Numerical Simulation of the Effects of Sea Level Rise on Estuarine Processes

by

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(ABSTRACT)

The increasing concentration of carbon monoxide and other gases in the earth's atmosphere is expected to cause temperatures on earth to increase. This condition, known as the greenhouse effect, could cause the sea level to rise due to the partial melting of the polar icecaps and the thermal expansion of the oceans. Such a rise in the sea level would affect the tides, currents, and sediment and salinity distributions within estuaries.

To see the nature of these effects, a parametric study was performed on the Rappahannock River in Virginia with a two-dimensional, laterally averaged, time-dependent numerical model which simulates the movement of water and suspended sediment in the estuary. The model is a systematic sequence of mathematical procedures derived from the mass-balance equation and the equation of motion. These equations are solved through an explicit finite difference scheme.

The astronomical tide, the increased height of the sea level due to the greenhouse effect and the additional tidal height due to a storm surge form the boundary conditions at the mouth of the river. Freshwater streamflows constitute the boundary condition at the upstream end of the estuary. A frequency analysis is performed for both the freshwater streamflows and the tidal heights. A procedure is developed which allows one to calculate the return period for various combinations of streamflow and tidal height.

The results from each run of the estuary model are reviewed to study the tidal hydraulics and the longitudinal and vertical distributions of the sediment and salinity with and without the sea level rise.

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Finally, special thanks must go to my parents. It is true that they may have been skeptical of my desire to attend graduate school, but they supported my decision nevertheless. I will always appreciate their understanding and tremendous patience.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Scientists are coming to the consensus that the sea level is rising. While predictions for this rise vary, even small increases can severely affect coastal areas. One ecosystem which will be affected is the estuary, the region where freshwater from a river meets the saline seawater. This freshwater/saltwater boundary provides a unique environment for many organisms. While the ecological changes which accompany a higher sea level could be adverse to the environment and these organisms, local economies could also be hurt since some of these organisms are commercially valuable. The scope of this study investigates how the distribution of suspended sediment and salinity throughout the Rappahannock River estuary is altered by the rising sea level. This might provide biologists some guidance for their assessment of the possible responses by the estuary's organisms. First, though, it might be helpful to review the causes and projected magnitude of the sea level rise. With this background, the effects of sea level rise on the estuarine environment will be discussed.

1.2 THE GREENHOUSE EFFECT AND SEA LEVEL RISE

The growing industrialization in the twentieth century has greatly increased the concentration of carbon dioxide and other gases in the earth's atmosphere. This layer of gases forms a blanket through which sunlight may enter to warm the earth, but the infrared radiation reflected by the warmed earth is trapped by these gases in the atmosphere. With the buildup of this trapped heat, the temperature of the earth's atmosphere is expected to rise. Since this process occurs much like the warming of a greenhouse, it is commonly called the "greenhouse effect" (Hull and Titus, 1986).

Although considered a bad thing, the greenhouse effect occurs naturally, and without it, the earth would be approximately 60°F(33°C) cooler (Hull and Titus, 1986). The problem is that the concentration of these gases is growing very rapidly, and it is feared that this will cause an unnatural warming of the earth. These rising concentrations can be traced to many sources such as the burning of fossil fuels, deforestation and the use of aerosol sprays. Since 1958, the concentration of carbon dioxide has risen by eight percent (Keeling, Bacastow and Whorf, 1982). Carbon dioxide is not the only gas concerned. Concentrations of methane, nitrous oxide, chlorofluorocarbons and other trace gases are also increasing, and it is estimated that they will contribute as much to the earth's warming as the carbon dioxide alone (Lacis *et al.*, 1981; Ramanthan *et al.*, 1985).

One significant result of the greenhouse effect will be the increasing height of the global sea level. This is due to the resulting warmer temperatures which will cause snow and ice melt from mountains and polar glaciers, ice discharges from the ice sheets in Greenland, West Antarctica and East Antarctica, and the thermal expansion of the oceans. Some scientists dispute the contribution due to the melting of the icecaps. They reason that the redistribution of this water would increase the earth's moment of inertia. To maintain the same angular momentum, the earth's rotation must slow down. Although the length of the days are increasing, this increase is not as great as expected given the amount of sea level rise which has already occurred (Barnett, 1983).

While questions still remain over the cause of the sea level rise, records for the last century show the trend of increasing sea level is occurring. In the last one hundred years, the sea level along the Atlantic Coast has risen one foot (30 cm), and studies have calculated that the average worldwide sea level has risen four to six inches (10-15 cm) (Hickes, Debaugh and Hickman, 1983; Gornitz *et al.*, 1982).

Projections of future sea levels vary markedly depending on the assumptions made by the researcher. First, one must estimate the future concentrations of carbon dioxide and the other gases which create the greenhouse effect. From this, a predicted increase in the earth's temperature might be calculated. Next, a determination is made of the magnitude of the effect this increased temperature will have on the melting of the icecaps and the thermal expansion of the oceans. Complicating these predictions is the fact that the increased temperatures on earth will create climatic changes which may counteract the rise of the sea level. It is felt, though, that these climatic changes will not be sufficient to stop the sea level from rising.

By reviewing the pertinent literature, Hoffman, Keyes and Titus (1983) came up with low, medium and high estimates of future sea levels. The low estimate, the most optimistic one is for a rise of five inches (13cm) by 2025 and fifteen inches (38 cm) by 2075. The high estimate, or worst case scenario, calls for a two foot (55 cm) sea level rise by 2025 and an increase of seven feet (211 cm) by 2075. The mid-range predictions are for an eleven to fifteen inch (26-39 cm) rise by 2025 and an increase of three to four and one-half feet (91-136 cm) by 2075. All of these estimates are for increases above the sea level as of 1980.

1.3 THE EFFECTS OF SEA LEVEL RISE ON THE ESTUARINE ENVIRONMENT

For engineers, the problems associated with sea level rise should become apparent. With flat terrains, small hydraulic heads, and tidal effects, drainage in coastal areas through gravity storm sewers and channels is already difficult (Kuo, 1984, 1986; Titus *et al.*, 1987). Heightening the sea level only exacerbates these difficulties. Further effects include flooding of marshes, wetlands and other coastal areas, the deterioration of coastal aquifers due to saltwater intrusion, the alteration of the salinity distribution in estuaries, beach erosion and all of the social, economic and legal problems which accompany these conditions.

Much of the work which has been done concerning sea level rise has concentrated on the speed and magnitude with which the sea level will rise, but this sea level rise poses special problems in estuaries. Due to the mingling of the freshwater and seawater, estuaries provide an environment conducive for the growth of marine plants and animals. The salinity and suspended sediment concentration lies within a range which may be intolerable to marine and freshwater predators. This factor and the physical stresses inflicted by the tides create a harsh environment for those organisms which have not adapted to life in the estuary. The advantages of this situation for the estuarine lifeforms are brought out by the fact that 66 to 90 percent of the fisheries in the United States depend upon estuaries for their life cycle (Douglas and Stroud, 1971). Some of these organisms, such as oysters, have commercial value, so it is important to know what changes would occur with a higher sea level.

Qualitatively, it is known that as the sea level rises saltwater will move further into the estuary. Spawning migrations by many fish species could be changed since the increased salinity would alter the physico-chemical signals which lead the fish into the estuary (de Sylva, 1986). Furthermore, nuisance organisms and predators which require a high-salinity environment would move into the estuary and damage the breeding grounds of the native organisms.

Besides changing conditions in the estuary, the intrusion of saltwater will affect nearby population centers. Many towns and cities have water intakes on these rivers in areas not now threatened by saltwater, but this could change as the sea level rises. Even those communities which get their water from groundwater sources may find those supplies threatened by saltwater in those locations where the river recharges the aquifer. The implications of saltwater intrusion were demonstrated during a severe drought which struck the Delaware River Basin in the 1960's. During the worst period of the drought, the salt front advanced 33 miles up the river and forced some industries near Philadelphia to seek water from a municipal system that imports water from the Susquehanna River Basin (Hull and Titus, 1986).

To quantify the extent of the saltwater intrusion, this parametric study has been made for the Rappahannock River in Virginia. A modified version of the two-dimensional, time-dependent numerical estuary model developed by Kuo, Nichols and Lewis (1978) was used to complete this study. The boundary conditions for the model are the freshwater flows into the estuary and the tidal heights at the mouth of the river. Several inflows and tides of varying return periods are chosen. These inflows and tides are put into different combinations, and each combination is used as the boundary conditions for one model run. Thus, the tidal hydraulics and the vertical and longitudinal distribution of the salinity and sediment for each scenario may be studied. In addition to observing the changes which take place in the estuary, a method for estimating the joint probability of exceedence of a particular streamflow and tidal height occurring simultaneously has been developed. This will allow one to properly match the upstream streamflows with the appropriate downstream tidal height for any joint probability of exceedence.

CHAPTER 2

THE NUMERICAL MODEL OF THE ESTUARINE PROCESSES

2.1 BASIC EQUATIONS

In 1978, Kuo, Nichols and Lewis developed a two-dimensional, time-dependent numerical model which would simulate the movement of water and suspended sediment in an estuary. Within the estuary, the model computes values for four main parameters: tidal height, current, salinity, and suspended sediment concentration. Three basic external forces are entered into the model as boundary conditions: tidal wave propagation, river inflow, and river-borne sediment inflow. The model is time dependent because these parameters and forces interact with one another and are continually changing with time. A complete computer listing of the model is in Appendix C.

In their classification of tidal models, Hinwood and Wallis (1975) state that a two-dimensional model is quite satisfactory for narrow estuaries which have no abrupt changes in cross-section. Since Virginia's estuaries fit this description generally, a two-dimensional approach is taken. This means that the model will simulate the transport processes longitudinally and vertically throughout the estuary. All of the parameters computed by the model will be uniformly distributed laterally across the estuary at their respective transects.

