge, Q, distributions at time $t + \Delta t$ and $t + 2\Delta t$ respectively. Then the salinity, or Salt Balance Section, is executed using the $\eta$'s, at $t + \Delta t$ and $t - \Delta t$ and the Q's at time t. The salinity distribution calculated is at time $t + \Delta t$. The new $\eta$, S, and Q distributions then become the old distributions for the next time step's calculation. The time subscripting is unfortunately a bit complicated in this calculation which is accomplished in subroutine MARCH. This subroutine uses subscripts I, IH, or IQ for the old time step and K, KH, or KQ for the new time step. These subscripts can be either 1 or 2. At the end of a time step when the new values of $\eta$, S, and Q become the old values for the next time step. This transposition is accomplished by simply setting the new value of subscripts I, IH or IQ equal to the old value of subscript K, KH or KQ.

References

1. Thatcher, M. L. and Harleman, D. R. F., "A Mathematical Model for the Prediction of Unsteady Salinity Intrusion in Estuaries", R. M. Parsons Laboratory for Water Resources and Hydrodynamics Technical Report No. 144, Department of Civil Engineering, M.I.T., February 1972.

2. Harleman, D. R. F. and Lee, C. H., "The Computation of Tides and Currents in Estuaries and Canals", Technical Bulletin No. 16, Committee on Tidal Hydraulics, U.S. Army Corps of Engineers, September 1969.

3. "FORTRAN IV Language", IBM System/360, Manual Form C28-6515, International Business Machines.

4. "CALCOMP PLOTTER SUBROUTINES FOR THE IBM 360", Applications Program Series AP-59, Information Processing Service Center, M.I.T., January 31, 1972.

5. "Programming CALCOMP PEN PLOTTERS", California Computer Products, Inc., Anaheim, California 92801.

Data Source References

1. Jaworski, N.A. and Clark, L.J., "Physical Data Potomac River Tidal System Including Mathematical Model Segmentation", Technical Report No. 43, Chesapeake Technical Support Laboratory, EPA (former FWQA), about 1970.