To describe the estuarine processes, six equations are used in the model:

a) the equation of motion for an incompressible but non-homogeneous fluid

$$\frac{\partial u}{\partial t} + \frac{\partial (u^2)}{\partial x} + \frac{\partial (uv)}{\partial y} + \frac{\partial (uw)}{\partial z} =$$

$$- \frac{1}{\rho}\frac{\partial P}{\partial x} + \frac{\partial}{\partial x}\left(e_x \frac{\partial u}{\partial x}\right) + \frac{\partial}{\partial y}\left(e_y \frac{\partial u}{\partial y}\right) + \frac{\partial}{\partial z}\left(e_z \frac{\partial u}{\partial z}\right) \quad (2.1)$$

b) the hydrostatic equation

$$-g = \frac{1}{\rho}\frac{\partial P}{\partial z} \quad (2.2)$$

c) the continuity equation for an incompressible fluid

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0 \quad (2.3)$$

d) the mass-balance equation for salts

$$\frac{\partial s}{\partial t} + \frac{\partial (\mathrm{us})}{\partial x} + \frac{\partial (vs)}{\partial y} + \frac{\partial (ws)}{\partial z} =$$

$$\frac{\partial}{\partial x}\left(\varepsilon_x \frac{\partial s}{\partial x}\right) + \frac{\partial}{\partial y}\left(\varepsilon_y \frac{\partial s}{\partial y}\right) + \frac{\partial}{\partial z}\left(\varepsilon_z \frac{\partial s}{\partial z}\right) \quad (2.4)$$

e) an empirically derived equation of state (Eckart, 1958)

$$(P + P_o)\left(\frac{1}{\rho} - \frac{1}{\rho_o}\right) = \lambda \quad (2.5)$$

f) the mass-balance equation for suspended sediment

$$\frac{\partial c}{\partial t} + \frac{\partial(uc)}{\partial x} + \frac{\partial(vc)}{\partial y} + \frac{\partial((w - V)c)}{\partial z} =$$

$$\frac{\partial}{\partial x}\left(\varepsilon_x \frac{\partial c}{\partial x}\right) + \frac{\partial}{\partial y}\left(\varepsilon_y \frac{\partial c}{\partial y}\right) + \frac{\partial}{\partial z}\left(\varepsilon_z \frac{\partial c}{\partial z}\right) - d + r \qquad (2.6)$$

where

u,v,w = velocity component in the x,y, and z directions, respectively

t = time

P = pressure

ρ = density of water

e_x, e_y, e_z = turbulent eddy viscosities in the x,y, and z directions, respectively

g = gravitational acceleration

s = salinity in parts per thousand

ε_x, ε_y, ε_z = turbulent diffusion coefficients in the x,y, and z directions, respectively

P_o, ρ_o, λ = empirical functions of temperature and salinity

c = suspended sediment concentration

V = sediment settling velocity

d = sediment deposition rate

r = sediment resuspension rate

Figure 1 shows the coordinate system for these equations.

With these equations, the flow field and suspended sediment concentration field may be represented and calculated. The longitudinal momentum equation is represented by Eq. (2.1). Equation (2.2) is the equation of motion in the vertical direction where the dominant force is assumed to be gravity. Equation (2.5) relates the water density with the salinity, temperature, and pressure. Since the effect of pressure on density is negligible for the water depths discussed here, Eq. (2.5) may be simplified:

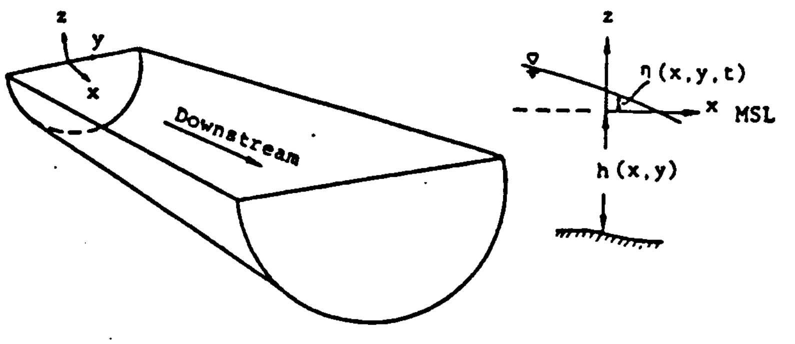

Figure 1. Coordinate system used in the numerical model (from Kuo, Nichols and Lewis, 1978).

$$\rho = \frac{P_0}{\lambda + \frac{P_o}{\rho_o}} \tag{2.7}$$

where

$$\lambda = 1779.5 + 11.25T - 0.0745T^2 - (3.80 + 0.01T)s \tag{2.7a}$$

$$\rho_o = 1.4326 \tag{2.7b}$$

$$P_o = 5890 + 38T - 0.375T^2 + 3s \tag{2.7c}$$

Here, ρ is the density in grams per cubic centimeter, T is the temperature in degrees Celsius, and s is the salinity in parts per thousand. Finally in Eq. (2.6), resuspension and deposition are treated as a source and sink respectively.

As stated previously, all of the parameters are uniformly distributed laterally across the estuary. To incorporate this assumption Eqs. (2.1), (2.3), (2.4) and (2.6) are integrated with respect to the y direction. By going from three to two dimensions, it is assumed that the fluid is laterally homogeneous and that there is no flux of material or momentum through the lateral boundary of the estuary except at those points where tributaries enter.

With Eqs. (2.1), (2.3), (2.4) and (2.6) having been integrated laterally, the resultant equations are then integrated vertically over a horizontal layer. To do this, the estuary will be cut into horizontal slices through which mass and momentum may be exchanged. Figure 2 shows how this grid system is arranged. To locate a variable within this system a longitudinal and vertical subscript are used.

It is assumed that all of the variables are nearly constant throughout the height of each layer and that the momentum and mass fluxes normal to the bottom of the channel and to the free surface are zero. With these assumptions, the vertical integration gives

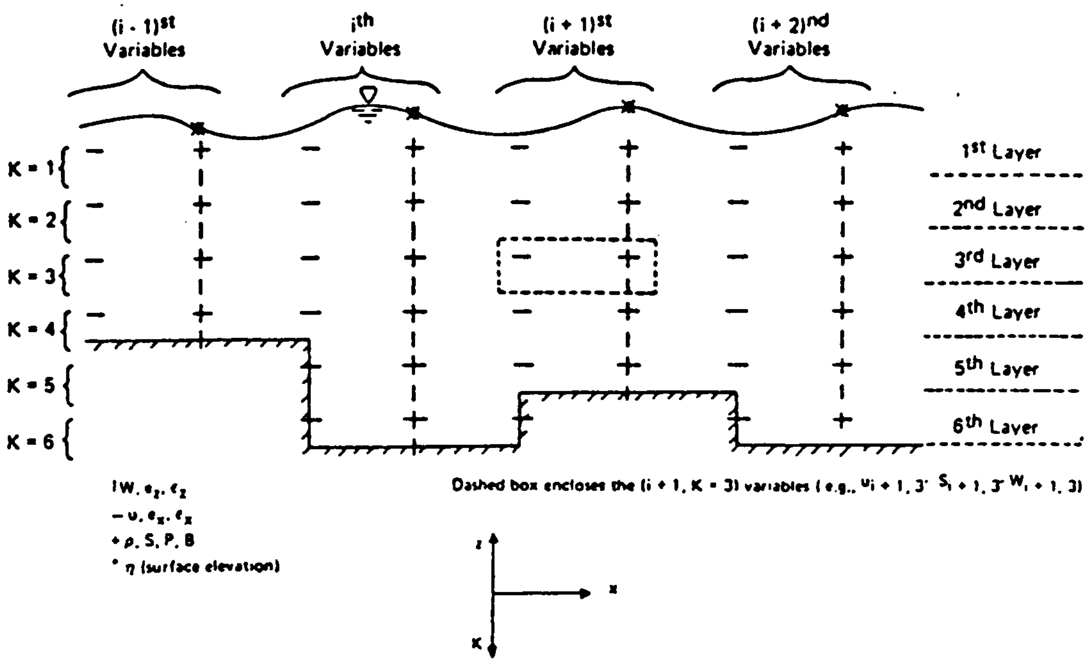

Figure 2. Grid pattern, location and indexing of variables (from Kuo, Nichols and Lewis, 1978).

a) the continuity equation for the top layer

$$\frac{\partial \eta}{\partial t} = \frac{1}{B_1} \left(w_b B_b - \frac{\partial}{\partial x}(u_1 B_1 h_1) + q_1 h_1\right) \tag{2.8}$$

b) the continuity equation for all other layers

$$w_T = \frac{1}{B_T} \left(w_b B_b - \frac{\partial}{\partial x}(u_k B_k h_k) + q_k h_k\right) \tag{2.9}$$

c) the longitudinal equation of motion

$$\frac{\partial}{\partial t} (u_k B_k h_k) + \frac{\partial}{\partial x} (u_k B_k h_k u_k) + w_T u_T B_T - w_b u_b B_b =$$

$$- \frac{B_k h_k}{\rho_k} \left(\frac{\partial P}{\partial x}\right)_k + \frac{\partial}{\partial x} \left(e_{x_k} B_k h_k \left(\frac{\partial u}{\partial x}\right)_k\right) + \tau_T - \tau_b + q_k u_t h_k \tag{2.10}$$

d) the mass-balance equation for salts

$$\frac{\partial}{\partial t}(s_k B_k h_k) + \frac{\partial}{\partial x} (u_k B_k h_k s_k) + w_T s_T B_T - w_b s_b B_b =$$

$$\frac{\partial}{\partial x} \left(\varepsilon_x h \frac{\partial s}{\partial x}\right)_k + \left(\varepsilon_z B \frac{\partial s}{\partial z}\right)_T - \left(\varepsilon_z B \frac{\partial s}{\partial z}\right)_b + q_k s_t h_k \tag{2.11}$$

e) the mass-balance equation for suspended sediment

$$\frac{\partial}{\partial t} (c_k B_k h_k) + \frac{\partial}{\partial x} (u_k B_k h_k c_k) + (w_T - V) c_T B_T - (w_b - V) c_b B_b =$$

$$\frac{\partial}{\partial x} \left(\varepsilon_x h B \frac{\partial c}{\partial x}\right)_k + \left(\varepsilon_z B \frac{\partial c}{\partial z}\right)_T - \left(\varepsilon_z B \frac{\partial c}{\partial z}\right)_b - Bd + Br + q_k c_t h_k \tag{2.12}$$

where

B_k, u_k, h_k, q_k = width, longitudinal velocity, height, and tributary inflow for k th layer, respectively

u_b, w_b, B_b = longitudinal velocity, vertical velocity, and estuary width, respectively, at the bottom of a layer

u_T, w_T, B_T = longitudinal velocity, vertical velocity, and estuary width, respectively, at the top of a layer

$\tau_T = \left(e_z B \frac{\partial u}{\partial z}\right)_T$ and $\tau_b = \left(e_z B \frac{\partial u}{\partial z}\right)_b$ = interfacial shear stresses

The equation of state, Eq. (2.7), is used to evaluate the pressure term in the longitudinal equation of motion, Eq. (2.10). To solve Eq. (2.10), the continuity equations, Eqs. (2.8) and (2.9), and the salt mass-balance equation, Eq. (2.11), are used. This gives a time-varying solution for the longitudinal and vertical velocity field. To find the time-varying concentration field of the suspended sediment, this solution of the velocity field is substituted into Eq. (2.12).

The last equation to be examined is the equation of motion in the vertical direction Eq. (2.2). Using an approximation of this equation gives:

$$\left(\frac{\partial P}{\partial x}\right)_k = \left(\frac{\partial P}{\partial x}\right)_{k-1} + \frac{gh_{k-1}}{2}\frac{\partial \rho_{k-1}}{\partial x} + \frac{gh_k}{2}\frac{\partial \rho_k}{\partial x} \tag{2.13}$$

For the top layer, the equation is written as

$$\left(\frac{\partial P}{\partial x}\right)_1 = \frac{g}{2}(h_1 + \eta)\cdot\frac{\partial \rho_1}{\partial x} + g\rho_1\frac{\partial \eta}{\partial x} \tag{2.14}$$

where η represents the surface elevation with respect to mean sea level.

2.1.1 Mass and Momentum Exchange Coefficients

The relationships between the vertical mass and momentum exchange coefficients and the density stratification of the water column take the form

$$\varepsilon_z = \nu_o \ (1 + \beta \mathrm{Ri})^p \tag{2.15}$$

and

$$e_z = v'_o \ (1 + \mathrm{mRi})^q \tag{2.16}$$

where v_o and v'_o are the values in the homogeneous flow field and β, m, p, and q are constants to be determined empirically (Bowden and Hamilton, 1975). The Richardson number, *Ri*, is defined as

$$\mathrm{Ri} = -\frac{g}{\rho}\frac{\frac{\partial \rho}{\partial z}}{\left(\frac{\partial u}{\partial z}\right)^2} \tag{2.17}$$

The model as developed by Kuo *et al.* (1978) uses an empirical formula for the mass exchange coefficient suggested by Pritchard (1960):

$$\varepsilon_z = (v_o + v_w)(1 + 0.276\mathrm{Ri})^{-2} \tag{2.18}$$

where

$$v_o = \frac{8.59 \times 10^{-3}|u|[z(h' - z)]^2}{h'^3} \tag{2.18a}$$

$$v_w = 9.57 \times 10^{-3}\ \frac{z(h' - z)H}{h'T}\ \exp\left(-\frac{2\pi z}{L}\right) \tag{2.18b}$$

and where

z	=	depth at which ε_z is being calculated
h'	=	total depth of the water
H	=	wave height
T	=	wave period
L	=	wavelength

To solve for the vertical momentum exchange coefficient Eq. (2.16), v'_o and m are assumed to have the same values as v_o and β, respectively. The constant q is taken to be $-\frac{1}{2}$. For the horizontal exchange coefficients, the relationships given by Dyer (1973) were used:

$$e_x = 10^5 \cdot e_z \tag{2.19}$$

$$\varepsilon_x = 10^5 \cdot \varepsilon_z \tag{2.20}$$

2.1.2 Sediment Deposition and Resuspension Rates

In a study by Parthenaides (1962), the resuspension rate is given as

$$r = M\left(\frac{\tau}{\tau_e} - 1\right)$$

if $\tau > \tau_e$ or (2.21)

$$r = 0$$

if $\tau \leq \tau_e$. Before erosion can occur the bed shear stress τ must exceed the critical shear stress τ_e. The resuspension constant M is equal to the rate of erosion at $\tau = 2\ \tau_e$.

For deposition the probability P of a particle depositing itself onto the bed increases linearly from zero to one as the bed shear falls below the critical bed shear stress τ_d (Krone, 1962). This may be written mathematically as

$$P = 1 - \frac{\tau}{\tau_d}$$

if $\tau < \tau_d$ or (2.22)

$$P = 0$$

if $\tau \geq \tau_d$. The deposition rate can by represented by the equation

$$d = Vc(1 - \frac{\tau}{\tau_d}) \tag{2.23}$$

where c is the sediment concentration in the bottom layer, and V is the fall velocity of the sediment.

2.1.3 Settling Velocity

While the downward transport due to settling is affected by turbulent diffusion (Sverdrup *et al.*, 1942), there has not been enough research in this area to define a relationship between the settling velocity and the turbulence. For particles of diameters ≤ 62.5 microns, only Stokes' Law provides a theoretical basis for determining the settling velocities:

$$V = \frac{1}{18\nu} \frac{\rho_s - \rho}{\rho} g D^2 \tag{2.24}$$

The equations for the mass-balance of the suspended sediment (Eq. 2.12) and the rate of sediment deposition (Eq. 2.23) contain the product $V \cdot c$ which represents the vertical sediment fluxes. For one to evaluate these fluxes, the size-dependence of the settling velocity must be taken into account. When this is done, one obtains the equation

$$V \cdot c = K(D_m^2 + \theta^2)c \tag{2.25}$$

where

$$K = \frac{1}{18\nu} \frac{\rho_s - \rho}{\rho} g \tag{2.25a}$$

and D_m is the mean diameter of the particles and θ^2 is the variance of the particle sizes. It is this equation which is used in the mass-balance equation for suspended sediment.

2.2 BOUNDARY CONDITIONS

2.2.1 Boundary Conditions at the Surface and the Bottom of the Estuary

At the bottom of the channel and at the free surface, the vertical velocity is zero. In addition, there may not be any mass flux of salt or suspended sediment across the top or bottom boundaries. Therefore, for the top layer

$$\left(\varepsilon_z \frac{\partial s}{\partial z}\right)_T = 0, \quad \left(\varepsilon_z \frac{\partial c}{\partial z}\right)_T = 0 \tag{2.26}$$

and for the bottom layer

$$\left(\varepsilon_z \frac{\partial s}{\partial z}\right)_b = 0, \quad \left(\varepsilon_z \frac{\partial c}{\partial z}\right)_b = 0 \tag{2.27}$$

Within the estuary, energy may be introduced by wind stresses or dissipated by the frictional forces created by bottom stresses. For the model, these stresses are formulated in the following manner:

$$\text{Wind stress} = C\rho_a W^2 \tag{2.28}$$

In Eq. (2.28), the drag coefficient C is equal to $1.3x10^{-3}$, and the air density ρ_a equals $1.2x10^{-3}$ gm/cm^3. The variable W represents the wind speed at a height of ten meters. As for the bottom stresses

$$\text{Bottom stress} = \rho u_b |u_b| \text{g} n^2 (h_b)^{-1/3} \tag{2.29}$$

In Eq. (2.29), the density, longitudinal velocity component in the bottom layer, thickness of the bottom layer, and the Manning friction coefficient are represented by ρ, u_b, h_b, and n respectively.

2.2.2 Upstream Boundary Conditions

The upstream boundary of the model is located at the landward limit of tidal influence. It is at this point where the velocity and the sediment concentrations are specified:

$$U_{2,k} = Q(t)/A \tag{2.30}$$

$$C_{2,k} = M(t)/Q(t) \tag{2.31}$$

$Q(t)$ and $M(t)$ represent the freshwater and sediment discharge respectively, and A is the cross-sectional area. The subscript 2 signifies that these equations are for transect number two, the most landward cross-section. The salinity at this boundary is set equal to zero for all time.

2.2.3 Downstream Boundary Conditions

The downstream boundary is at the mouth of the river where the tides may be calculated with a harmonic function:

$$\eta_j(t) = \sum_{n=1}^{5} A_n \cos(\theta_n + \sigma_n t) \tag{2.32}$$

Equation (2.32) finds the tidal height η above mean sea level (MSL). Time is represented by t, and j is the number of the most seaward transect. The subscript n identifies each variable with one of five tidal constituents, also called harmonic constants. These harmonic constants are derived from an analysis of tide observations made over a 365 day period. Before the analysis is made, this data is corrected for the influence of astronomical phenomena with longer periods. To predict the tide at the tide observation station, these harmonic constants are substituted into Eq. (2.32). In addition, the mean tide level, tidal range, and other tidal relationships are calculated for the station. Since this standard tide analysis is not based upon periods containing major storm surges, there is no significant error resulting from the actual pattern of the storms during the 365 day period. While NOAA uses 37 constituents to calculate the tides for its tide tables, this model only uses the five major constituents:

- O_1 Main lunar diurnal component.
- K_1 Lunisolar diurnal constituent. This constituent, with O_1, expresses the effect of the Moon's declination. Both account for diurnal inequality and, at extremes, diurnal tides. It is one of the constituents which expresses the effect of the Sun's declination.
- M_2 Principal lunar semidiunal constituent. This constituent represents the rotation of the Earth with respect to the Moon.
- S_2 Principal solar semidiurnal constituent. This constituent represents the rotation of the Earth with respect to the Sun.
- N_2 Lunar elliptic semidiurnal constituent. This constituent modulates the amplitude and frequency of M_2 for the effect of variation in the Moon's orbital speed due to its elliptical orbit.

The subscript on each harmonic constant indicates the approximate number of cycles per tidal day. Each tidal constituent has an associated tidal amplitude A, phase angle θ, and tidal frequency σ. These five constituents give a good approximation of the tides since the other 32 constituents do not add to the accuracy of the predicted tide level by an appreciable amount (Harris, 1981).

2.3 MODIFICATIONS TO THE MODEL

As the model sits now, it will solve problems with a constant rate of streamflow and incoming suspended sediment at the upstream boundary and a time-varying tide at the downstream boundary. The conditions under which the model has been previously used involved near normal flows with normal tidal variations. This study, though, will use the normal flow-normal tide condition as only a base on which to reference later model runs. These other runs will include major flood events, droughts, storm surges and, of course, sea level rise.

Since the cross-sectional data available for the Rappahannock River is for the river under normal conditions, some steps were taken to augment this cross-sectional data to handle the higher river stages that would occur with a flood or storm surge. It will be assumed that at the top of the cross-section the sidebanks slope up and away from the river at the rate of one foot of vertical rise per ten feet horizontally (i.e. 10:1). It is true that this slope was determined rather arbitrarily, but it is a best estimate of the topography of the shoreline. Although the cross-sections cover the length of the estuary, the exact location of each transect was not given, so it was not possible to determine the precise side slope from other sources. It must be stressed that the answers the model gives are not exact, but instead, the model results will give only a better perspective on the magnitude of the problems involved with sea level rise. With this goal in mind, these approximations should be permissible.

2.3.1 The Downstream Boundary

Because the basic issue here is sea level rise, a way was designed so that this adjustment is made in the function statement TIDE. This function is called up by the main program to set the downstream tidal heights. In TIDE, Eq. (2.32) takes the given amplitude, frequency and phase angle of each tidal constituent and generates a periodic tide.