## List of Figures and Tables

```
C        MAIN LINE FOR TRANSIENT SIMULATION
      INTEGER CASE
      REAL  FQ(200), BB(200),  D(200), SS(200),  B(200),MANCO(200)
      REAL  ZZ(200),  R(200),  C(200), D4(200),  W(200)
      REAL  BS(200),   E(200),H(2,200),S(2,200),Q(2,200)
      REAL HOA(900),QOB(900)
      DIMENSION DUM(100),ZO(200),ADUM(100)
      DIMENSION MFQ(10),PFQ(10)
      DIMENSION ETA(3),FW(4),LFW(4)
      COMMON KO,KIN,KKK,JJJ
      COMMON NOS,CASE,DELT,DELX,NMAX,NMAXH,JMAX,JMAXH,JJTEM,JMAXQ
        COMMON D1,D2,D3,EH,EZ,EXLM,SZERO,ES
        COMMON MH,MS,ISW0,ISW1,ISW2,ISW3,ISW4,ISW5,ISW6,ISW7
      COMMON H,Q,HOA,QOB,FQ,BB,D,SS,B,ZZ,R,MANCO,C,D4,W,BS,S,E
      COMMON /SW/ ISW10,ISW11
      COMMON /T/ MMM,QF,IPF,IPE,NNN
      COMMON /EXLIM/ JLIM,J2LIM,MOUT,LOUT
      COMMON/SL/SLD,ZO
      COMMON /OUTP/ LFW,ND1,ADUM,NC
      DATA DUM /100*0./
      DATA PI/3.141593/,KP/7/
C
C        FILE 'MMM'  HOLDS THE SEQUENTIAL OUTPUT OF 'NC' CYCLES
      KO=6
      KIN=5
      LLL=3
      CALL TIDIN
      CALL OSIN
      CALL TDISP
      NMAXQ=NMAX+1
      NMD2=(NMAX-1)/2
      NF=JMAX/2
      ST=PI*2./(NMAX-1)
C
C        NFW IS NO. OF VARYING FRESH WATER INPUTS.
C        NCQF IS THE NO. OF THESE WHICH ARE TO BE SUMMED INTO 'QF',
```

```
C         THE FRESH WATER FLOW USED TO CALCULATE THE ESTUARY NUMBER.
C         THESE VALUES WILL BE TAKEN IN SEQUENCE.
C         THE LFW(J),J=1,NFW   ARE THE STATION LOCATIONS.
      READ(KIN,1112) NFW,NCQF,(LFW(J),J=1,NFW)
1112  FORMAT(16I5)
      WRITE(KO,720) (LFW(J),J=1,NFW)
720   FORMAT(/,' TRANSIENT FRESH WATER INPUTS AT SEGMENTS',4I5)
      IF(ISWO .EQ. 1)    WRITE(KO,1428)
1428  FORMAT(' TRANSIENT MIN-MAX OCEAN ELEVATIONS WRT MWL')
      READ(KIN,1112) NC
      WRITE(KO,4285) NC
4285  FORMAT('0',T55,'CALCULATION FOR',I4,' CYCLES')
C
C         BEGIN  MASTER LOOP BY TIDAL CYCLE
C         ETA'S ARE WRT MWL AT THE OCEAN
      ETA(1)=HOA(1)
      DO 1111 LEW=1,NC
      IF(NOS .EQ. 0)    GOTO 5
      READ(KIN,721)KCK,ETA(2),ETA(3),SZERO,FEND,(FW(J),J=1,NFW)
721   FORMAT(I5,5X,7F10.0,(8F10.0))
C         SET RIVER END DISCHARGE FOR OPEN END CASE
      DO 7 J=2,NMAXQ,2
7     QOB(J)= -FEND
      GOTO 6
5     READ(KIN,721) KCK,ETA(2),ETA(3),SZERO,(FW(J),J=1,NFW)
6     WRITE(KO,2857)
2857  FORMAT(/,'0',120('*'))
      IF(ISWO .EQ. 2)    GOTO 722
      WRITE(KO,1113) KCK,ETA(2),ETA(3),SZERO,(FW(J),LFW(J),J=1,NFW)
1113  FORMAT(/,'0CYCLE',I4,5X,'HMIN=',F7.2,3X,'HMAX=',F7.2,4X,'SZERO=',
     1        F7.2,5X,'QF''S AND STATIONS ARE',4(F10.3,I4))
      GOTO 723
722                   WRITE(KO,1133) KCK,SZERO,(FW(J),LFW(J),J=1,NFW)
1133  FORMAT(/,'0CYCLE',I4,4X,'SZERO=',F7.2,5X,'QF''S AND STATIONS ARE',
     1        4(F10.3,I4))
C
```

```
723    WRITE(KO,1114) EZ
1114   FORMAT(T16,'K=',F10.2)
       IF(NOS .NE. 0) WRITE(KO,724) FEND
724    FORMAT('+',T31,'UPSTREAM BOUNDARY DISCHARGE=',F10.2)
C         TEST SEQUENCE
       IF(KCK .EQ. LEW)    GOTO 1117
       WRITE(KO,207)
207    FORMAT(' CARDS NOT IN SEQUENCE, EXIT TAKEN AFTER LAST CYCLE''S',
     1         ' CALCULATION')
       GOTO 1118
1117   DO 1115 J=1,NEW
       MYJO=LFW(J)
1115   FQ(MYJO)=FW(J)
C
C         CALC. 'QF' FOR ESTUARY NUMBER.
       QF=0.
       DO 1116 J=1,NCQF
       MYJO=LFW(J)
1116   QF=QF+FQ(MYJO)
       IF(NOS .NE. 0)  QF=QF+FEND
C
C         ISWO TO CALCULATE TRANSIENT TIDAL ELEVATIONS
       GOTO(20,25),ISWO
20     RANG1=(ETA(1)-ETA(2))/2.
       RANG2=(ETA(3)-ETA(2))/2.
       IF((RANG1 .LT. 0) .OR. (RANG2 .LT. 0))  GOTO 22
       GOTO 23
22     WRITE(KO,221) LEW
221    FORMAT(' WARNING EQUAL ELEVATIONS IN CYCLE',I5)
23     DO 30 II=1,NMAXH,2
       ARG=ST*(II-1)
       IF(ARG .GT. PI)      GOTO 21
C         GOING DOWN
       HOA(II)=ETA(1)-RANG1*(1.-COS(ARG))
       GOTO 30
C         GOING UP
```

```
21     HDA(II)=ETA(3)-RANG2*(1.-COS(ARG))
30     CONTINUE
       ETA(1)=ETA(3)
C
25     CALL MARCH
1111   CONTINUE
1118   IF(ISW1 .EQ. 1)    GOTO 1119
       END FILE MMM
       REWIND MMM
1119   IF(ISW4 .EQ. 1)     GOTO 1120
       END FILE NNN
       REWIND NNN
1120   WRITE(KO,2857)
C
C         OUTPUT FINAL TIME STEP'S H,S,&Q
C         REFER H TO MSL
       DO 182 J=1,JMAXH,2
182    H(LOUT,J)=H(LOUT,J)-SLD+ZO(J)+D(J)
       CALL SPEW(1,1)
       CALL SPEW(2,1)
       CALL SPEW(3,1)
       GOTO (1200,1201),ISW3
1201   WRITE(KP,1202) (H(LOUT,J),J=1,JMAXH,2)
1202   FORMAT(5F10.5)
       WRITE(KP,1203) (S(LOUT,J),J=1,JMAXH,2)
1203   FORMAT(5F10.4)
       WRITE(KP,1204) (Q(LOUT,J),J=2,JMAX,2)
1204   FORMAT(5F10.0)
1200   WRITE(KO,1205)
1205   FORMAT(/,'0END OF ALL CALCULATIONS',/,'1')
       CALL EXIT
       END
```

```
      SUBROUTINE TIDIN
C     ESTUARY CLOSED AT ONE END
C     ALL TIDAL ELEVATIONS REFER TO PRINCIPLE DATUM DEFINED
C     ALL WATER DEPTHS MEASURED FROM PRINCIPLE DATUM TO THE BOTTOM
C     CASE=1, RECTANGULAR CROSS-SECTION
C     CASE=2, IRREGULAR CROSS-SECTION (STORAGE)
C     CASE=3, TRAPEZOIDAL CROSS-SECTION
C     CASE=4, FOR EXPONENTIALLY VARYING WIDTH, RECTANGULAR CROSS-SECTION
C     CASE=5, CONSTANT RECTANGULAR CROSS-SECTION
C     ROUGH=1, CONSTANT ROUGHNESS AND CONSTANT WIND EFFECT
C     ROUGH=2, EITHER ROUGHNESS OR WIND EFFECT VARIES
C     CLASA=1,  ENTRANCE SURFACE A FIT TO TRANSIENT HW AND LW DATA
C     CLASA=2, FOR OCEAN TIDE INPUT OF HARMONIC TYPE
C     CLASA=3, FOR OCEAN TIDE INPUT FROM TIDE TABLE OR FIELD DATA
C
      INTEGER CLASA,CASE,ROUGH,SLOPE
      INTEGER WEND
      REAL KB
      REAL  FQ(200), BB(200),  D(200), SS(200),  B(200),MANCO(200)
      REAL  ZZ(200),  R(200),  C(200), D4(200),  W(200)
      REAL  BS(200),  E(200),H(2,200),S(2,200),Q(2,200)
      REAL HOA(900),QOB(900),DP(200),COREA(200)
      LOGICAL LDP
      DIMENSION AMP(4),T(4),OMEGA(4),THETA(4)
      DIMENSION SCEL(200),WALEN(200)
      DIMENSION ZO(200),V(200),PHI(200),WDUM(20)
      COMMON KO,KIN,KKK,JJJ
      COMMON NOS,CASE,DELT,DELX,NMAX,NMAXH,JMAX,JMAXH,JJTEM,JMAXQ
        COMMON D1,D2,D3,EH,EZ,EXLM,SZERO,ES
      COMMON MH,MS,ISWO,ISW1,ISW2,ISW3,ISW4,ISW5,ISW6,ISW7
         COMMON H,Q,HOA,QOB,FQ,BB,D,SS,B,ZZ,R,MANCO,C,D4,W,BS,S,E
      COMMON /STOR/DP,COREA,LDP
      COMMON/SL/SLD,ZO
      EQUIVALENCE (KO,KOUT)
      DATA PI/3.14159/,G/32.2/,WAUWT,ARDEN,BETA/64.0,0.078,0.0026/
C
```

```
C                                                                         TIDI
C        SECTION 1, DESCRIPTION OF SCHEMATIZED ESTUARY                    TIDI
      WRITE(KO,200)                                                       TIDI
200   FORMAT('1',T16,37('* '),/,T16,'*',T88,'*',/,T16,'*',T20,'M.I.T. ',TIDI
     1       'SALINITY INTRUSION PROGRAM, ONE-DIMENSIONAL ',              TIDI
     2       'SCHEMATIZATION',T88,'*',/,T16,'*',T88,'*',/,T16,37('* '),   TIDI
     3       ///,'OSECTION 1,  DESCRIPTION OF THE SCHEMATIZED ESTUARY',   TIDI
     4       //)                                                          TIDI
      DO 1010 I=1,2                                                       TIDI
      READ(KIN,1020) WDUM                                                 TIDI
1020  FORMAT(20A4)                                                        TIDI
1010  WRITE(KOUT,1021)WDUM                                                TIDI
1021  FORMAT(1X,20A4)                                                     TIDI
C                                                                         TIDI
      READ(KIN,1050) JMAX,CHLEN,NMAX,TCOM                                 TIDI
1050  FORMAT(I5,F10.0)                                                    TIDI
C        NOS =0 FOR CLOSED END, = ANYTHING ELSE FOR OPEN END              TIDI
      READ(KIN,1055) CASE,NOS                                             TIDI
1055  FORMAT(2I5)                                                         TIDI
      IF(NOS .EQ. 0)   GOTO 300                                           TIDI
      WRITE(KO,3001)                                                      TIDI
3001  FORMAT('OGEOMETRIC DATA',5X,'*** OPEN END ESTUARY ***')             TIDI
      GOTO 302                                                            TIDI
300   WRITE(KO,3002)                                                      TIDI
3002  FORMAT('OGEOMETRIC DATA',5X,'*** CLOSED END ESTUARY ***')           TIDI
302   WRITE(KO,1090) JMAX,CHLEN,NMAX,TCOM                                 TIDI
1090  FORMAT(/,'0   NUMBER OF STATIONS =',I4,5X,                          TIDI
     1       'ESTUARY LENGTH=',F10.0,' FT.',/,'   NUMBER OF TIME ',       TIDI
     2      'INCREMENTS PER PERIOD=',I4,5X,'PERIOD=',F7.0,'SECONDS')      TIDI
      IF(2*(JMAX/2) .NE. JMAX)    CALL ERRL(1)                            TIDI
      IF(2*(NMAX/2) .NE. NMAX)    CALL ERRL(2)                            TIDI
      NMAX=NMAX+1                                                         TIDI
      JMAXH=JMAX-1                                                        TIDI
      JMAXQ=JMAX                                                          TIDI
      NMAXH=NMAX                                                          TIDI
      NMAXQ=NMAX+1                                                        TIDI
```

```
      NEQ=NMAXQ-2
      JJTEM = JMAXQ-2
      DELT=TCOM/(NMAX-1)
      DELX=CHLEN/(JMAX-1)
C        SELECT SCHEMATIZATION CASE
      IF((CASE .LT. 1) .OR. (CASE .GT. 5))      CALL ERRL(3)
C        INPUT SCHEMATIZED GEOMETRY
      GO TO (540,550,560,565,566),CASE
C
C        CASE 1   RECTANGULAR CROSS-SECTION
  540 WRITE(KOUT,1110)
      WRITE(KOUT,1120)
 1110 FORMAT('0 CASE 1,  RECTANGULAR CROSS-SECTION')
 1120 FORMAT('0  MILES',8X,'D',11X,'ZO',14X,'B',7X,'B(CORE)',6X,
     1       'FEET',3X,'SECTION')
      DO 1 J=1,JMAX
      READ(KIN,1130) ISEQ,D(J),ZO(J),B(J)
 1130 FORMAT(I5,5X,5F10.0)
      DFEET=(J-1)*DELX
      DIST=DFEET/5280.
      BS(J)=B(J)
      WRITE(KOUT,1140) DIST,D(J),ZO(J),B(J),BS(J),DFEET,J
 1140 FORMAT (F10.5,2(2X,F10.5),2(2X,F10.2),2X,F10.0,I8)
      CALL SEQTST(J,ISEQ)
    1 CONTINUE
      GO TO 570
C
C        CASE 2    IRREGULAR CROSS-SECTION, (STORAGE)
  550 WRITE(KOUT,1150)
      WRITE(KOUT,1160)
 1150 FORMAT('0 CASE 2,  IRREGULAR CROSS-SECTION (STORAGE)')