The predictions for the amount of sea level rise refer to coastal areas. For waterways located away from the coast, the magnitude of this rise in the sea level will not be the same. Since the mouth of the Rappahannock River lies inside the Chesapeake Bay, this change in the sea level rise must be taken into account. This matter is handled by inserting the tidal constituents for Hampton Roads at the mouth of the James River into Eq. (2.32). The amount of sea level rise is added onto the tidal height calculated by Eq. (2.32). To find the downstream boundary condition at the mouth of the Rappahannock River, the sum of the tidal height and the sea level rise at Hampton Roads are modified by using the tide conversion factor found in the tide tables published by NOAA. Although Hampton Roads is not on the coast, the tide tables show a tide difference of only 0.3 feet between Hampton Roads and Cape Henry which is on the coast. Given the uncertainty of these sea level rise forecasts, this difference is not considerable, and the sea level rise may be referred to the Hampton Roads tide heights.

Another factor included in TIDE is the storm surge. The return period of the storm surge is determined by the tide frequency analysis to be discussed in Section 3.1. The storm surge computed in this analysis is a combination of the astronomic tide and the tidal surge due to a meteorological event. For now, though, only the manner in which these tide frequencies are used is presented. To begin, a storm surge with a specified return period is chosen. The longest return period considered in this study is 100 years. Since these storm surge values taken from the frequency analysis also include the astronomic tide, it would be improper to simply add the surge atop the tidal height calculated by Eq. (2.32). Instead, the highest astronomic tide over the period of the model run is found. The height of this highest high tide is subtracted from the magnitude of the chosen storm surge. This difference is added onto the value computed by Eq. (2.32) throughout the time of the model run. For example, the 100-year storm surge may be five feet, and the highest high tide through the duration of the model run may be two feet. The increment added to the tide heights calculated by Eq. (2.32) would be the difference, three feet. It should be noted that the highest high tide is found before the sea level rise has been added.

For the Rappahannock River, though, there is a small complication because the tidal constituents at Hampton Roads are used to calculate the tide. These tide heights must be modified with the tide conversion factors in the tide tables. Having made this modification, the highest high tide is determined. The final form of the equation used in TIDE to form the downstream boundary condition includes the astronomic tide, the sea level rise, and the storm surge. This equation takes the following form:

$$\eta(t) = F\left[\sum_{n=1}^{5} A_n \cos(\theta_n + \sigma_n t) + SLR\right] + (\text{Storm Surge} - HHW) \qquad (2.33)$$

In the first term, F is the tide conversion factor. The sum within the brackets is Eq. (2.32) and the magnitude of the sea level rise SLR. The last term is the difference between the storm surge and the highest high water HHW.

2.3.2 The Upstream Boundary

At the upstream boundary, more complicated changes are required. The model, as written, handles only a constant streamflow and sediment load over the length of the model run. In the case of a drought, this condition would be all right because the average low flow over several days is used to calculate the return period of the drought. Even for flows near normal, it would not be unreasonable to expect the flow to stay close to that level for five or seven days. Such an assumption for a flood, though, is far from being realistic. No one expects the river to flow at a 100-year flood level for a week. A method is developed which will allow the streamflow to vary with time just as the tides do. Besides the quantity of water, one must also consider how the sediment load will vary with these changing streamflow conditions.

For the purposes of this study, the average seven day low flow with a return period of ten years will be used to simulate a drought. From a stage-flow chart for the upstream boundary of the estuary, the river stage at this low flow is found. With the same stage-flow chart, the river stage for normal flow is also determined. The depth of each river cross-section is reduced by an amount equal to the difference between the river stages at low flow and normal flow. Unless the amount of this reduction is equal to or greater than the thickness of the top layer, though, no change is made to the river cross-sections. This maintains a constant layer thickness throughout the depth of the estuary.

In order to allow the model's computations to stabilize, the estuarine conditions at the end of the tenth tidal cycle are examined for the drought and normal flow model simulations. Since each tidal cycle lasts 12.42 hours, ten tidal cycles would take 124 hours or about five days. By considering the average seven day low flow, the model's assumption of constant inflow is valid.

To accommodate a flood, the upstream boundary condition of the estuary model is changed to accept a varying inflow. For the first ten tidal cycles of a model run a constant inflow is used to allow the computations to stabilize. The inflow is increased at the end of the tenth tidal cycle by the new subroutine UPDATE. This subroutine first updates the velocity, salinity and sediment concentration values for each layer within each transect for the next time step. Next, new values for the horizontal velocity and sediment concentration at the upstream boundary are entered. These new values reflect the change of the streamflow and sediment load during the next time step.

In Section 2.2.1, it was noted that at the free surface no mass flux is permitted across the boundary. In the course of a flood, one knows that the water surface will rise, but this boundary condition constricts this rise. To overcome this, a new layer is added atop the estuary each time the inflow is increased. The values for the velocities, salinity and sediment concentration in the new top layer are set equal to the values of these same quantities in the second layer except at the upstream boundary where they are known. The velocities, salinity and sediment concentration for the other layers maintain the values calculated during the previous time step. With the new boundary conditions and the new configuration of the layers, the calculations begin again for a new time step. Since there is a new layer over the old top layer, the restriction of mass fluxes through the free surface of the old top layer is removed.

The determination of the new streamflow is made in the following manner. First, the incremental change in the river stage for each new inflow is set at a value which will maintain uniform layer thicknesses throughout the depth of the estuary. For the previous time step, the inflow will be a value Q_1. The corresponding river stage to this inflow is H_1 as shown in the stage-flow diagram,

Fig. 3. The new river stage will be H_2, and its value is equal to H_1 plus the incremental change. From Fig. 3, the new inflow at the river stage H_2 is Q_2

These inflows are expressed as volume of water per unit of time. To convert these flows into longitudinal velocities for use in the model, the inflows must be divided by the cross-sectional area of the river. Since complete cross-sectional information is unavailable for the Rappahannock River, an assumption is made that the riverbanks for the river slope up and away from the river at a slope of 10:1. With this assumption, the width of the new top layer is determined, and the new cross-sectional area of the upstream boundary can be calculated. The new streamflow Q_2 is divided by the new area to find the updated longitudinal velocity.

Now that the new longitudinal velocity has been computed, the time when this new velocity occurs must be specified for the estuary model. For this, the inflow hydrograph is used to find the time T_2 when the new inflow Q_2 occurs. This procedure, as shown in Figs. 3 and 4, is followed several more times in order to break up the inflow hydrograph into discrete parts. These inflows and their corresponding times of occurrence are read into the estuary model from a data file. After the model completes the calculations for a time step, it will update the time for the next time step. This new time is compared with the time values in the data file. If the new time matches with a time in the data file, the subroutine UPDATE is called and the appropriate changes are made. Otherwise, the model continues its execution as it did before the modifications were made.

A similar procedure can be applied to the variation of the sediment concentration with the changing streamflow. It is assumed that the suspended sediment concentration varies linearly with the streamflow, and the peak sediment concentration occurs with the peak streamflow. This assumption is made because of the lack of data on the relationship between streamflow and suspended sediment load for the Rappahannock River. For this reason, a peak sediment concentration is chosen from the available suspended sediment data. In addition, it is also assumed that suspended sediment load varies over time in the same manner as the streamflow. In other words, the peak suspended sediment concentration occurs at the same time as the peak streamflow. Therefore,

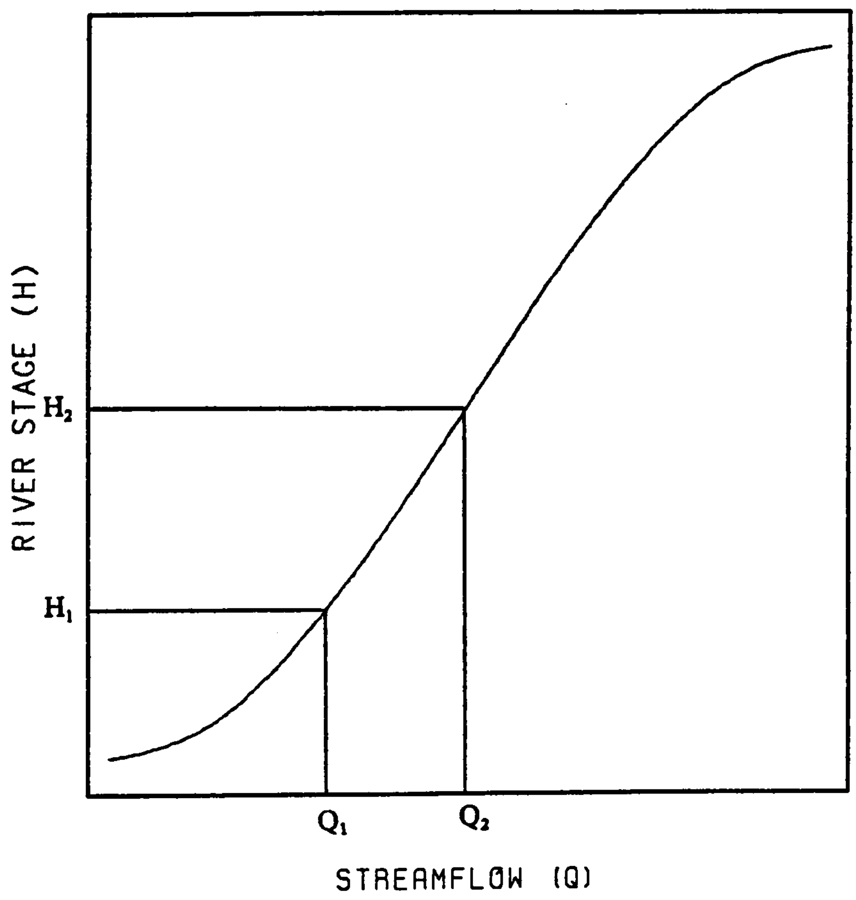

Figure 3. Example of the stage - discharge relationship

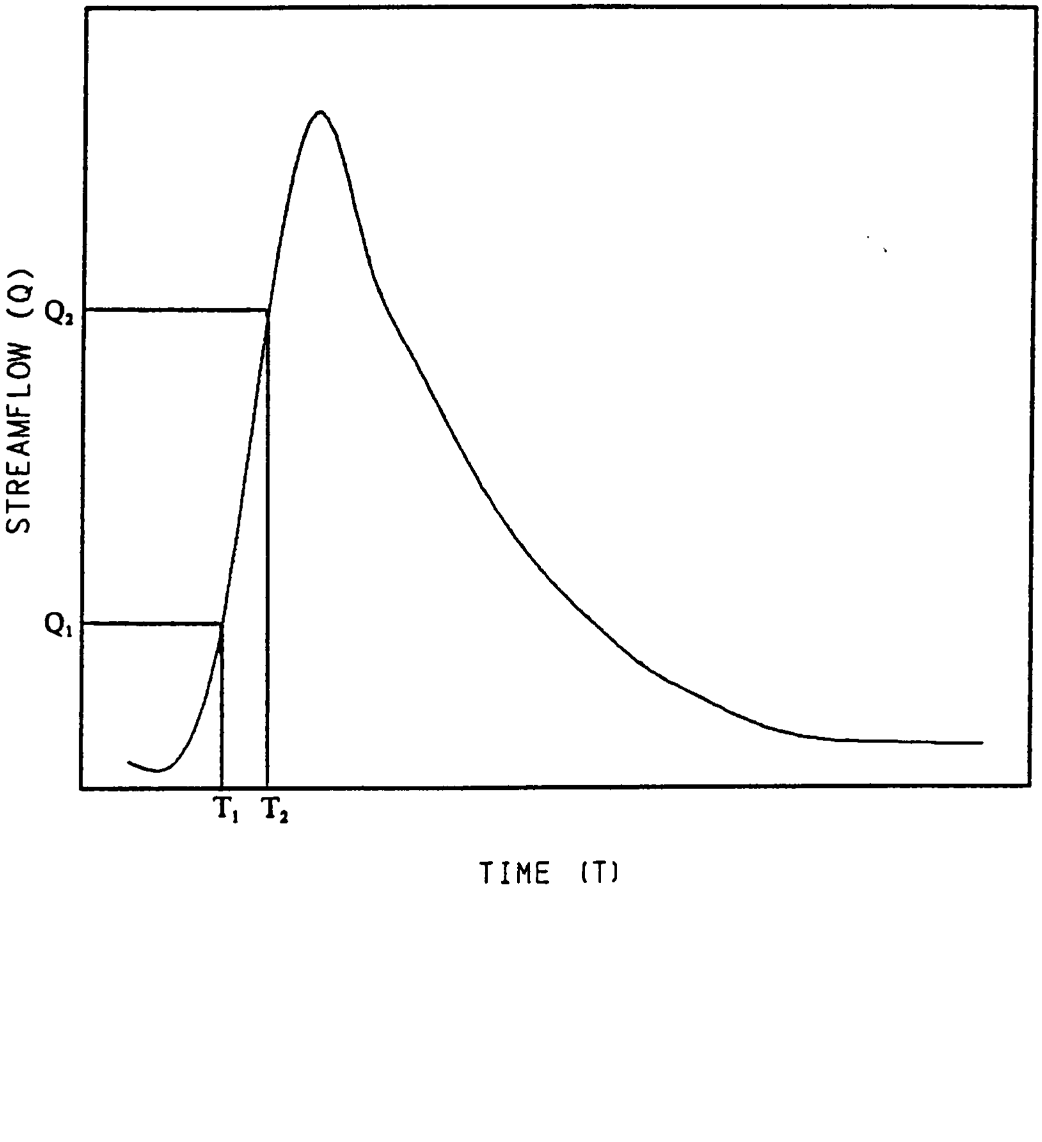

Figure 4. Example of an inflow hydrograph

when the subroutine UPDATE is called the incoming suspended sediment load is changed along with the inflow.

If the new time matches with a time in the hydrograph data file and this time is after the hydrograph's time to peak, another new subroutine, UPDAT2, is called. To readjust the boundary conditions, UPDAT2 first strips off the new top layer added by UPDATE and redefines the second layer as the top layer. All of the layers remaining after the top one is discarded retain the velocity, salinity and suspended sediment concentration values calculated during the previous time step. At the upstream boundary, the longitudinal velocity and incoming sediment load are changed to reflect the lower streamflow. With these changes made, the calculations for the new time step begin.

2.3.3 Summary of the Subroutines UPDATE and UPDAT2

A listing of the new subroutines UPDATE and UPDAT2 is included with the listing of the numerical model in Appendix C. This summary gives a more specific outline of what these subroutines do.

The subroutine UPDATE is used for the rising limb of the hydrograph. UPDATE enables the river stage and incoming suspended sediment concentration to increase as flood flows enter the estuary. Each time it is called, the subroutine follows a procedure which updates the velocity, salinity and sediment concentration values within the estuary, and revises the geometry and boundary conditions of the estuary:

1. The number of layers for each transect is increased by one due to the addition of the new top layer. This also means that the maximum number of layers in any one transect also is increased by one. For each transect, the ordering of the layers is rearranged. This means the top layer is now the second layer, the second layer becomes the third layer, and so on for all of the layers in each transect.

2. The thickness of the new top layer is defined in centimeters, and variables used in the numerical model which are functions of the top layer's thickness are recalculated.

3. Due to the new configuration of the layers, the mean depths and depths at which vertical velocities exist for each transect are recalculated.

4. The arrangement of the channel widths are reordered in the same manner used to reorder the layers in Step 1. The width of the new top layer is calculated assuming a 10:1 slope for the riverbanks.

5. The number of layers used at each transect for the calculation of the longitudinal velocities is set.

6. The channel widths for the upstream and downstream boundary transects are set equal to the channel widths of the adjacent transects.

7. The average width of adjacent reaches or layers are calculated.

8. The longitudinal velocity, vertical velocity, salinity, and suspended sediment concentration for each layer of each transect are reordered in accordance with the new arrangement of the estuary layers.

9. The longitudinal velocity, vertical velocity, salinity, and suspended sediment concentration values for the new top layer are set equal to the values in the second layer.

10. The new longitudinal velocity and sediment load at the upstream boundary replace the old boundary conditions. At the downstream boundary, the salinity and sediment concentrations for the new top layer at the seaward transect are set equal to the values in the second layer.

With the completion of Step 10, the new boundary conditions are set in place and control is returned to the main program so that execution of the calculations may continue.

The subroutine UPDAT2 makes adjustments required for simulating the falling limb of the hydrograph. Like UPDATE, UPDAT2 also modifies the velocity, salinity and suspended sediment values within the estuary. Unlike UPDATE however, UPDAT2 revises the size of the estuary downward to account for the falling river stage which accompanies the reduced streamflows:

1. The number of layers for each transect is decreased by one due to the elimination of the top layer. This also means that the maximum number of layers in any one transect also is decreased by one. For each transect, the ordering of the layers is rearranged. This means the second layer is now the top layer, the third layer becomes the second layer, and so on for all of the layers in each transect.

2. The new top layer was previously the second layer, and its thickness remains unchanged. Variables used in the numerical model which are functions of the top layer's thickness are recalculated.

3. Due to the new configuration of the layers, the mean depths and depths at which vertical velocities exist for each transect are recalculated.

4. The arrangement of the channel widths are reordered in the same manner used to reorder the layers in Step 1. With the elimination of the top layer, the widths of the remaining layers remain unchanged. This means that the width of the second layer for the previous time step now becomes the width of the new top layer. Because the layers are effectively shifted upward with the elimination of the top layer, the channel width of the old bottom layer is set equal to zero to prevent errors from occurring in Step 5.

5. The number of layers used at each transect for the calculation of the longitudinal velocities is set.

6. The channel widths for the upstream and downstream boundary transects are set equal to the channel widths of the adjacent transects.

7. The average width of adjacent reaches or layers are calculated.

8. The longitudinal velocity, vertical velocity, salinity, and suspended sediment concentration for each layer of each transect are reordered in accordance with the new arrangement of the estuary layers. Again, the top has been discarded, and the remaining layers retain the values for the longitudinal velocity, vertical velocity, salinity, and sediment concentration calculated in the previous time step.

9. The new longitudinal velocity and sediment load at the upstream boundary replace the old boundary conditions. At the downstream boundary, the salinity and sediment concentrations from the previous time step are retained.

2.3.4 Review of the Model Boundary Conditions, Input and Output

The numerical model simulates the estuary by taking cross-sections at a constant distance Δx apart. Each section of the estuary is broken up into layers. While there exists a mass flux between the layers, no mass flux is permitted through the free surface nor through the riverbed (Eqs. 2.26 and 2.27). Along the free surface, wind stresses are considered, and along the stream bottom, stresses created by the frictional forces are calculated. Since the model is time-dependent, a fixed time step Δt is specified.

Following the modifications to the model, the upstream boundary conditions now consist of a time-varying streamflow $U(t)$ and suspended sediment concentration $C(t)$. The streamflow can be taken from a flood frequency analysis. This single value is converted into a hydrograph by searching the stream records for a storm of similar magnitude and using the hydrograph of that storm as the input hydrograph. The variation of the suspended sediment concentration with time is assumed to follow the same pattern as the streamflow. The suspended sediment is also assumed to increase linearly with increasing streamflow

At the downstream boundary (Eq. 2.32), a harmonic function is used to simulate the time-varying astronomic tide $\eta(t)$. Added onto the astronomic tide is the projected sea level rise. Atop of this sum, a storm surge taken from the tide frequency analysis is added. Since the tidal heights used in the frequency analysis include both the astronomic tide and the tidal surge due to a storm, the storm surge must be broken down into its components. This is accomplished by taking the highest high water computed by the harmonic function (Eq. 2.32) for the duration of the model simulation and subtracting this highest high water from the storm surge taken from the tide frequency analysis. The resulting difference is added to the astronomic tide and sea level rise over the timespan of the model simulation (Eq. 2.33).

These boundary conditions are shown in Fig. 5. Table 1 gives the input variables and the results which are presented at the end of each tidal cycle.

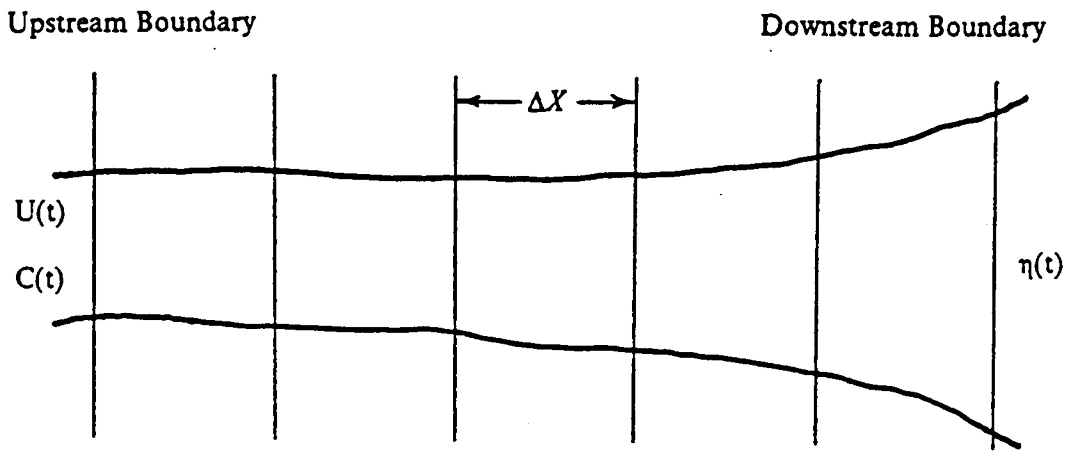

Figure 5. Plan view showing the boundary conditions for the numerical model

Table 1. Model input and output variables

Input

Variable	Description
Flow Velocity	Time-varying velocity at upstream boundary determined by flood frequency analysis, joint probabilities and streamflow records.
Suspended Sediment	Time-varying suspended sediment concentration at upstream boundary. Constant suspended sediment concentration at downstream boundary. Linear interpolation between the two boundaries for each layer is made to initialize suspended sediment concentrations. In addition, input critical shear stresses and constants for calculation of sediment deposition.
Salinity	Constant salinity for each layer at downstream boundary. Set initial upstream saltwater intrusion limit. Model makes a linear interpolation for each layer between this limit and the downstream boundary to initialize the estuary salinities.
Estuary Geometry	Input estuary widths, depths, surface storage areas and Manning friction coefficients for each transect. Define layer thicknesses.
Tide	Enter value of tidal constituents for calculation of astronomic tide. Set the magnitude of the sea level rise and the tidal surge.