 1160 FORMAT ('0  MILES',8X,1HD,11X,2HZO,14X,1HB,7X,'B(CORE)',8X,
     1       'D''',8X,'FEET',3X,'SECTION')
      DO 2 J=1,JMAX
      READ(KIN,1130) ISEQ,D(J),ZO(J),B(J),BS(J),DP(J)
      DFEET=(J-1)*DELX
```

```
      DIST=DFEET/5280.
      WRITE(KOUT,1180) DIST,D(J),ZO(J),B(J),BS(J),DP(J),DFEET,J
 1180 FORMAT (F10.5,2(2X,F10.5),3(2X,F10.1),2X,F10.0,I8)
      CALL SEQTST(J,ISEQ)
    2 CONTINUE
C
C        CALCULATE CORE AREA IF STORAGE TO BE CONSIDERED
      DO 30 J=1,JMAX
      COREA(J)=BS(J)*(D(J)-DP(J))
      IF ( COREA(J) .LT. 0)  WRITE(KO,31)J
31    FORMAT('0 NOTE, D'' DEEPER THAN D FOR SECTION',I5)
30    CONTINUE
      GO TO 570
C
C        CASE 3    TRAPEZOIDAL CROSS-SECTION
  560 WRITE(KOUT,1190)
1190  FORMAT('0 CASE 3,  TRAPEZOIDAL CROSS-SECTION')
      WRITE(KOUT,1200)
 1200 FORMAT ('0  MILES',8X,1HD,11X,2HZO,13X,2HBB,7X,2HSS,11X,2HZZ,
     1       8X,'FEET',3X,'SECTION')
      DO 3 J=1,JMAX
      READ(KIN,1130) ISEQ,D(J),ZO(J),SS(J),BB(J)
      ZZ(J)=1.+SS(J)**2
      ZZ(J)=SQRT(ZZ(J))
      DFEET=(J-1)*DELX
      DIST=DFEET/5280.
      WRITE(KOUT,1230) DIST,D(J),ZO(J),BB(J),SS(J),ZZ(J),DFEET,J
 1230 FORMAT (F10.5,2(2X,F10.5),2X,F10.1,2(2X,F10.5),F10.0,I8)
      CALL SEQTST(J,ISEQ)
    3 CONTINUE
      GO TO 570
C
C        CASE 4  EXPONENTIALLY VARYING WIDTH, RECTANGULAR CROSS-SECTION
  565 READ(KIN,1231) KB,BO
1231  FORMAT(2F10.0)
      WRITE(KOUT,1232) KB
```

```
1232  FORMAT('0 CASE 4,  EXPONENTIALLY VARYING WIDTH, RECTANGULAR',
     1         ' CROSS-SECTION    B= ',E12.4)
      WRITE(KOUT,1120)
      DO 9 J=1,JMAX
      READ(KIN,1130) ISEQ,D(J),ZO(J)
      X1=KB*(J-1)*DELX
      B(J)=BO*EXP(-X1)
      BS(J)=B(J)
      DFEET=(J-1)*DELX
      DIST=DFEET/5280.
      WRITE(KOUT,1140) DIST,D(J),ZO(J),B(J),BS(J),DFEET,J
      CALL SEQTST(J,ISEQ)
    9 CONTINUE
      GOTO 570
C
C        CASE 5, CONSTANT RECTANGULAR CROSS-SECTION
566   WRITE(KO,1112)
1112  FORMAT('OCASE 5, CONSTANT RECTANGULAR CROSS-SECTION')
      WRITE(KO,1120)
      READ(KIN,1130) ISEQ,D(1),ZO(1),B(1)
      DO 567 J=1,JMAX
      DFEET=(J-1)*DELX
      DIST=DFEET/5280.
      D(J)=D(1)
      ZO(J)=ZO(1)
      B(J)=B(1)
      BS(J)=B(1)
567   WRITE(KO,1140) DIST,D(J),ZO(J),B(J),BS(J),DFEET,J
C     END OF GEOMETRIC DATA INPUT
C
C        SECTION 2    CHANNEL ROUGHNESS AND WIND EFFECTS
570   WRITE(KO,1260)
1260  FORMAT(   '1',T10,'SECTION 2   CHANNEL ROUGHNESS AND WIND EFFECTS'
     1)
      READ(KIN,1050) ROUGH
      GOTO(1294,1292),ROUGH
```

```
C
C          CONSTANT ROUGHNESS AND WIND
C               NOTE THAT ALL LATERAL INFLOWS ARE SET TO ZERO AT THIS POINT
1294  READ(KIN,1300) ISEQ,MANCO(1),V(1),PHI(1)
      DO 1296 J=2,JMAX
      MANCO(J)=MANCO(1)
      FQ(J-1)=0.
      V(J)=V(1)
1296  PHI(J)=PHI(1)
      FQ(JMAX)=0.
      WRITE(KO,1310)
1310  FORMAT('0 CASE 1 CONSTANT ROUGHNESS AND CONSTANT WIND')
      GOTO 630
C
C          VARIABLE ROUGHNESS OR VARIABLE WIND
1292  DO 4 J=1,JMAX
      READ(KIN,1300) ISEQ,MANCO(J),V(J),PHI(J)
1300  FORMAT(I5,5X,F10.7,10X,2F10.7)
      CALL SEQTST(J,ISEQ)
4     FQ(J)=0.
      WRITE(KOUT,1320)
1320  FORMAT('0 CASE 2  EITHER ROUGHNESS OR WIND EFFECTS VARY')
C
C          TEST FOR NO WIND
630   WEND=1
      DO 5 J=1,JMAX
      IF(V(J) .NE. 0)  WEND=2
5     CONTINUE
      GOTO(640,650),WEND
C          NO WIND EFFECT
  640 WRITE(KOUT,1350)
1350  FORMAT('0   NO WIND')
      DO 6  J=2,JMAXQ,2
      W(J)=0.
    6 CONTINUE
      GOTO 661
```

```
C         WIND BEING CONSIDERED
  650 WRITE(KOUT,1360)
1360  FORMAT('0     WIND EFFECT  INCLUDED')
      DO 7 J=2,JMAXQ,2
      VCOS = V(J)*COS(PHI(J))
      VCOS = VCOS*ABS(VCOS)
      W(J)=        BETA*ARDEN*VCOS/WAUWT
    7 CONTINUE
      WRITE(KO,1380) WAUWT,BETA,ARDEN
1380  FORMAT(' DENSITY OF WATER=',F6.2,'  BETA=',F8.4,'  AIR DENSITY=',
     1        F10.4)
C         OUTPUT
661   WRITE(KOUT,1390)
 1390 FORMAT ('0  MILES',5X,5HMANCO,11X,2HFQ,7X,1HV,10X,3HPHI,
     1        12X,'FEET   SECTION')
      DO 8 J=1,JMAX
      DFEET=(J-1)*DELX
      DIST=DFEET/5280.
      WRITE(KOUT,1400) DIST,MANCO(J),FQ(J),V(J),PHI(J),DFEET,J
 1400 FORMAT (F10.5,2X,F10.7,2X,F10.3,2(2X,F10.7),2X,F10.0,I5)
    8 CONTINUE
C
C         SECTION 3   SURFACE ELEVATION AT THE ENTRANCE
      ISWO=2
      WRITE(KOUT,1405)
1405  FORMAT(//,'0  SECTION 3,  SURFACE ELEVATION AT THE ENTRANCE'/)
      READ(KIN,1410) CLASA,DSLD
1410  FORMAT(I5/F10.0)
      SLD=ZO(1)+D(1)-DSLD
      WRITE(KO,1406) DSLD,SLD
1406  FORMAT('  MWL',F5.2,' FT ABOVE MSL AT OCEAN',/,
     1      '  MSL',F7.2,' FT ABOVE THE HORIZONTAL DATUM')
      GOTO(665,680,670),CLASA
C
C         CASE 1,  COSINE FIT TO HW,LW SERIES
C            PUT FIRST HW IN VARIABLE HOA(1)
```

```
665   READ(KIN,1231) HOA(1)
      WRITE(KO,1407) HOA(1)
1407  FORMAT('0 CASE 1, COSINE FIT TO HW-LW SERIES',/,
     1         '  FIRST HW VALUE RELATIVE TO MWL =',F10.2,/)
      ISWO=1
      GOTO 745
C
C         CASE 2,  ELEVATIONS REPEATING AND HARMONIC
680   READ(KIN,1050) LMAX
      WRITE(KO,1450)
1450  FORMAT('0 CASE 2, ELEVATIONS AT ENTRANCE REPEAT AND ARE HARMONIC')
      DO 10 L=1,LMAX
      READ(KIN,1231) AMP(L),T(L)
      IF(LMAX .EQ. 1)   T(L)=TCOM
      WRITE(KO,1441) AMP(L),T(L)
1441  FORMAT(5X,'A=',F10.4,5X,'T=',F10.2)
      OMEGA(L)=2.*PI/T(L)
   10 CONTINUE
      DO 11 N=1,NMAXH,2
      HOA(N)=0.
      DO 11 L=1,LMAX
      THETA(L)=OMEGA(L)*(N-1)*DELT
      HOA(N)=HOA(N)+AMP(L)*COS(THETA(L))
   11 CONTINUE
      GO TO 745
C
C         CASE 3,  REPEATING ELEVATIONS FROM TABLE
670   WRITE(KOUT,1430)
1430  FORMAT('0 CASE3, REPEATING ELEVATIONS FROM TABLE')
      NDUM=NMAXH-2
      READ(KIN,1420) (HOA(N), N=1,NDUM,2)
 1420 FORMAT (5F10.5)
      WRITE(KO,1408) (HOA(N),N=1,NDUM,2)
1408  FORMAT(5X,5F10.5)
      HOA(NMAXH)=HOA(1)
C     BOUNDARY CONDITION AT OCEAN A DEFINED
```

```
C
C
C       SET UP BOUNDARY CONDITIONS AT RIVER END
  745 DO 19 N=2,NMAXQ,2
      QOB(N)=0.
   19 CONTINUE
C       INITIAL CONDITIONS DEFINED
      D1=DELT/DELX
      D2=.5/(DELT*G)
      D3=.5/DELX
      DTEM=1./D1
      TDH=DELT/3600.
      DO 21 J=2,JJTEM,2
      D4(J)=D3*(D(J-1)-D(J+1)+ZO(J-1)-ZO(J+1))
   21 CONTINUE
      WRITE(KOUT,1500) DELT,DELX
1500  FORMAT(//,' DT=',F10.2,' SEC.   DX=',F10.1,' FT.')
      WRITE(KOUT,1510) DTEM
 1510 FORMAT(15H DELTAX/DELTAT=,F8.2, 9H FT./SEC.)
C       COMPUTATION OF CELERITY WITH RESPECT TO MEAN DEPTH
C       SCEL DENOTES THE CELERITY WITH RESPECT TO THE DEPTH ONLY
      WRITE(KOUT,1520)
 1520 FORMAT (36HOCELERITY WITH RESPECT TC DEPTH ONLY)
      WRITE(KOUT,1530)
1530  FORMAT(T11,'CELERITY  WAVE LENGTH',/,' SECTION  (FT/SEC)',
     1       T23,'(MILES)')
      IWARN=0
      DO 22 J=1,JMAX
      SCEL(J)=(G*D(J))**.5
      WALEN(J)=SCEL(J)*TCOM/5280.
      WRITE(KOUT,1540) J,SCEL(J),WALEN(J)
1540  FORMAT(1X,I7,F10.2,2X,F10.2)
      IF(SCEL(J) .GT. DTEM)  IWARN=1
   22 CONTINUE
      IF(IWARN .EQ. 1)  WRITE(KOUT,1550)
1550  FORMAT('0*** WARNING, CELERITY GREATER THAN DX/DT IN SOME',
```

```
     1        ' SECTIONS.  INSTABILITY COULD RESULT')
      RETURN
      END
```

```
      SUBROUTINE OSIN
      INTEGER CASE,ODS1,ODS2
      REAL  FC(200), BB(200),  D(200), SS(200),  B(200),MANCO(200)
      REAL  ZZ(200),  R(200),  C(200), D4(200),  W(200)
      REAL  BS(200),  E(200),H(2,200),S(2,200),Q(2,200)
      REAL HOA(900),QOB(900)
      DIMENSICN OPT(4),OKEY(4),KVAR(3)
      DIMENSICN DUM(100),ZC(200)
      COMMCN KO,KIN,KKK,JJJ
      CCMMCN NOS,CASE,DELT,DELX,NMAX,NMAXH,JMAX,JMAXH,JJTEM,JMAXQ
      COMMON D1,D2,D3,EH,EZ,EXLM,SZERC,ES
       COMMCN MH,MS,ISW0,ISW1,ISW2,ISW3,ISW4,ISW5,ISW6,ISW7
        CCMMCN H,Q,HOA,QOB,FC,BB,D,SS,B,ZZ,R,MANCO,C,D4,W,BS,S,E
      COMMCN /CEPT/ XNCPT
      COMMCN /T/ MMM,QF,IPF,IPE,NNN,IETM
      COMMON /SL/ SLD,ZO
      DATA OKEY/'KEEP','HWS','FC  ','E   '/,KVAR/'H','S','Q'/
      DATA INCPT/0/
      ISW1=1
      ISW2=1
      ISW3=1
      ISW4=1
      ISW5=-1
      ISW6=-1
      ISW7=-1
      IETM=1
C
C        SECTION 4, DEFINITICNS RELATIVE TC THE SALT BALANCE EQN.
C        AND TO INITIAL SALINITIES
      WRITE(KC,200)
200   FORMAT(//,'1 SECTION 4,  DEFINITICNS RELATIVE TO THE SALT BALANCE
     1EQUATION, AND TO INITIAL SALINITIES',//)
      NMD2=(NMAX-1)/2
      NF=JMAX/2
      III=5
      MMM=15
```

```
      NNN=11
      LLL=3
C
      READ(KIN,199) EZ, ODS2
199   FORMAT(F10.0,I5)
      IF(ODS2 .NE. 0)   IETM=ODS2
      READ(KIN,100) XNCPT,EXLM,PF,PE
100   FORMAT(5F10.0)
      WRITE(KO,201) IETM,EZ
201   FORMAT(//,' E=K(DS/DX)+',I2,'*E(TAYLOR)',5X,' K FOR THE NEXT ',
     1       'TIDAL CYCLE IS',F10.2,/)
      IF(XNCPT .EQ. 0.)   XNCPT=2.15E-3
      WRITE(KO,205) XNCPT
205   FORMAT('OK VS. ED GIVEN BY K/(UZ*L)=',E10.3,'ED**(-1/4)',/)
      IF(EXLM) 51,1,2
51    CALL ERRL(4)
1     WRITE(KO,202)
202   FORMAT(/,' SALINITY EXCURSION NOT LIMITED',/)
      GOTO 3
2     WRITE(KO,203) EXLM
203   FORMAT(/,' SALINITY EXCURSION LIMIT =',F10.2,' FT',/)
3     IPF=PF*NMD2+0.5
      IPE=PE*NMD2+0.5
      WRITE(KO,204) PF,PE,IPF,IPE
204   FORMAT(' SALINITY RETURNS TO SZERO AFTER LWS IN',F5.2,
     1       ' OF A TIDAL PERIOD',/,' EXTENTION OF SZERO AFTER HWS FOR',
     2       F5.2,' OF A TIDAL PERIOD',T100,2I8)
C
C       DEFINITION OF THE SOURCE OF INITIAL CONDITIONS
C       ALL ELEVATIONS IN INITIAL CONDITIONS ARE WITH RESPECT TO MSL
      READ(KIN,101) ICASE,ODS1
101   FORMAT(2I5)
      IF(ODS1 .NE. 0)     LLL=ODS1
C
C       DEFINE INITIAL CONDITIONS
      GOTO(19,195,18),ICASE
```

```
C
C        CASE 3, INPUT ALL I.C. FROM CARDS
C        H INPUT WRT MSL, THEN REFERED TO MWL AT THE OCEAN
C        ALL STARTING VALUES FROM UNIT III
18    WRITE(KO,217)
217   FORMAT('OCASE 3, INITIAL CONDITIONS ALL FROM CARDS')
      READ(III,100) (H(1,J),J=1,JMAXH,2)
      CALL SPEW(1,4)
      DO 180 J=1,JMAXH,2
180   H(1,J)=H(1,J)+SLD-ZO(J)-D(J)
      READ(III,100) (S(1,J),J=1,JMAXH,2)
      READ(III,100) (Q(1,J),J=2,JMAXQ,2)
      GOTO 17
C
C        CASE1, ALL I.C. FROM DATASET
19    WRITE(KO,216)
216   FORMAT('OCASE 1, ALL INITIAL CONDITIONS FROM DATASET')
      GOTO 20
C
C        CASE 2, ELEVATIONS AND DISCHARGES FROM DATASET,
C        SALINITY FROM CARDS
195   WRITE(KO,218)
218   FORMAT('OCASE 2, INITIAL ELEVATIONS AND DISCHARGES FROM DATASET',
     1       ', SALINITIES FROM CARDS')
      READ(KIN,100) (S(1,J),J=1,JMAXH,2)
20    NTNL=NMD2-1
      DO 520 I=1,NTNL
      READ(LLL)      (DUM(J),J=1,NF)
      READ(LLL)      (DUM(J),J=1,NF)
520   READ(LLL)      (DUM(J),J=1,NF)
C         SET UP H,S AND Q  ON LST  READ
      READ(LLL)      (H(1,J),J=1,JMAXH,2)
      CALL SPEW(1,4)
      DO 181 J=1,JMAXH,2
181   H(1,J)=H(1,J)+SLD-ZO(J)-D(J)
C        DECIDE WHETHER OR NOT TO USE S(INIT) FROM CARDS
```

```
      GOTO(4560,4550),ICASE
4550  READ(LLL)      (DUM(J),J=1,NF)
      GOTO 4570
4560  READ(LLL)      (S(1,J),J=1,JMAXH,2)
4570  READ(LLL)      (Q(1,J),J=2,JMAXQ,2)
C
C        PLACE INTO S(2,J) FOR RHO CALC EXCEEDING JLIM
17    DO 4580 J=1,JMAXH,2
4580  S(2,J)=S(1,J)
      CALL  SPEW(2,4)
      CALL  SPEW(3,4)
C
C        SECTION 5.   OUTPUT SELECTION
C        OPTIONS
      WRITE(KO,210)
210   FORMAT('0',/,' SECTION 5,   OUTPUT SELECTION')
      READ(KIN,120)(OPT(I),I=1,4),ODS1,ODS2
120   FORMAT(4(A4,1X),2I5)
      DO 3001 I=1,4
      DO 3001 II=1,4
      IF(OPT(I) .NE. OKEY(II))   GOTO 3001
      WRITE(KO,270) OKEY(II)
270   FORMAT('0OPTION ',A4,' SPECIFIED')
      INOPT=INOPT+1
      IF(II .EQ. 1)  ISW1=2
      IF(II .EQ. 2)  ISW2=2
      IF(II .EQ. 3)   ISW3=2
      IF(II .EQ. 4)  ISW4=2
3001  CONTINUE
      IF(INOPT .EQ. 0)  WRITE(KO,271)
271   FORMAT('0 NO OPTIONS SPECIFIED')
C        GET DATASET NO.S FOR 'KEEP' AND 'E'  OPTIONS
      IF((ISW1 .EQ. 2) .AND. (ODS1.NE.0))    MMM=ODS1
      IF((ISW4 .EQ. 2) .AND. (ODS2 .NE. 3))  NNN=ODS2
C        GET FRQUENCY OF BASIC OUTPUT
      WRITE(KO,272)
```

```
272    FORMAT('0 BASIC OUTPUT',T20,'FREQUENCY')
       DO 275 I=1,3
       READ(KIN,121) KEY,NFREQ
121    FORMAT(A1,4X,I5)
       DO 276 II=1,3
       IF(KEY .NE. KVAR(II))    GOTO 276
       IF(II .EQ. 1)  ISW5=NFREQ
       IF(II .EQ. 2)  ISW6=NFREQ
       IF(II .EQ. 3)  ISW7=NFREQ
       GOTO 277
276    CONTINUE
       CALL ERRL(5)
277    WRITE(KO,273) KEY,NFREQ
273    FORMAT(7X,A1,T19,I5)
       IF((NFREQ/2)*2 .NE. NFREQ)     CALL ERRL(7)
275    CONTINUE
C
C         CHECK  FOR NON-FATAL ERROR ACCUMULATION
       CALL ERRL(8)
       RETURN
       END
```

```
      SUBROUTINE MARCH
      INTEGER CASE,IHWS(100)
      REAL  FQ(200),  BB(200),  D(200),  SS(200),  B(200),MANCO(200)
      REAL  ZZ(200),  R(200),   C(200),  D4(200),  W(200)
      REAL  BS(200),  E(200),H(2,200),S(2,200),Q(2,200)
      REAL HOA(900),QOB(900),DP(200),COREA(200)
      LOGICAL LV(100),KEY(100),LP,LDP
      DIMENSION HKH(200),Z(200),WP(200),ZD(200),RHO(200),ZO(200)
      DIMENSION CU(100),CD(100),CL(100),F(100)
      DIMENSION A(2,200),HWS(100),HH(450),QQ(450)
      COMMON KO,KIN,KKK,JJJ
      COMMON NOS,CASE,DELT,DELX,NMAX,NMAXH,JMAX,JMAXH,JJTEM,JMAXQ
      COMMON D1,D2,D3,EH,EZ,EXLM,SZERO,ES
      COMMON MH,MS,ISW0,ISW1,ISW2,ISW3,ISW4,ISW5,ISW6,ISW7
      COMMON H,Q,HOA,QOB,FQ,BB,D,SS,B,ZZ,R,MANCO,C,D4,W,BS,S,E
      COMMON /SW/ ISW10,ISW11
      COMMON /T/ MMM,QF,IPF,IPE,NNN
      COMMON /EXLIM/ J1LIM,J2LIM,K,I
      COMMON /STOR/DP,COREA,LDP
      COMMON /AREAS/A
      COMMON /OUTP/ LEW,NN,HWS,NDUMM,IHWS
      COMMON /SL/ SLD,ZO
      EQUIVALENCE (I,IH,IQ),(K,KH,KQ),(NREC,JM2)
      DATA THETA/0.333333/
      DATA INIT/1/
      DATA RHOS/0.75/,P/0.166667/,G/32.2/
C
C
C        INITIALIZATION
      GOTO(1,2),INIT
 1    NSEG=JMAX
      INIT=2
      GG=1.-THETA
      NREC=NSEG/2
      JM2M1=JM2-1
      NMD2=(NMAX-1)/2
```

```
      DX2=DELX*2.
      XL  =(JMAX-1)*DELX
      DT2=DELT*2.
      DTX=DELT/DELX
      F(JM2+1)=0.
      CT2=2.*THETA*DELX/DELT
      CG4=4.*(1.-THETA)*DELX/DELT
      CC4=2.*(1.-THETA*0.5)/DTX
      CF4=2.*(THETA*0.5)/DTX
      JLMM1=JLIM-1
      J2LIM=2*JLIM-1
C
C        IH=I=IQ IS THE PREVIOUS TIME STEP
C        KH=K=KQ IS THE NEXT TIME STEP
      IH=1
      KH=2
C      NORMAL ENTRY
C        AVERAGE MASS BALANCE FOR ITERATION
2     TSUM=0.
C        FOR HIGH WATER SLACK CALCS
      DO 13 J=1,JLIM
      IF(Q(IH,2*J)) 11,11,12
11    LV(J)=.FALSE.
      GOTO 13
12    LV(J)=.TRUE.
13    KEY(J)=.FALSE.
C
C        SET COUNTERS FOR SELECTIVE OUTPUT
      KHCT=1+ISW5
      KSCT=1+ISW6
      KQCT=1+ISW7
C
C        MASTER LOOP  TIME
      DO 23 NN=3,NMAXH,2
      H(IH,1)=HOA(NN-2)
      H(KH,1)=HOA(NN)
```

```
      Q(IQ,JMAXQ)=QOB(NN-1)
      Q(KQ,JMAXQ)=QOB(NN+1)
C
C   CONTINUITY EQUATION
      DO 24 J=3,JMAXH,2
      FRDIS = FQ(J)+FQ(J+1)
      GO TO (770,770,760,770,770),CASE
  760 B(J)= BB(J)+ 2.*(D(J)+H(IH,J))*SS(J)
  770 H(KH,J)=H(IH,J)-(Q(IQ,J+1)-Q(IQ,J-1)-FRDIS)*D1/B(J)
   24 CONTINUE
C         GET RHO
      DO 8020 J=1,JMAXH,2
8020  RHO(J)=RHOS*S(I,J)+1000.
C
C         MOMENTUM EQUATION
      DO 25 J=2,JJTEM,2
C         JJTEM =JMAXQ-2=JMAX-2    IN THIS CASE
      GO TO (790,790,780,790,790),CASE
  780 HTEM=D(J)+.5*(H(KH,J-1)+H(KH,J+1))
      B(J)= BB(J)+2.*HTEM*SS(J)
      BS(J)= BB(J)+HTEM*SS(J)
C          CALC. DIST. SURFACE TO CENTROID
      ZD(J)=HTEM*(2.*BS(J)+B(J))/6./BS(J)
      Z(J)=BS(J)*HTEM
      WP(J)= BB(J)+2.*HTEM*ZZ(J)
      GO TO 800
  790 Z(J)=BS(J)*(D(J)+.5*(H(KH,J+1)+H(KH,J-1)))
      WP(J)=2.*D(J)+BS(J)+H(KH,J+1)+H(KH,J-1)
C          CALC. DIST. SURFACE TO CENTROID
      ZD(J)=(Z(J)/BS(J))*0.5
  800 R(J)=Z(J)/WP(J)
C         TEST FOR NEGATIVE DEPTH AS AN EVIDENCE OF INSTABILITY
      IF(Z(J) .LT.0)          CALL ERRL(9)
      C(J)=1.486*(R(J)**P)/MANCO(J)
      E1=D2/Z(J)
      E2=.5/((C(J)**2)*(Z(J)**2)*R(J))
```

```
      E3=2.*B(J)      /(G*(Z(J)**2))                                    MARC 109
      E4=.25*(H(KH,J+1) +H(KH,J-1)-H(IH,J+1)-H(IH,J-1))/DELT            MARC 110
      FRDIS=(FQ(J)+FQ(J+1))/DX2                                         MARC 111
      E5=FRDIS/(G*(Z(J)**2))                                            MARC 112
      D6= ZD(J)/DELX*(RHO(J-1)-RHO(J+1))/(RHO(J-1)+RHO(J+1))            MARC 113
      Q(KQ,J)=(Q(IQ,J)*(E1-ABS(Q(IQ,J))*E2+E3*E4-E5)+D3*(H(KH,J-1)-     MARC 114
     1H(KH,J+1))+W(J)/R(J)+D4(J)+D6)/(E1+E2*ABS(Q(IQ,J)))               MARC 115
   25 CONTINUE                                                          MARC 116
C                                                                       MARC 117
C        AREA CALCULATION                                               MARC 118
      DO 10 J=1,J2LIM,2                                                 MARC 119
      GOTO (3001,3,5,3001,3001),CASE                                    MARC 120
5     DO 6 IT=1,2                                                       MARC 121
      HTEM=D(J)+H(IT,J)                                                 MARC 122
6     A(IT,J)= (BB(J)+HTEM*SS(J))*HTEM                                  MARC 123
      GOTO 10                                                           MARC 124
3     IF(B(J) .EQ. BS(J))      GOTO 3001                                MARC 125
      DO 4 IT=1,2                                                       MARC 126
      DPPN=DP(J)+H(IT,J)                                                MARC 127
      IF(DPPN .LT. 0)     CALL ERRL(10)                                 MARC 128
4     A(IT,J)=B(J)*DPPN+COREA(J)                                        MARC 129
      GOTO 10                                                           MARC 130
3001  DO 3002 IT=1,2                                                    MARC 131
3002  A(IT,J)=BS(J)*(D(J)+H(IT,J))                                      MARC 132
10    CONTINUE                                                          MARC 133
C        CALCULATE DISPERSION COEFFICIENTS                              MARC 134
      CALL TDISP                                                        MARC 135
C        OCEAN BOUNDRY CONDITION                                        MARC 136
      CALL TOCNB(CD,CU,F,(NN-1)/2,NMD2)                                 MARC 137
C                                                                       MARC 138
C        CALCULATE COEFFICIENTS                                         MARC 139
      DO 7 M=2,JLMM1                                                    MARC 140
      M2=2*M-1                                                          MARC 141
      M2M2=M2-2                                                         MARC 142
      M2P2=M2+2                                                         MARC 143
      A2M=(A(2,M2)+A(1,M2))/2.                                          MARC 144
```

```
      A2MM2=(A(2,M2M2)+A(1,M2M2))/2.
      A2MP2= (A(2,M2P2)+A(1,M2P2))/2.
      A2MM1=0.5*(A2M+A2MM2)
      A2MP1=0.5*(A2M+A2MP2)
      EBM1=E(M2-1)*A2MM1/DELX
      EBP1=E(M2+1)*A2MP1/DELX
      CL(M-1)=CT2*A(K,M2M2)-Q(I,M2-1)-EBM1
      CD(M)= CG4*A(K,M2)-Q(I,M2-1)+Q(I,M2+1)+EBM1+EBP1
      CU(M)=CT2*A(K,M2P2)+Q(I,M2+1)-EBP1
      F(M)=S(I,M2M2)*(CT2*A(I,M2M2)+Q(I,M2-1)+EBM1)+
     1     S(I,M2)*(CG4*A(I,M2)+Q(I,M2-1)-Q(I,M2+1)-EBM1-EBP1)+
     2     S(I,M2P2)*(CT2*A(I,M2P2)-Q(I,M2+1)+EBP1)
C
7     CONTINUE
C        MASS BALANCE HEAD BOUNCARY CONDITION
C
      M=JLIM
      EB=E(M2+1)*A2MP1/DELX
      CD(M)=CC4*A(K,M2P2)-Q(I,M2P2-1)+EB
      CL(M-1)=CF4*A(K,M2)-Q(I,M2P2-1)-EB
      F(M)=S(I,M2)*(CF4*A(I,M2)+Q(I,M2P2-1)+EB)+
     1     S(I,M2P2)*(CC4*A(I,M2P2)+Q(I,M2P2-1)-EB)
C
C        CALL  EQUATICN SOLVER AT THIS POINT
      CALL TRIDG(M    ,CL,CD,CU,F)
C
      DO 20 M=1,JLIM
      J=2*M-1
20    S(K,J)=F(M)
C
C        OUTPUT SELECTION
C        FREQUENCY OF OUTPUT CONTAINED IN ISW5,ISW6,ISW7 FOR H,S,&Q
      IF(ISW5 .EQ. 0)     GOTO 851
      IF( NN .NE. KHCT)   GOTO 851
      CALL SPEW(1,2)
      KHCT=KHCT+ISW5
```

```
851   IF(ISW6 .EQ. 0)    GOTO 852
      IF(NN .NE. KSCT)  GOTO 852
      CALL SPEW(2,2)
      KSCT=KSCT+ISW6
852   IF(ISW7 .EQ. 0)  GOTO 86
      IF(NN .NE. KQCT)  GOTO 86
      CALL SPEW(3,2)
      KQCT=KQCT+ISW7
C
C        MASS BALANCE
86    SUM=0.
      DO 31 J=3,J2LIM,2
31    SUM=SUM+S(K,J)*A(K,J )
      SUM=SUM+0.5*S(K,1)*A(K,1)
      TSUM=TSUM+SUM
C
C        TEST TO SEE IF OUTPUT TO A SEQUENTIAL DATASET IS SPECIFIED
      IF(ISW1 .EQ. 1)     GOTO 4000