Output

Variable	Description
Salinity	Concentrations are given in parts per thousand
Suspended Sediment	Concentrations are given in mg/l
Vertical Velocities	Velocities are given in cm/sec
Tidal Heights	Heights are given in centimeters
Horizontal Velocities	Velocities are given in cm/sec

Output results are given for each layer of each transect. An exception to this rule is the tidal height. Only one tidal height is given for each transect.

CHAPTER 3

JOINT PROBABILITY OF EXCEEDENCE OF STREAMFLOWS AND TIDES IN AN ESTUARY

3.1 FREQUENCY ANALYSIS OF THE STREAMFLOWS AND TIDES

As stated in Chapter 2, the stream inflow constitutes the upstream boundary condition and the tide forms the downstream boundary condition. The objective of this study is to examine how the estuarine processes are affected by sea level rise under different combinations of streamflow and tides. For an accurate judgment of the severity of a particular combination of streamflow and tidal height, some procedure is needed to calculate their joint probability of exceedence. With streamflow records from the U.S. Geological Survey (USGS) and tidal information from the National Oceanic and Atmospheric Administration (NOAA), such a procedure is developed, and the results showing the joint probabilities of exceedence for several streamflow-tidal height pairs are presented. While for this study streamflows and tidal heights are paired together, this procedure is applicable to other quantities which may be dependent upon one another such as tidal height and precipitation. Although a joint probability of exceedence is computed, the validity of converting this value to a return period is uncertain due to the differing effects each streamflow-tidal height pair has on the estuarine processes.

Beginning with streamflow, USGS daily average streamflow records were obtained through the Hydrologic Information Storage and Retrieval System (HISARS). Records were retrieved for the gaging station on the Rappahannock River near Fredericksburg. Details about this gaging station are contained in Appendix A. Besides the flow records, a flood frequency analysis using the log Pearson III distribution was done by the HISARS program for the Fredericksburg station. Results of this analysis are shown in Fig. 6.

Next, tidal records were obtained from NOAA. The only records readily available from NOAA are the extreme high and low tides for each month and the date on which the extreme value occurred. Since this study is concerned with the intrusion of saltwater into the estuary, only the extreme high tides were considered. At the mouth of the Rappahannock River, though, there are no long term tidal records available. The only tidal records existing for the mouth of the Rappahannock River are for Windmill Point. These records only include the 365 day period of tide observations used for the standard tide analysis described in Section 2.2.3. This analysis computes the harmonic constants used in Eq. (2.32), the mean tide level and the tidal range at Windmill Point.

The nearest station with long term tidal records is at Gloucester Point, but this station has a mean tidal range double the 1.2 foot tidal range at Windmill Point. The people at NOAA advised against using Gloucester Point because of this large difference in the tidal ranges. The nearest station they found with a similar tidal range as that found at Windmill Point was on Solomons Island near the mouth of the Patuxent River in Maryland. Solomons Island, though, is 52 miles from Windmill Point while Gloucester Point is only 30 miles away. Another disadvantage is the fact that the Patuxent River has a mean flow one-third that of the Rappahannock River (506 cfs versus 1658 cfs). This drawback can be discounted since river flow has a very small effect on the tidal stage at

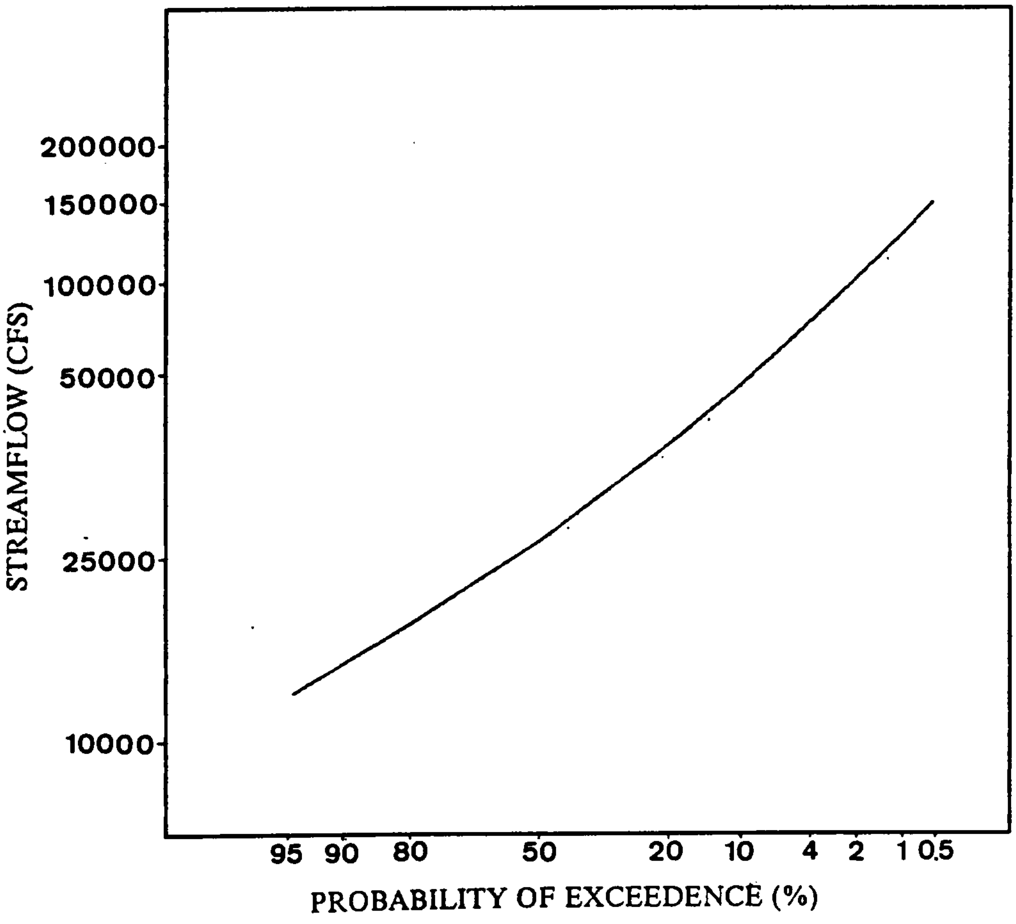

Figure 6. Flood frequencies on the Rappahannock River near Fredericksburg, Virginia

the mouth of the river (Yeh, 1980). Furthermore, high tide elevations predicted by the tide tables for Windmill Point and Solomons Island differ by only 0.0 to 0.2 feet. Considering the magnitude of a storm surge, this two-tenths of a foot is negligible. The only major difference in the high tides was a five hour lag for the high tide to reach Solomons Island after it had already occurred at Windmill Point. For this study, the tidal records at Solomons Island are assumed to be representative of the tides at Windmill Point and are used to compute the tidal frequencies at the mouth of the Rappahannock River.

By using the tidal records at Solomons Island for the Rappahannock River, a frequency analysis is made for the extreme high tides on the river. For this analysis, the highest high tide for each year is used as one data point. This high tide is considered to be a storm surge. Although the storm surge consists of the astronomic tide and the tidal surge due to a meteorological event, it is impossible to differentiate between the two in the tidal data provided by NOAA. Therefore, the tide levels calculated by the frequency analysis include both components of the storm surge. Three methods of analysis were used: log normal, log Pearson III, and Gumbel's distribution. These methods are normally applied to streamflows for storm frequency analysis. This use of streamflows for the storm frequency analysis is accepted because there is a definite causal relationship between floods and storms. For high tides, this relationship is not always true. Rare alignments of the moon, Sun and other planets may cause very high tides without any storm present. In this tidal analysis, though, it is reasonable to assume that the very highest tide of the year is due to a storm. Figure 7 shows the tide frequencies at the mouth of the Rappahannock River.

The results of the flood and tide frequency analyses are used in determining the boundary conditions of the estuary model. From the frequency analyses, streamflows and tides of various return periods may be chosen and paired together for use in the estuary model. It would be helpful to know the probability that a particular streamflow and tidal height will be equalled or exceeded simultaneously. How this joint probability distribution is determined is described in Section 3.2.