C        OUTPUT TIME STEP RESULTS TO FILE 'MMM'
      DO 400 J=1,JMAXH,2
400   HKH(J)=H(K,J)-SLD+ZO(J)+D(J)
      WRITE(MMM) (HKH(J),J=1,JMAXH,2)
      WRITE(  MMM) (S(K,J),J=1,JMAXH,2)
      WRITE(MMM) (Q(K,J),J=2,JMAX,2)
C
C        TEST TO SEE IF HWS OUTPUT HAS BEEN SPECIFIED
4000  IF(ISW2 .EQ. 1)  GOTO 4001
C        HIGH WATER SLACK CALCULATIONS
      DO 40 J=1,JLIM
      IF(KEY(J))   GO TO 40
C        SIGN OF NEW 'Q' TO LP
      IF(Q(KH,2*J))  41,41,42
41    LP=.FALSE.
      GOTO 43
42    LP=.TRUE.
C        TEST FOR HIGH WATER SLACK BY ZERO CROSSING OF Q, + TO -
```

```
43    IF(LV(J) .AND. .NOT. LP)     GOTO 44
C        NOT HWS,  SET UP FOR NEXT TRY
      LV(J)=LP
      GOTO 40
C        FOUND THE HWS
44    IHWS(J)=NN
      KEY(J)=.TRUE.
      HWS(J)=S(KH,2*J-1)
40    CONTINUE
C
C        SAVE H AND Q VALUES AT THE OCEAN FOR PRISM CALCS
4001  ISUB=(NN-1)/2
      HH(ISUB)=0.5*(H(KH,1)+H(KH,3)) + C(2)
      QQ(ISUB)=Q(KH,2)
C         END OF MAIN LOOP
C   SWAP BEFORE AND AFTER INDICES.
      ITTP=IH
      IH=KH
      KH=ITTP
   23 CONTINUE
C
      TSUM=TSUM*DX2/NMD2
      WRITE(KC,503)      TSUM
503   FORMAT(T101,'AVE MASS =',E16.6)
C
      IF(ISW2 .EQ. 1)   GOTO 46
C        OUTPUT  HWS
      DO 405 J=1,JLIM
C        IF HWS UNDEFINED, FILL WITH 999
      IF(KEY(J))   GOTO 405
      IHWS(J)=999
      HWS(J)=999.
405   CONTINUE
      CALL SPEW(4,3)
C
C        CALL TO PRISM ROUTINE
```

```
46    CALL ESNOD(DT2,NMD2,NREC,D(2),B(2),MANCO(2),QF,EEZ,HH,QQ,SZERO,XL)
      EZ=EEZ
      RETURN
      END
```

```
      SUBROUTINE TDISP
      INTEGER CASE
      REAL  FQ(200), BB(200),  D(200), SS(200),  B(200),MANCC(200)
      REAL  ZZ(200),  R(200),  C(200), D4(200),  W(200)
      REAL  BS(200),  E(200),H(2,200),S(2,200),Q(2,200)
      REAL HOA(900),QOB(900)
      DIMENSICN DZERO(200),EXK(200),A(2,200)
      COMMON KO,KIN,KKK,JJJ
      COMMON NDS,CASE,DELT,DELX,NMAX,NMAXH,JMAX,JMAXH,JJTEM,JMAXQ
      COMMON D1,D2,D3,EH,EZ,EXLM,SZERO,ES
      COMMON MH,MS,ISW0,ISW1,ISW2,ISW3,ISW4,ISW5,ISW6,ISW7
        CCMMON H,Q,HOA,QOB,FQ,BB,D,SS,B,ZZ,R,MANCO,C,D4,W,BS,S,E
      COMMON /AREAS/ A,Q1
      COMMON /EXLIM/ JLIM,J2LIM,K,M
      COMMON /T/ MMM,QF,IPF,IPE,NNN,IETM
      DATA INIT/1/
C
C        M IS THE PREVIOUS TIME STEP
C        K IS THE NEXT TIME STEP
      GOTO(1,2),INIT
1     JLIM=JMAX/2
      XKFAC=(JMAX-1)*0.5
      ETM=IETM
      IF(EXLM)40,41,40
41    J2LIM=JMAXH
      GOTO 42
40    JLIM= IFIX(EXLM/DELX/2.)+2
      J2LIM=2*JLIM-1
42    INIT=2
      E(JMAXH)=0.
      J2M2=J2LIM-2
      FAC4=DELX/DELT*0.25
      RETURN
C
C        GET DZERO ON THE ODD INTERVALS
2     XK=EZ*XKFAC/SZERO
```

```
      DO 10 J=1,J2LIM,2
      IF(J-1) 16,16,17
C        Q1 BY CONTINUITY
16    H2OLD=0.5*(H(M,1)+H(M,3))
      H2NEW=0.5*(H(K,1)+H(K,3))
      Q1=Q(M,2)+FAC4*(B(1)*(H(K,1)-H(M,1))+B(2)*(H2NEW-H2OLD))
      QODD=ABS(Q1)
      GOTO 18
C        NORMAL ... INTERIOR POINTS
17    QODD=0.5*ABS(Q(M,J-1)+Q(M,J+1))
18    HTEM=D(J)+0.5*(H(1,J)+H(2,J))
      GOTO(13,13,14,13,13),CASE
C        TRAPEZOIDAL SECTION
14    AR=0.5*(A(1,J)+A(2,J))
      R(J)=AR/(BB(J)+2.*HTEM*ZZ(J))
      GOTO 15
C        OTHER SECTIONS
13    AR= BS(J)*HTEM
      R(J)=AR/(BS(J)+HTEM+HTEM)
15    V=QODD/AR
      DZERO(J)=77.*MANCO(J)*(R(J)**0.833333)*V*ETM
10    CONTINUE
C
C        GET EXK ON THE EVEN INTERVALS
      DO 11 J=1,J2M2,2
C        TEST FOR SEAWARD POINT NEG.
      SD=S(M,J)
      IF(SD) 9,9,8
9     EXK(J)=0.
      GOTO 11
8     EXK(J)=XK*ABS(SD-S(M,J+2))
11    CONTINUE
C
C        INTERPOLATE TO EVEN INTERVALS
      DO 12 J=1,J2M2,2
12    E(J+1)=EXK(J)+0.5*(DZERO(J)+DZERO(J+2))
```

```
      E(1)=EXK(1)+DZERO(1)                                              TDIS  73
      GOTO(30,20),ISW4                                                  TDIS  74
   20 WRITE(NNN   ) E(1),(E(J-1),J=3,J2LIM,2)                           TDIS  75
   30 RETURN                                                            TDIS  76
      END                                                               TDIS  77
```

```
      SUBROUTINE   TOCNB (CD,CU,F,L,NMD2)
      INTEGER CASE
      REAL  FQ(200), BB(200),  D(200), SS(200),  B(200),MANCO(200)
      REAL  ZZ(200),  R(200),  C(200), D4(200),  W(200)
      REAL  BS(200),  E(200),H(2,200),S(2,200),Q(2,200)
      REAL HOA(900),QOB(900)
      DIMENSION CD(1),CU(1),F(1)
      DIMENSION A(2,200)
      COMMON KO,KIN,KKK,JJJ
      COMMON NOS,CASE,DELT,DELX,NMAX,NMAXH,JMAX,JMAXH,JJTEM,JMAXQ
      COMMON D1,D2,D3,EH,EZ,EXLM,SZERO,ES
      COMMON MH,MS,ISW0,ISW1,ISW2,ISW3,ISW4,ISW5,ISW6,ISW7
      COMMON H,Q,HOA,QOB,FQ,BB,D,SS,B,ZZ,R,MANCO,C,D4,W,BS,S,E
      COMMON /T/ MMM,QF,IPF,IPE
      COMMON /AREAS/ A,Q1
      COMMON /EXLIM/ JD1,JD2,K,M
      DATA INIT/1/
      DATA THETA/0.333333/
C
C        INITIALIZE SIGN OF PREVIOUS DISCHARGE, SMIN, COUNTER OF
C        INCREMENTS SINCE FLOOD BEGAN
      GOTO(1,2),INIT
C        IF THE FIRST CYCLE BEGINS ON FLOOD SMIN MUST BE
C        ARBITRARILY DEFINED.  IT IS SET TO SZERO FOR FIRST CYCLE ONLY
1     QLST=1.
      SMIN=SZERO
      NMAXM=NMAX-1
      NFLD=NMD2/2
      NEBB=0
      DXDT=DELX/DELT
      CC4=2.*(1.-THETA*0.5)*DXDT
      CF4=2.*(THETA*0.5)*DXDT
      INIT=2
C
C        NORMAL ENTRY
2     IF(QLST*Q(M,2)) 10,20,20
```

```
C          CHANGE OF SIGN
10      IF(Q(M,2)) 11,12,12
C          TO EBB
11      NEBB=0
        GOTO 21
C          TO FLOOD
12      NFLD=1
        SMIN =S(M,1)
        GOTO 22
C          NO SIGN CHANGE
20      IF(Q(M,2)) 21,22,22
C          FLOOD
22      IF(NFLD-IPF) 23,24,24
C          WITHIN RANGE
23      SX=SMIN+(SZERO-SMIN)*NFLD/FLOAT(IPF)
        NFLD=NFLD+1
        GOTO 77
C          OUT OF RANGE
24      SX=SZERO
        GOTO 77
C          EBB
21      IF(NEBB-IPE) 25,26,26
C          WITHIN RANGE
25      NEBB=NEBB+1
        SX=SZERO
        GOTO 77
C
C          OUT OF RANGE  *** SPECIAL ROUTINE ***
C
C          Q1 AND AREAS FROM COMMON
26      A1B=(A(2,1)+A(1,1))*0.5
        A3B=(A(2,3)+A(1,3))*0.5
        EB=0.5/DELX*(E(1)*A1B-E(2)*(A1B+A3B)*0.5)
        CD(1)=CC4*A(K,1)-Q1-Q1+Q(M,2)-EB
        CU(1)=CF4*A(K,3)+Q(M,2)+EB
        F(1)=S(M,1)*(CC4*A(M,1)+Q1+Q1-Q(M,2)+EB)+
```

```
     1        S(M,3)*(CF4*A(M,3)-Q(M,2)-EB)
       GOTO 80
C         CALCULATE COEFFICIENTS
77     F(1)=SX
       CD(1)=1.0
       CU(1)=0.
C         HOUSEKEEP
80     QLST=Q(M,2)
       RETURN
       END
```

```
      SUBROUTINE TRIDG (N,A,B,C,D)
C        ALGORITHM 24 OF ACM... BY B. LEAVENWORTH
C            TRANSLATED TO FORTRAN IV BY M.L. THATCHER
      REAL W, A(100),B(100),C(100),D(100)
      INTEGER J,N,NM1,I
      D(1)=C(1)/B(1)
      W=B(1)
      NM1=N-1
      DO 1 J=1,NM1
      B(J)=C(J)/W
      W= B(J+1)-A(J)*B(J)
1     D(J+1)=(D(J+1)-A(J)*D(J))/W
      DO 2 J=1,NM1
      I=N-J
2     D(I)=D(I)-B(I)*D(I+1)
      RETURN
      END
```

```
      SUBROUTINE ESNOD(DT,NT,NX,D,B,XN,FRESH,EEZ,H,Q,S,XL)
C
C        THIS IS A MODIFICATICN OF SUBROUTINE 'PRISM'
C        WHICH CCNVERTS THE ESTUARY NC. TC A DENSIMETRIC ONE AND
C        EVALUATES THE GROSS DISPERSICN PARAMETER 'K' IN TERMS
C        OF (U*L)
C        CALCULATION OF TIDAL PRISM, MAX. VELOCITY, DENSIMETRIC FROUDE N
C        Q(F)  AND THE ESTUARY NUMBER(DENSIMETRIC)
      REAL          Q(450),H(450),V(450)
      COMMCN KO
      COMMON /CEPT/ XNCPT
C        CONST FOR CCNVERTING SALINITY TO CENSITY DEFINED BELOW
      DATA TCCNS/0.75/
      VOLB(Q1,Q2)=Q2*Q2*DT*0.5/(Q2-Q1)
      VOLN(Q1,Q2)=0.5*(Q1+Q2)*CT
      VOLL(Q1,Q2)= Q1*Q1*DT*0.5/(Q1-Q2)
C
      PT=0.
      DRO=TCONS*S/1000.
      I=1
      IF(Q(I)) 1,2,2
C        STARTS GOING NEGATIVE
1     I=I+1
      IF(Q(I) .LT. 0.)  GOTO 1
      PT=VOLB(Q(I-1),Q(I))
11    I=I+1
      IF(I .GT. NT)     GOTO 30
      IF(Q(I) .LT. 0.)   GOTO 12
      PT=PT+VOLN(Q(I-1),Q(I))
      GOTO 11
12    PT=PT+VCLL(Q(I-1),Q(I))
      GOTO 30
C        STARTS GOING POSITIVE
2     I=I+1
      IF(Q(I) .LT. 0.)   GOTO 20
      PT=PT+VCLN(Q(I-1),Q(I))
```

```
      GOTC 2
20    PT=PT+VOLL(Q(I-1),Q(I))
21    I=I+1
      IF(I .GT. NT)     GOTO 30
      IF(Q(I) .LT. 0.)  GOTO 21
      PT=PT+VOLB(Q(I-1),Q(I))
22    I=I+1
      PT=PT+VCLN(Q(I-1),Q(I))
      IF(I .LT. NT)   GOTO 22
C
C        FIND VMAX
30    NTM1=NT-1
      DO 40 I=1,NTM1
4C    V(I)=Q(I)/B/(H(I)+H(I+1))*2.
      V(NT)=Q(NT)/B/(H(NT)+H(1))*2.
      VMAX=0.
      DO 41 I=1,NT
      IF(ABS(V(I)) .LT. VMAX)  GCTO 41
      IH=I
      VMAX=ABS(V(I))
41    CONTINUE
      TIME=IH*DT/3600.
      WRITE(KO,200) PT,VMAX,TIME
200   FORMAT('OPRISM=',E16.7,' CUFT',16X,'VMAX=',F10.4,' FT/SEC',3X,
     1       'AT',F7.2,' HRS FRCM BEGINNING OF CYCLE')
      IF(IH .EQ. NT)  H(NT+1)=H(1)
      RH=B*(H(IH)+H(IH+1))*0.5/(B+H(IH)+H(IH+1))
      FR=VMAX/SQRT(32.2*D)
      FRDS=FR/SQRT(DRO)
      WRITE(KC,202) FRDS,FRESH
202   FORMAT(' DENSIMETRIC FROUDE NO.=',F10.6,10X,
     1       'SUM OF QF''S=',F10.3,' CU.FT/SEC')
      T=NT*DT
      ESNC= PT*FR*FR/FRESH/T/DRO
C        CORRELATION FOR K/(UL)=F(ESNO)
      EEZ=VMAX*XL*XNCPT  *(ESNC**(-.25))
```

```
      WRITE(KC,203) ESNO,EEZ
  203 FORMAT(' DENSIMETRIC ESTUARY NO.=',F9.3,10X,'K FOR THE NEXT',
     1       ' CYCLE IS',F10.2,' SQFT/SEC')
      RETURN
      END
```

```
      SUBROUTINE SPEW(KEY,IL)                                           SPEW   1
C        ARGUMENT 'KEY' IS 1 FOR H, 2 FOR S, 3 FOR Q, AND 4 FOR HWS     SPEW   2
C        ARGUMENT 'IL' IS 1 FOR FINAL CONDITION OUTPUT                  SPEW   3
C                         2 FOR NORMAL OUTPUT                           SPEW   4
C                         3 FOR HWS                                     SPEW   5
C                         4 FOR I.C.                                    SPEW   6
      INTEGER CASE                                                      SPEW   7
      REAL  FC(200), BB(200),  D(200), SS(200),  B(200),MANCO(200)      SPEW   8
      REAL  ZZ(200),  R(200),  C(200), D4(200),  W(200)                 SPEW   9
      REAL  BS(200),  E(200),H(2,200),S(2,200),Q(2,200)                 SPEW  10
      REAL HOA(900),QOB(900)                                            SPEW  11
      DIMENSION HWS(100),ZO(200),DUM(200),IHWS(100),KNO(200)            SPEW  12
      COMMON KO,KIN,KKK,JJJ                                             SPEW  13
      COMMON NOS,CASE,DELT,DELX,NMAX,NMAXH,JMAX,JMAXH,JJTEM,JMAXQ       SPEW  14
        COMMON D1,D2,D3,EH,EZ,EXLM,SZERO,ES                             SPEW  15
        COMMON MH,MS,ISW0,ISW1,ISW2,ISW3,ISW4,ISW5,ISW6,ISW7            SPEW  16
      COMMON H,Q,HOA,QOB,FC,BB,D,SS,B,ZZ,R,MANCO,C,D4,W,BS,S,E          SPEW  17
      COMMON /EXLIM/ JLIM,J2LIM,K,M                                     SPEW  18
      COMMON/SL/SLD,ZO                                                  SPEW  19
      COMMON /OUTP/ NC,NN,HWS,NTCT,IHWS                                 SPEW  20
      DATA INIT/1/                                                      SPEW  21
C                                                                       SPEW  22
C        NUMBER SEQUENTIAL ARRAY                                        SPEW  23
      GOTO(1000,2000),INIT                                              SPEW  24
1000  DO 1001 J=1,200                                                   SPEW  25
1001  KNO(J)=J                                                          SPEW  26
      INIT=2                                                            SPEW  27
      T=(NMAX-1)*DELT/3600.                                             SPEW  28
      TFAC=T/(NMAX-1)                                                   SPEW  29
C                                                                       SPEW  30
C        SET UP THE 'FROM WHENCE' CONDITIONS                            SPEW  31
2000  GOTO(2001,2002,2003,2004),IL                                      SPEW  32
C        FROM MAIN,  OUTPUT FINAL CONDITIONS                            SPEW  33
2001  NP=1                                                              SPEW  34
      IT=M                                                              SPEW  35
      NTC=NTCT                                                          SPEW  36
```

```
      GOTO 2005
C        FROM MARCH,  NORMAL OUTPUT
2002  NP=NN
      IT=K
      NTC=NC
      GOTO 2005
C        FROM MARCH, HWS
2003  NP=1
      NTC=NC
      GOTO 2005
C        FROM OSIN,  I.C. READ IN
2004  NP=1
      NTC=1
      IT=1
      J2LIM=JMAXH
C
C
2005  ISTOP=1
C        TIME CALCULATION
      IF(KEY .EQ. 3)   NP=NP+1
      CYHR=(NP-1)*TFAC
      DAY=((NTC-1)*T+CYHR)/24.
      IDAY=DAY
      DAYHR=(DAY-IDAY)*24.
      WRITE(KC,200) NTC,CYHR,IDAY,DAYHR
200   FORMAT('OTIDAL CYCLE',I4,2X,F7.3,' HOURS',5X,'DAY',I4,2X,
     1       F7.3,' HOURS')
      GOTO(1,2,3,4),KEY
C        H-  ELEVATION  WRT  MSL
1     WRITE(KC,201)
201   FORMAT('+',T65,'INSTANTANEOUS SURFACE ELEVATION WITH RESPECT TO ',
     1       'MSL, FT')
      JM=JMAXH
      IF(IL .NE. 2)   GOTO 70
      DO 10 J=1,JMAXH,2
10    DUM(J)=H(IT,J)-SLD+ZO(J)+D(J)
```

```
      GOTO 70
12    WRITE(KO,202) (KNC(J),J=NS,NF,2)
202   FORMAT(' STATICNS',I5,13I8)
      IF(IL .EQ. 2)  GOTO 1212
      WRITE(KC,203) (H(IT,J),J=NS,NF,2)
203   FORMAT(' ELEV.    ',14F8.3)
      GOTC 80
1212  WRITE(KO,203) (DUM(J),J=NS,NF,2)
      GOTO 80
C        S-  SALINITY
2     WRITE(KC,220)
220   FORMAT('+',T65,'INSTANTANEOUS SALINITIES IN PPT')
      JM=J2LIM
      GOTO 70
21    WRITE(KO,202) (KNC(J),J=NS,NF,2)
      WRITE(KO,207) (S(IT,J),J=NS,NF,2)
207   FORMAT(' SALINITY',14F8.3)
      GOTC 80
C        Q-       DISCHARGE
3     WRITE(KC,230)
230   FORMAT('+',T65,'INSTANTANEOUS DISCHARGES IN CFS')
      NS=2
      NF=20
33    IF(NF .LT. JMAX)  GOTO 31
      ISTOP=2
      NF=JMAX
31    WRITE(KO,205) (KNC(J),J=NS,NF,2)
205   FORMAT(' STATIONS',2X,I5,9I10)
      WRITE(KC,204) (Q(IT,J),J=NS,NF,2)
204   FORMAT(' DISCHARGE ',10F10.0)
      IF(ISTOP .EQ. 2)  RETURN
      NS=NF+2
      NF=NS+18
      GOTO 33
C        S-  HWS
4     WRITE(KC,240)
```

```
240   FORMAT('+',T65,'HIGH WATER SLACK SALINITIES IN PPT')              SPEW 109
      JM=J2LIM                                                          SPEW 110
C        GET TIME OF HWS IN HOURS FROM BEGINNING OF CYCLE               SPEW 111
C        AND SET THE CODE IN CASE SOME HWS NOT DEFINED                  SPEW 112
      ICODE=0                                                           SPEW 113
      DO 42 J=1,JLIM                                                    SPEW 114
      IF(IHWS(J) .NE. 999)   GOTO 45                                    SPEW 115
      DUM(J)=999.                                                       SPEW 116
      HWS(J)=999.                                                       SPEW 117
C        THIS WILL CAUSE 999. TO PRINT ON OUTPUT                        SPEW 118
C        SET THE CODE                                                   SPEW 119
      ICODE=1                                                           SPEW 120
      GOTO 42                                                           SPEW 121
45    DUM(J)=(IHWS(J)-1)*TFAC                                           SPEW 122
42    CONTINUE                                                          SPEW 123
      IF(ICODE .EQ. 1)  WRITE(KO,242)                                   SPEW 124
242   FORMAT(' 999. INDICATES     THAT NO HWS WAS FOUND FOR THAT STATIONSPEW 125
     1 ')                                                               SPEW 126
      GOTO 70                                                           SPEW 127
41    WRITE(KO,202) (KNC(J),J=NS,NF,2)                                  SPEW 128
C        AS HWS IS STORED COMPACTLY,  REFORMULATE INICES                SPEW 129
      NS1=(NS+1)/2                                                      SPEW 130
      NF1=(NF+1)/2                                                      SPEW 131
      WRITE(KO,243) (DUM(J),J=NS1,NF1)                                  SPEW 132
243   FORMAT(' TIME HRS',14F8.3)                                        SPEW 133
      WRITE(KO,207) (HWS(J),J=NS1,NF1)                                  SPEW 134
      GOTO 80                                                           SPEW 135
C                                                                       SPEW 136
C        GET INDICES                                                    SPEW 137
70    NS=1                                                              SPEW 138
      NF=27                                                             SPEW 139
75    IF(NF .LT. JM)   GOTO(12,21,55,41),KEY                            SPEW 140
      NF=JM                                                             SPEW 141
      ISTOP=2                                                           SPEW 142
      GOTO(12,21,55,41),KEY                                             SPEW 143
80    IF(ISTOP .EQ. 2) RETURN                                           SPEW 144
```

```
      NS=NF+2
      NF=NS+26
      GOTO 75
 55   WRITE(KO,255)
 255  FORMAT(' PROG. ERR. IN SPEW')
      CALL EXIT
      END
```

```
      SUBROUTINE ERRL(KEY)
      COMMON KO
C
C        THIS IS AN ERROR HANDLING ROUTINE, IT ISSUES MESSAGES TO HELP
C        THE USER IDENTIFY THE CAUSE OF INPUT AND OTHER ERRORS
      DATA JINX/0/
      IF(KEY .EQ. 8)    GOTO 8
      WRITE(KO,200)
200   FORMAT('0 *** SALINITY INTRUSION PROGRAM ERROR ***')
      IF((KEY .LT. 1) .OR. (KEY .GT. 10))       GOTO 60
       GOTO(1,2,3,4,5,6,7,8,9,10),KEY
1     WRITE(KO,201)
201   FORMAT(' NUMBER OF SECTIONS MUST BE EVEN')
      GOTO 500
2     WRITE(KO,202)
202   FORMAT(' NUMBER OF TIME INTERVALS MUST BE EVEN')
      GOTO 500
3     WRITE(KO,203)
203   FORMAT(' CASE IS NOT 1 THRU 5')
      GOTO 555
4     WRITE(KO,204)
204   FORMAT(' NEGATIVE INTRUSION LENGTH IN INPUT')
      GOTO 555
5     WRITE(KO,205)
205   FORMAT(' COLUMN 1  DOES NOT CONTAIN H,Q OR S')
      GOTO 500
6     WRITE(KO,206)
206   FORMAT(' SEQUENCING ERROR IN INPUT STREAM')
      GOTO 555
7     WRITE(KO,207)
207   FORMAT(' INTERVAL FOR OUTPUT MUST BE EVEN',/)
C
C        CHECK FOR INPUT ERRORS
8     IF(JINX .NE. 0) GOTO 80
      WRITE(KO,208)
208   FORMAT('1 CALCULATION BEGINS',/)
```

```
      RETURN                                                          ERRL  37
8C    WRITE(KO,2C80) JINX                                             ERRL  38
2C80   FORMAT('0',I3,' INPUT ERRCRS DETECTED, CALCULATION ABORTED',/)  ERRL  39
      CALL EXIT                                                       ERRL  40
9     WRITE(KO,209)                                                   ERRL  41
209   FORMAT(' WATER SURFACE BELOW THE BOTTOM WHICH INDICATES A ',    ERRL  42
     1       'PROBABLE NUMERICAL INSTABILITY.',/,' THE REMEDY MAY WELL',ERRL  43
     2       ' BE A SMALLER DELTA-T')                                 ERRL  44
      GOTO 555                                                        ERRL  45
10    WRITE(KC,210)                                                   ERRL  46
210   FORMAT(' THE WATER SURFACE IN TFE STORAGE AREA HAS FALLEN BELOW', ERRL  47
     1       ' THE BOTTOM.  THIS IS NOT NECESSARILY AN INSTABILITY,',/, ERRL  48
     2       ' BUT IS PROBABLY A PROBLEM IN SCHEMATIZATION')          ERRL  49
      GOTO 555                                                        ERRL  50
6C    WRITE(KC,298) KEY                                               ERRL  51
298   FORMAT(' ERROR CODE UNRECOGIZED, IT IS',I10)                    ERRL  52
      GOTO 555                                                        ERRL  53
555   WRITE(KC,299)                                                   ERRL  54
299   FORMAT('0 FATAL ERROR, EXIT TAKEN',/)                           ERRL  55
      CALL EXIT                                                       ERRL  56
5C0   JINX=JINX+1                                                     ERRL  57
      RETURN                                                          ERRL  58
      END                                                             ERRL  59
```

```
      SUBROUTINE SEQTST(J,ISEQ)
C        TEST SEQUENCING
      ITST1=ISEQ-J
      IF(J .EQ. 1) ITEST=ITST1
      IF(ITEST .NE. ITST1)   CALL ERRL(6)
      RETURN
      END
```