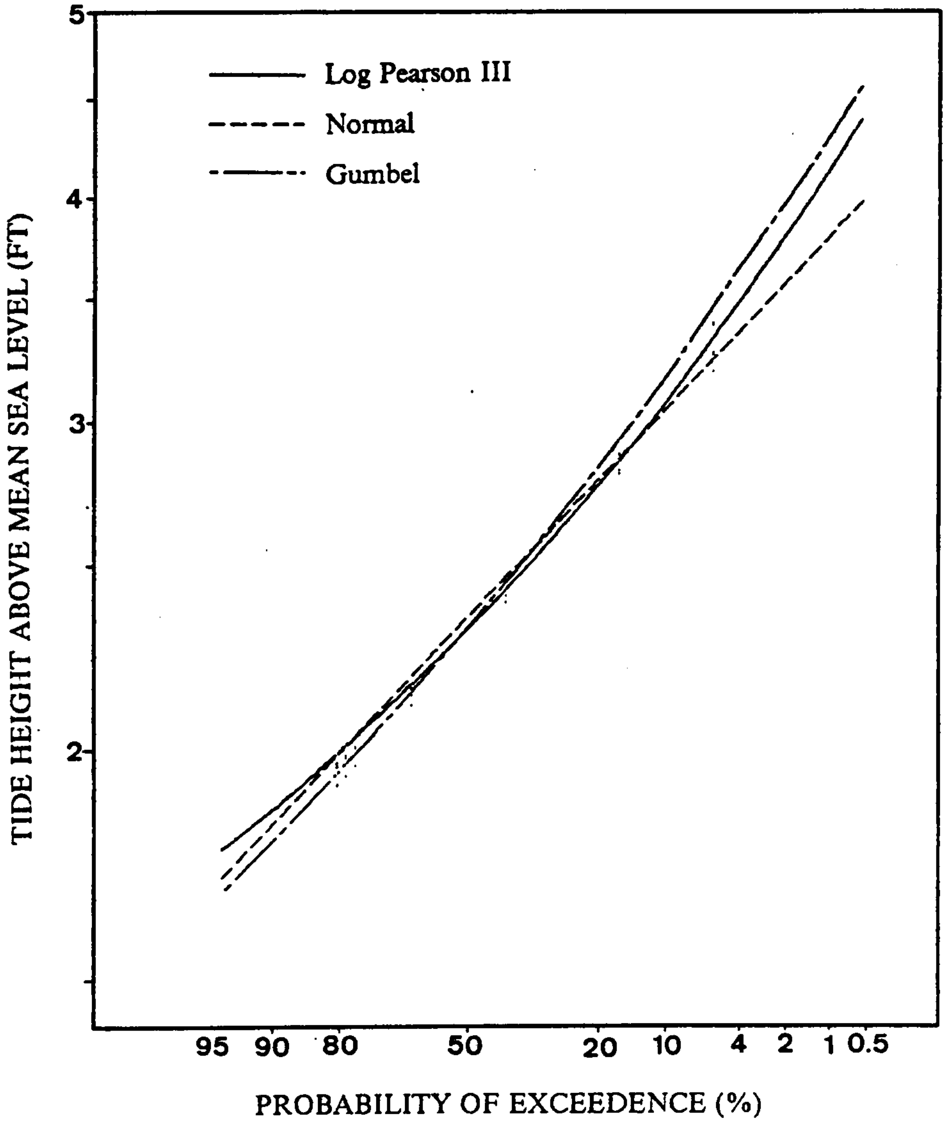

Figure 7. Tidal frequencies at the mouth of the Rappahannock River

3.2 JOINT DISTRIBUTION OF STREAMFLOWS AND TIDES

3.2.1 Pairing of Streamflow and Tidal Data

After the streamflow and tidal data was collected, coinciding streamflows and tides were paired together. For a given date and high tide at the mouth of the river, a corresponding average streamflow for that date was found for the USGS gaging station at the upstream boundary of the estuary. Many of these high tides occur as a storm comes ashore, rainfall from the storm may later fall mainly in the upper reaches of the river basin. This time lag between the storm surge and rainfall could cause an abnormally low streamflow to be paired with a very high tide. To alleviate this discrepancy, the streamflows for both the day of the high tide and the following day are compared, and the larger of the two values is paired with the high tide. It is figured that one day is enough time for the bulk of the runoff to reach the upstream end of the estuary.

Special problems occur with the Rappahannock River. The extreme high tide data used for the Rappahannock is from Solomons Island. It was stated in Section 3.1 that the high tides at Solomons Island lag those at Windmill Point by about five hours. This means that there may be times when the extreme high tide recorded at Solomons Island actually occurred on the previous day at the mouth of the Rappahannock River. To account for this situation, the highest average streamflow at the Fredericksburg gaging station is chosen from among three days: the day of the high tide, the following day, and the day preceding the occurrence of the high tide.

3.2.2 Determination of the Independence of the Variables

Now with these paired values of streamflow Q and tidal height S , a comparison is made to determine the independence of the two variables Q and S. First, the probability of exceedence for various pairs of streamflows and tidal heights are computed by the following expression:

$$P(q,s) = P(Q \geq q, S \geq s) \tag{3.1}$$

With Eq. (3.1), the number of n paired sets in which Q equals or exceeds q and S equals or exceeds s are counted. This sum is divided by the total number of paired sets n to give the probability that the specified values q and s will be equalled or exceeded simultaneously.

This is only one way to calculate $P(q,s)$. Another method is to assume that Q and S are independent. In this case, the probability of equalling or exceeding q and s is given by a different expression:

$$P(q,s) = P(Q \geq q)\, P(S \geq s) \tag{3.2}$$

Here, the number of observed streamflows which exceed a specified streamflow is calculated, and this number is divided by the total number of observations n. This quotient is the probability of exceedence, and it is computed for different values of q. The same approach is taken for the tidal observations. Next, these two sets of probabilities are paired together into different combinations to give $P(q,s)$

If Q and S are truly independent of one another, the results for $P(q,s)$ from Eqs. (3.1) and (3.2) should be nearly identical. The results are presented in Fig. 8, and it is evident from this figure that Eqs. (3.1) and (3.2) give different values for $P(q,s)$. This difference is most obvious when the probability of exceedence is small. Therefore, independence can not be assumed.

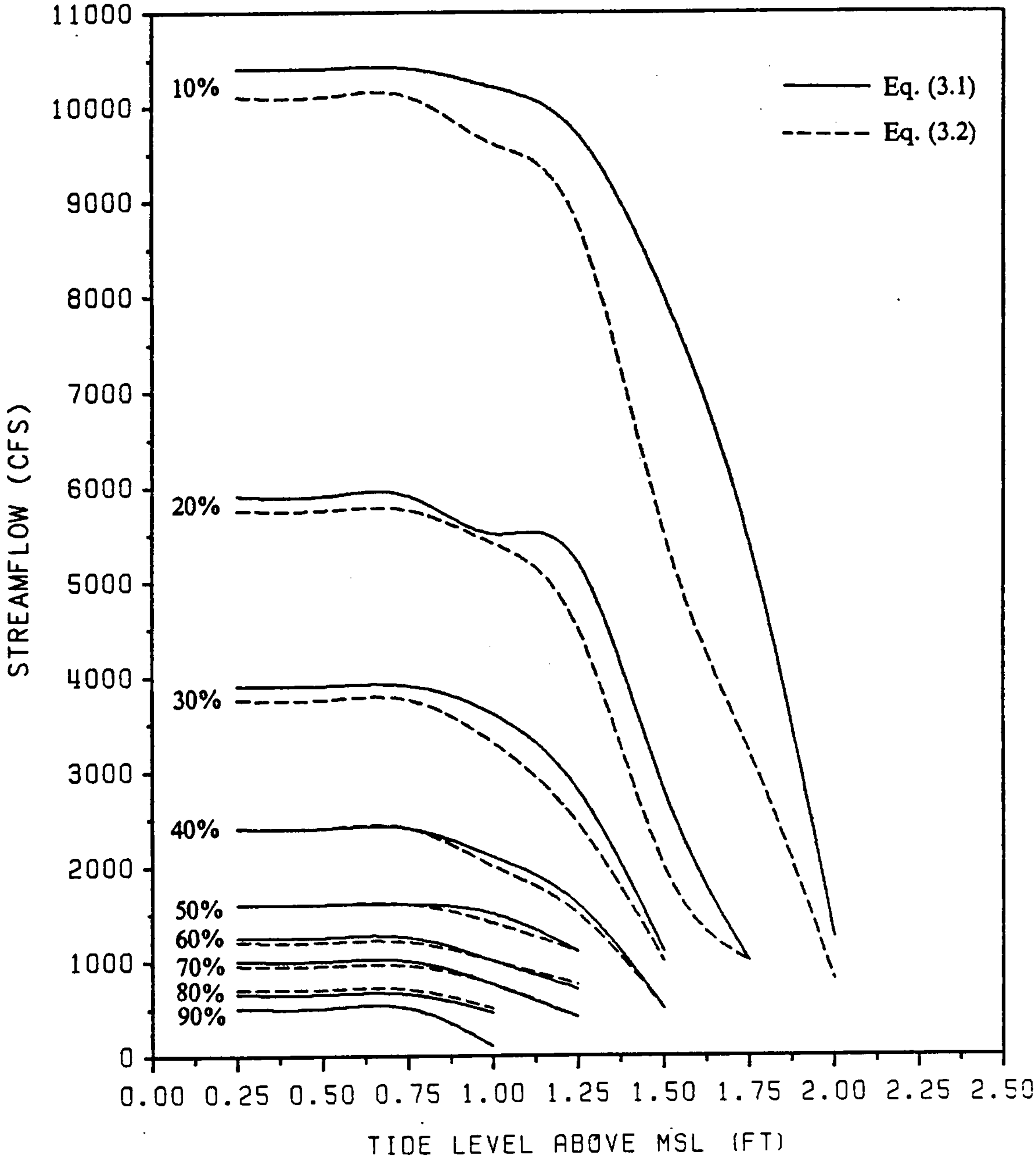

Figure 8. Joint probabilities on the Rappahannock River by Eqs. (3.1) and (3.2)

3.3 JOINT PROBABILITY THROUGH A VARIABLE TRANSFORMATION

3.3.1 Box-Cox Transformation

With the assumption of independence rejected, the distributions of the variables Q and S must be known in order to calculate the joint probability of Q and S. In this case, though, both distributions are unknown so the variables are transformed such that the transformed values follow a known distribution.

The transformation selected for this purpose was developed by Box and Cox (1964):

$$x^{(\lambda)} = \frac{x^{\lambda} - 1}{\lambda} \tag{3.3}$$

$$x^{(\lambda)} = \ln x \tag{3.4}$$

The transformed value $x^{(\lambda)}$ is determined by taking the original data value x and modifying it with the transformation constant λ. Equation (3.3) is used when $\lambda \neq 0$, and Eq. (3.4) applies when $\lambda = 0$. With the proper value of λ, the observed data values will be converted into a set of transformed values with a normal distribution.

The first step in the use of the Box-Cox transformation is the determination of a λ_1 for the streamflows and a λ_2 for the tides. There are two methods to do this: using the marginal distributions of Q and S, or using the joint distribution of Q and S. The computer programs used for the determination of the λ values by both methods are listed in Appendix D. It is anticipated but not always necessarily true that both of these methods will give the same results for λ_1 and λ_2. Throughout this chapter, variables with a subscript of 1 will correspond to the streamflow. Variables with a subscript of 2 will correspond to the tide.

3.3.2 Determining the Transformation Constants for the Marginal Distributions

To find the proper transformation constant λ for a variable's marginal distribution, a λ value is chosen, and each of the original data points are transformed according to either Eq. (3.3) or Eq. (3.4). From these transformed values, the following function of λ is calculated where $\bar{x}^{(\lambda)}$ represents the mean of the transformed values.

$$l(\lambda) = -\frac{n}{2} \ln\left[\frac{1}{n} \sum_{j=1}^{n} (x_j^{(\lambda)} - \bar{x}^{(\lambda)})^2\right] + (\lambda - 1) \sum_{j=0}^{n} \ln x_j \qquad (3.5)$$

Having computed $l(\lambda)$, a new λ is selected and the procedure is repeated. Figures 9 and 10 are plots of $l(\lambda)$ versus λ for the streamflow and tidal data on the Rappahannock. The λ-axis for each of these figures runs from $\lambda = -4$ to $\lambda = 4$ since λ generally lies within this range. The λ which will transform the original data into a data set with a normal distribution is the λ which gives the maximum value for $l(\lambda)$. The λ for which $l(\lambda)$ is maximized is marked in Figs. 9 and 10. For the marginal distributions of Q and S on the Rappahannock River, $\lambda_1 = 0.00$ for the streamflow and $\lambda_2 = 0.10$ for the tidal height.