# Appendix II

## Brief Description of Formats Used in Input

Fields are of three types: characters, integers and numbers with decimal points. A field is always given a width. Field specifications can be repeated n times by placing n in front of the field specification. For example 20A4 repeats a character field (A) of field width 4 a total of 20 times. This means effectively that all 80 columns (20 x 4) of the card are available for character information. The formats used here are:

Aw - a character field of width "w"

Iw - an integer field of width "w"

Fw.d - a decimal number field of width "w" and with a decimal point and "d" digits after the decimal point

nX - a spacing between fields of "n" columns

(There is one Ew.d format, but it will not be discussed.)

The integer specification contains the restraint that the number punched must be located all the way to the right of the field. This is called "right justified". For example the number 7 in a field of I5 must be punched in the 5th column. (The machine takes blank columns as zeros.)

The decimal specification requires a decimal point, but the location of the number within the field is completely up to the user as long as the decimal point is included.

As a final example the format 2F10.d, I5,5X, F10.d would require the first two fields to be decimal numbers of 10 columns each, then a 5 column field for an integer number, then skip 5 columns and finally a last decimal field of 10 columns.

# Appendix III

## A Plotting Program Using a CALCOMP Plotter

### III.1 Introduction

As the results produced by the computer program are essentially a time series of elevations, $\eta$, salinities, S, and discharges Q at each station the presentation of results in graphical form is an obvious advantage. The CALCOMP plotter is especially well suited for such an application because it is widely available and because it is a drum plotter permitting an abscissa of great length.

The plotting program is written in FORTRAN IV and utilizes the CALCOMP subroutines described fully in Ref. 4.

The subroutines used are modifications of those described in Ref. 5, however the modifications are minor. Most data processing installations with CALCOMP plotter facilities have made some modifications to the basic subroutines and the user is advised to consult the programming staff of his particular installation for assistance in rendering the plotting program compatible.

### III.2 Instructions for Use of the Plotting Program

The user must have specified the KEEP option in card E1 of the Salinity Intrusion Program, thereby generating a sequential data set such as a magnetic tape file which will serve as the source of data for the plotting program.

The user can plot any number of frames, each frame will consist of up to 8 curves of one variable, $\eta$, S or Q and any number of individual points corresponding to each curve.

The input data and its formats are described as follows:

| Card | Description | Format |
|---|---|---|
| 1 | The number of frames, right justified | I5 |
| | For each frame: | |
| A1 | Field 1: (right justified) Number of Sections (even) | I5 |
| | Field 2: Total Length in Feet | F10.d |
| A2 | Field 1: (right justified) Number of Time Intervals | I5 |
| | per Cycle (even). Field 2: Tidal Period in Seconds | F10.d |
| A3 | Field 1: Number of Tidal Cycles Being Plotted. | I5 |
| | Field 2: Plot Length in Inches | F10.d |
| A4 | Field 1: Maximum Ordinate ($\eta$, S or Q) | F10.d |

| Card | Description | Format |
|---|---|---|
| | Field 2: Plot height in inches which corresponds to the maximum ordinate | F10.d |
| A5 | Field 1: The letter H, S, or Q which determines the variable to be plotted (Elevation = H, Salinity = S, and Discharge = Q.) | A1 |
| | Field 2: Number of Stations to be Plotted | I4 |
| | Field 3: Place a number in Column 10 if points are to be plotted from card input. If left blank just the curves are plotted. | I5 |
| A6 | Fields 1 through 8: In each field starting from the left, punch the location of the station(s) to be plotted (feet from estuary entrance). | 8F10.d |
| | If points are to be plotted as well as the curves, then supply points corresponding to <u>each</u> curve as follows: | |
| B1 | Field 1: Number of Points of a Particular Symbol | I5 |
| | Field 2: Symbol Code Described in Figure III.1. | I5 |
| | For each point a card: | |
| C1,2 etc. | Field 1: Time of observation in days, assuming that the 1.0 days means 1200 hrs. from the beginning of the first tidal cycle | F10.d |
| | Field 2: Value of the observation | F10.d |

An example of such a plot is given by the following listing which is of the FORTRAN program and input deck. The resulting plot is shown in Figure III.2.

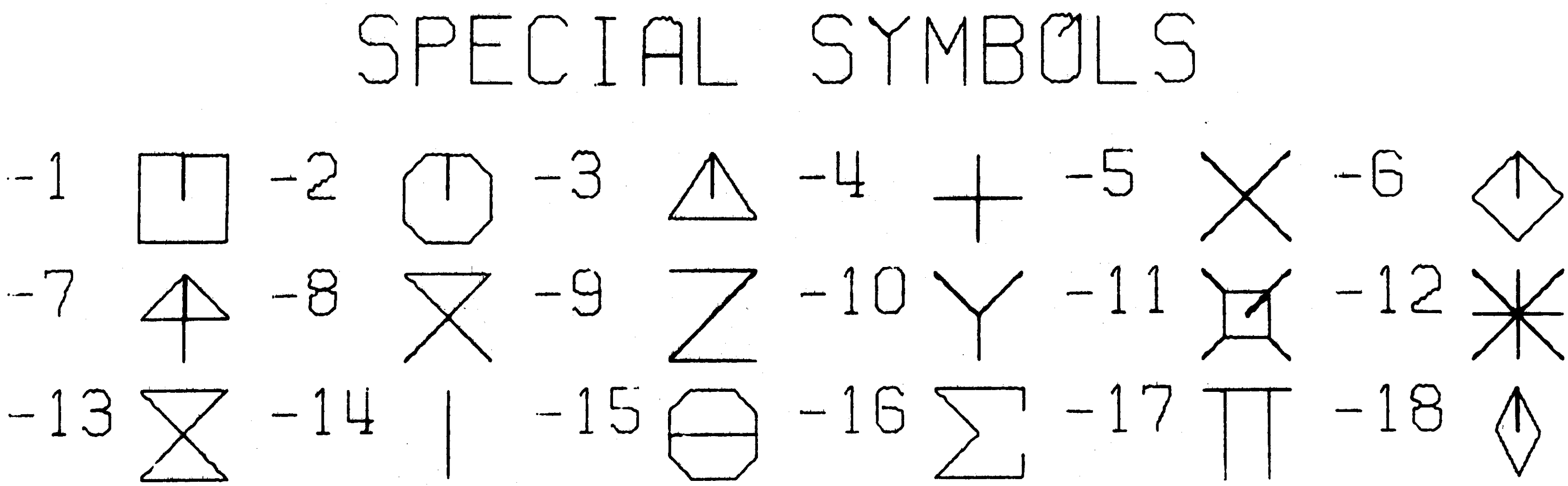


Figure III.1 Symbol Codes for M.I.T. Calcomp Subroutines

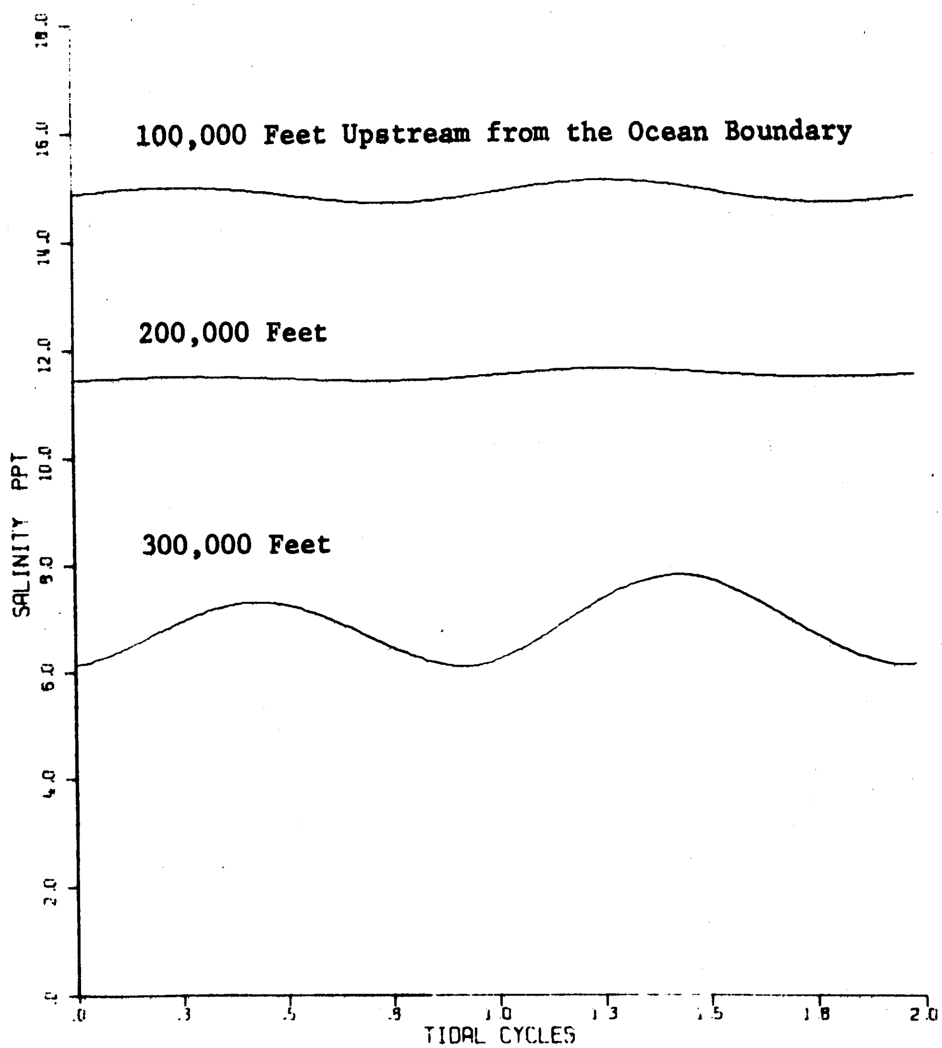


**Figure III.2 Typical Plot**

```
C
C
C       A PLOT LENGTH OF ABOUT 25 INCHES AT 50 PTS./INCH IS DIMENSIONED
C       IN THE MATRIX 'SAVE'
      REAL F(8),HSQ(100),Z(100),SAVE(8,1250),XO(1250)
      REAL ST(8),YLABEL(4),DLAB(3,4)
      INTEGER KID(3),NS(8)
      DIMENSION            UGDS(100),VGDS(100)
      DATA DLAB/'ELEV','SALI','DISC','ATIO','NITY','HARG',
     1     'N  F','  PP','E  C','T   ','T   ','FS  '/
      DATA KID/'H','S','Q'/,KIN,KO,KU/5,6,1/
C       SET PLOT DENSITY IN DATA STATEMENT, IN POINTS PER INCH
      DATA SDEN/50./
C       DEFINE VARIABLE KPROG =3, FOR H,S,Q, OR =2 FOR H AND Q ONLY
      DATA KPROG/3/,IODD/2/
C
C       READ THE NUMBER OF FRAMES
      CALL NEWPLT('M8238','C910','WHITE ','BLACK')
      READ(KIN,100) NOPLT
      DO 55 IPLCT=1,NOPLT
C
      READ(KIN,100) NX2,XLT,NT2,T,NTC,PL
100   FORMAT(I5,F10.0)
      NX=NX2/2
      XX=2.*XLT/(NX2-1)
      IF(2*NX .EQ. NX2)      GOTO 311
C       CASE WITH ODD NUMBERED STATIONS AS UPSTREAM END BC BY ELEVATION
      IODD=1
      NX=NX+1
311   NT=NT2/2
      IF(2*NT .NE. NT2)    GOTO 552
      READ(KIN,102) SCL,YL
      READ(KIN,101) ID,NSTA,IPCINT
101   FORMAT(A1,I4,I5)
      READ(KIN,102) (ST(I),I=1,NSTA)
102   FORMAT(8F10.0)
```

```
      NNN=NT*NTC
      DO 1 I=1,3
      IF(KID(I) .NE. ID)  GOTO 1
      IN=I
      GOTO 2
1     CONTINUE
      WRITE(KO,200)
200   FORMAT(' INPUT ERROR')
      CALL EXIT
C
C
C        PRINT BACK ON INPUT
2     WRITE(KO,300) NTC,PL,YL
300   FORMAT('1',T7,'CALCOMP  PLOTTING  FOR',I5,'  TIDAL CYCLES',/,
     1       T3,'PLOT LENGTH =',F5.1,' INCHES  HEIGHT =',F5.2,' INCHES')
      WRITE(KO,301) NT2,NX2,SCL,XX
301   FORMAT('0',I6,' TIME INCR. PER CYCLE',I6,' DISTANCE STATIONS',
     1       /,T4,'MAX. ORDINATE =',F11.1,/,T4,
     2       'DISTANCE BETWEEN STATIONS =',F8.0,' FEET',//
     3       ,T6,'LOCATION',T19,'DISTANCE',/,T7,'NUMBER',T20,'(FEET)')
      WRITE(KO,304) (DLAB(IN,J),J=1,4)
304   FORMAT('0PLOT OF ',4A4)
      DO 20 I=1,NSTA
      WRITE(KO,302) I,ST(I)
302   FORMAT(T9,I3,T19,F8.0)
C
C       FOR 'C' SHIFT ALIGNMENT DELTA-X/2
      IF(IN .NE. KPROG)   GOTO 20
      ST(I)=ST(I)-XX/2.
20    CONTINUE
C
C        CALCULATE SAMPLING INTERVAL 'IR'
      NOPTS=NTC*NT
      DEN=NOPTS/PL
      IR=1
      IF(DEN .GT. SDEN)     IR=DEN/SDEN
```

```
      WRITE(KC,303) IR
303   FORMAT('0 SAMPLING EVERY',I4,' POINTS')
C        FIND LAND SIDE OF INCR. FOR EACH STATION
      DO 6 I=1,NSTA
      DO 7 J=1,NX
      IF(ST(I) .EQ. 0.)  GOTO 8
      IF(XX*(J-1) .GE. ST(I))    GOTO 8
      GOTO 7
8     NS(I)=J
      IF(J .EQ. 1)    NS(I)=J+1
      JM2=NS(I)-2
      F(I)=(ST(I)-XX* JM2 )/XX
      GOTO 6
7     CONTINUE
      WRITE(KC,700)
700   FORMAT('0 STATION OUT OF RANGE')
      CALL EXIT
6     CONTINUE
C
C        SET YMIN AND Y-LABEL
      DO 3 I=1,4
3     YLABEL(I)=DLAB(IN,I)
      GOTO (4,5,4),IN
4     YMIN=-SCL
      DY=2.*SCL/YL
      GOTO 9
5     YMIN=0.
      DY=SCL/YL
C        THE INCREMENT IS IN TIDAL CYCLES
9     XINCR=1./NT*IR
      DX=NTC/PL
      XMAX=NTC
      NDX=1
      NDY=1
      KXY=0
C
```

```
C          ADJUST FILE LOCATION IF CASE IS FOR H QND Q ONLY
      IF((KPROG .EQ. 2) .AND. (IN .EQ. 3))       IN=2
C
C     BEGIN PLOTTING
      CALL AXIS1(0.,0.,'TIDAL CYCLES',12,PL,0.,0.,DX,NDX,KXY,1.)
      CALL AXIS1(0.,0.,YLABEL,16,YL,90.,YMIN,DY,NDY,KXY,1.)
      CALL PLOT1(0.,0.,3)
C
      X=0.
      IOUT=0
      IC=1
C          LOOP BY TIDAL CYCLE
      DO 5000 ITC=1,NTC
C          LOOP BY TIME INCREMENTS
      DO 1000 I=1,NT
      DO 11 N=1,KPROG
      LRECL=NX
      IF(IODD .EQ. 1 .AND. N .EQ. KPROG)   LRECL=NX-1
      READ(KU) (HSQ(J),J=1,LRECL)
      IF(N .NE. IN)      GOTO 11
      DO 1100 J=1,NX
1100  Z(J)=HSQ(J)
11    CONTINUE
      IF(IC .NE. 1)          GOTO 30
      IOUT=IOUT+1
      IF(IOUT .LE. 1250)    GOTO 24
      WRITE(KO,224)
224   FORMAT('0 TO MANY POINTS. SEE PROGRAM TO CHANGE DIMENSION OF ',
     1          '''SAVE''', AND THIS TEST')
      GOTO 555
C            BY STATION
24    DO 25 M=1,NSTA
      MU=NS(M)
      ML=MU-1
      Y= Z(ML)+F(M)*(Z(MU)-Z(ML))
      IF( M .GT. 1)     GOTO 25
```

```
      XO(ICUT)=X
      IF( X .GT. XMAX)      GOTO 50
      X=X+XINCR
25    SAVE(M,IOUT)=Y
      IF(ABS(Y) .GT. SCL)      GOTO 50
30    IC=IC+1
      IF(IC .GT. IR)      IC=1
1000  CONTINUE
5000  CONTINUE
      DO 12 M=1,NSTA
      WRITE(KC,2001) M,ST(M)
2001  FORMAT('1STATION NO.',I5,' AT',F10.0,' FEET',//)
      WRITE(KC,2002) (XO(J),SAVE(M,J),J=1,IOUT)
2002  FORMAT(F7.3,F12.3,F7.3,F12.3,F7.3,F12.3,F7.3,F12.3,F7.3,F12.3,
     1       F7.3,F12.3)
      DO 23 I=1,IOUT
23    CALL PLOT1(XO(I)/DX,(SAVE(M,I)-YMIN)/DY,2)
      IF(IPOINT .EQ. 0)  GOTO 12
C
C        READ IN THE NO. OF POINTS AND PLOT CODE
C        IF CURVE HAS NO POINTS THEN ENTER ZERO (0)
      READ(KIN,103) NPT,NCODE
103   FORMAT(2I5)
      WRITE(KC,221) T,NPT
221   FORMAT(//,' PERIOD=',F8.0,' SEC',I5,' POINTS')
      IF( NPT .EQ. 0)    GOTO 12
      IF( NCODE .EQ. 0)    NCODE =-12
      DO 1002 J=1,NPT
      READ(KIN,102) XX,Y
C
C        CONVERT THE DAY NUMBER TO TIDAL CYCLES, CENTERING THE
C        DAILY OBSERVATION AT 1200 HRS,  AND ASSUMING THAT T=0
C        IS AT 0000 HRS OF THE FIRST DAY.
      X=((XX-1.)*86400.++43200.)/T
      WRITE(KC,222) X,XX,Y
222   FORMAT(5X,F7.1,2F7.2)
```

```
      UGDS(J)=X/DX
1002  VGDS(J)=(Y-YMIN)/DY
      CALL GRAPH(UGDS,VGDS,-NPT,0.14,NCODE)
12    CALL PLOT1(0.,0.,3)
      REWIND KU
      CALL PLOT1(PL+3.,0.,-3)
55    WRITE(KC,201)
201   FORMAT('0 PLOTTED')
      CALL ENDPLT
      GOTO 555
552   WRITE(KC,2552)
2552  FORMAT('0NO. TIME INTERVALS NOT EVEN')
      GOTO 555
50    WRITE(KO,501)M,I,Y,X
501   FORMAT(' LOC',I3,' T INCR.',I10,' Y=',E16.6,' X=',E16.6,/,
     1       ' X  OR  Y   OUT OF RANGE,  EXIT TAKEN')
555   CALL EXIT
      END
```

```
   1
  40 603768.
 120 44640.
   2  8.
 18.       9.
S   3
100000.   200000.   300000.
```