3.3.3 Determining the Transformation Constants for the Joint Distribution

The procedure for determining a λ_1 and a λ_2 by the joint distribution of Q and S also begins by choosing a λ_1 for Q and a λ_2 for S. Both sets of data are transformed with either Eq. (3.3) or Eq. (3.4).

Using the transformed points, the elements of the sample covariance matrix are calculated. The diagonal elements of the covariance matrix are the variances of the transformed streamflow S_{11} and the transformed tidal data S_{22} . The non-diagonal elements of the matrix are the covariance of the transformed streamflow and tidal data, S_{12} and S_{21} (Birnbaum, 1962).

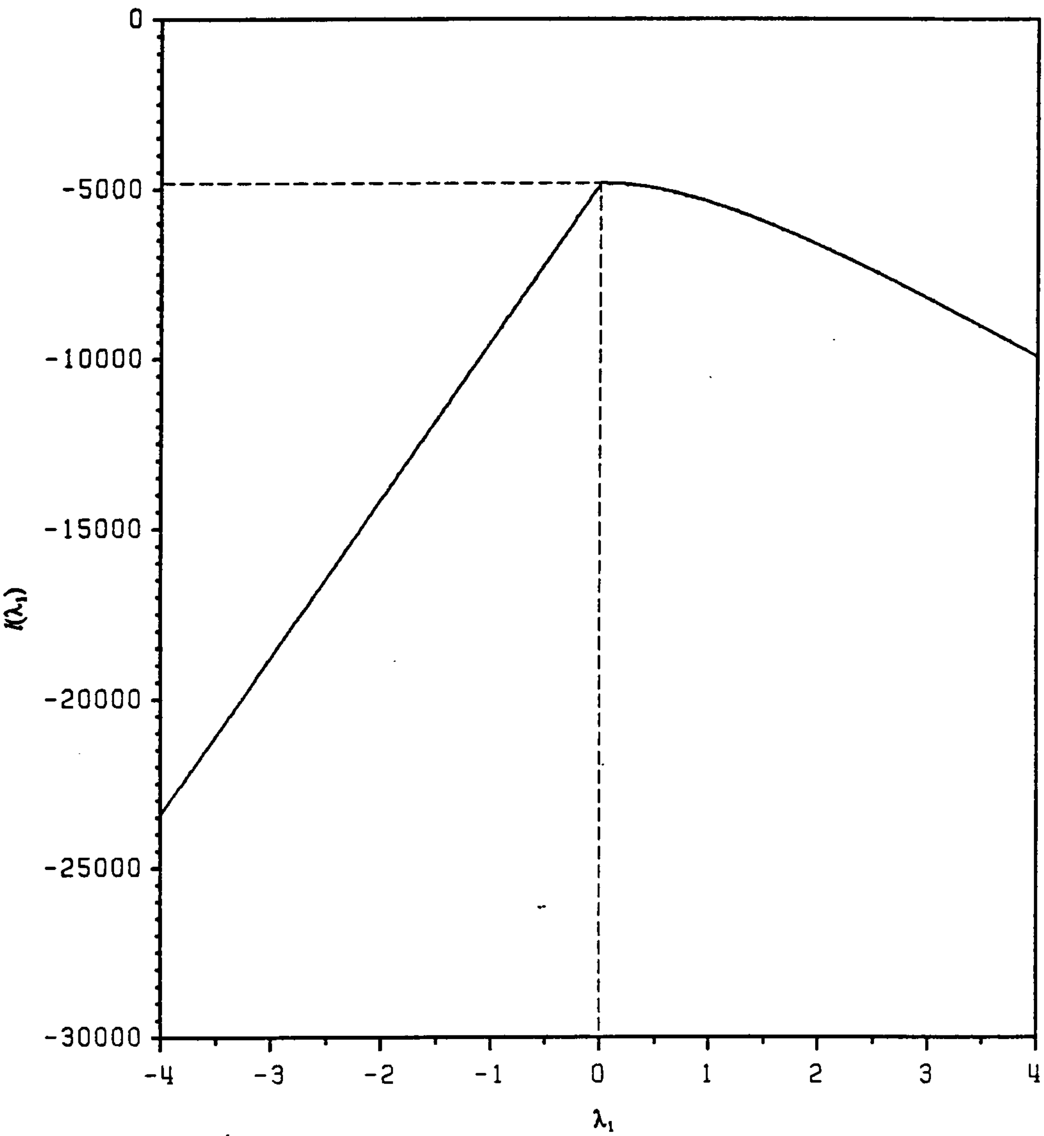

Figure 9. Selection of the transformation constant for the marginal distribution of the streamflows

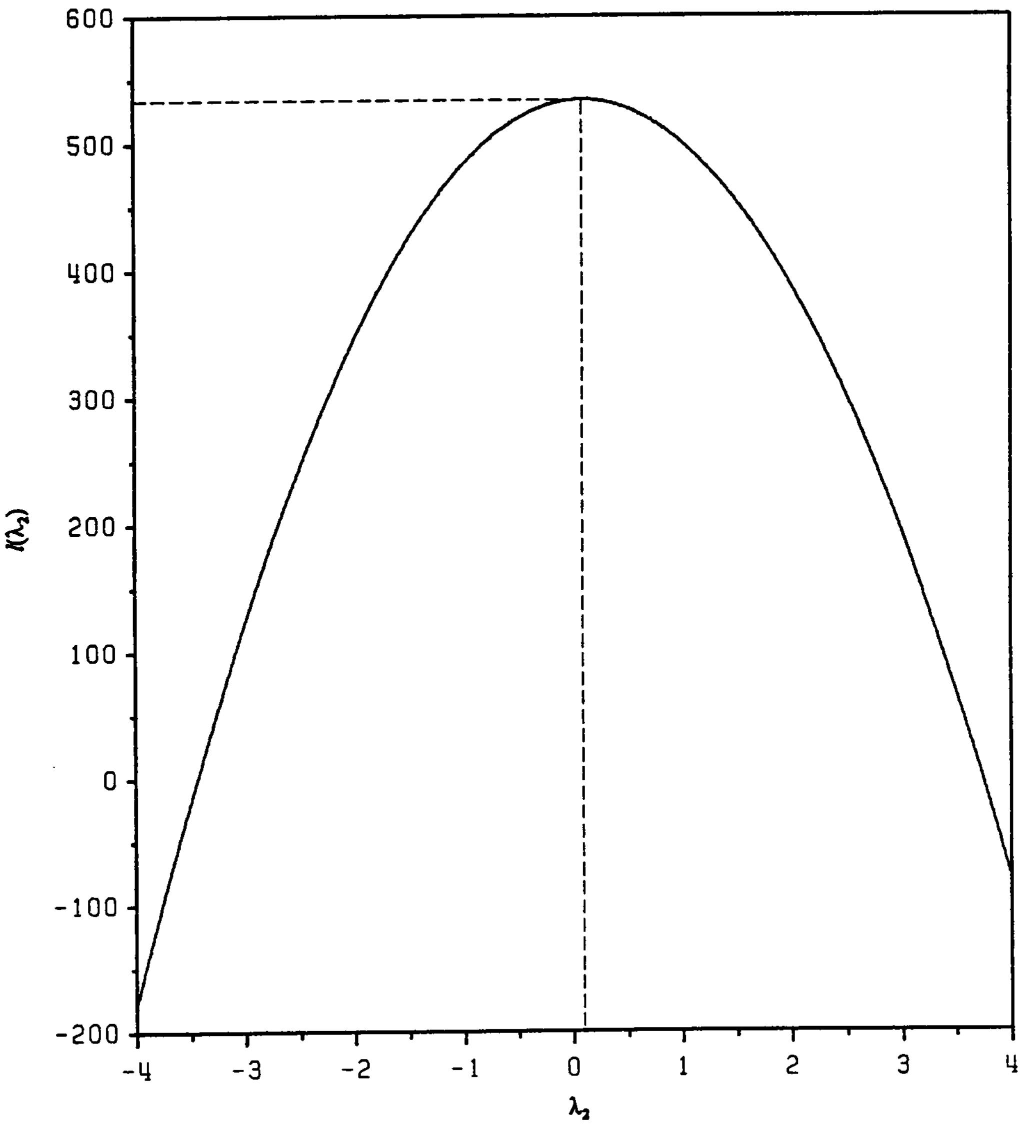

Figure 10. Selection of the transformation constant for the marginal distribution of the tidal heights

If λ_1 corresponds to the transformed streamflow data and λ_2 corresponds to the transformed tidal data, the sample covariance matrix is:

$$S(\lambda_1, \lambda_2) = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \tag{3.6}$$

where

$$S_{ii} = \frac{1}{n} \sum_{j=1}^{n} (x_{ij}^{(\lambda_i)} - \bar{x}_i^{(\lambda_i)})^2 \tag{3.7}$$

$$S_{12} = S_{21} = \frac{1}{n} \sum_{j=1}^{n} (x_{1j}^{(\lambda_1)} - \bar{x}_1^{(\lambda_1)}) \, (x_{2j}^{(\lambda_2)} - \bar{x}_2^{(\lambda_2)}) \tag{3.8}$$

where the subscript $i = 1, 2$.

The goal is to find the value of a function of λ_1 and λ_2:

$$l(\lambda_1, \lambda_2) = -\frac{n}{2} \ln |S(\lambda_1, \lambda_2)| + (\lambda_1 - 1) \sum_{j=1}^{n} \ln x_{1j} + (\lambda_2 - 1) \sum_{j=1}^{n} \ln x_{2j} \tag{3.9}$$

where the determinant of the sample covariance matrix is:

$$|S(\lambda_1, \lambda_2)| = S_{11}S_{22} - S_{12}S_{21} \tag{3.10}$$

With $l(\lambda_1, \lambda_2)$ computed, new values of λ_1 and λ_2 are chosen, and the process is repeated. When a suitable range of λ values have been used, a table is set up with axes λ_1 and λ_2. Each value of $l(\lambda_1, \lambda_2)$ is recorded at the appropriate coordinate point (λ_1, λ_2) as shown in Fig. 11. The correct values for λ_1 and λ_2 will be those coordinates where $l(\lambda_1, \lambda_2)$ is maximized.

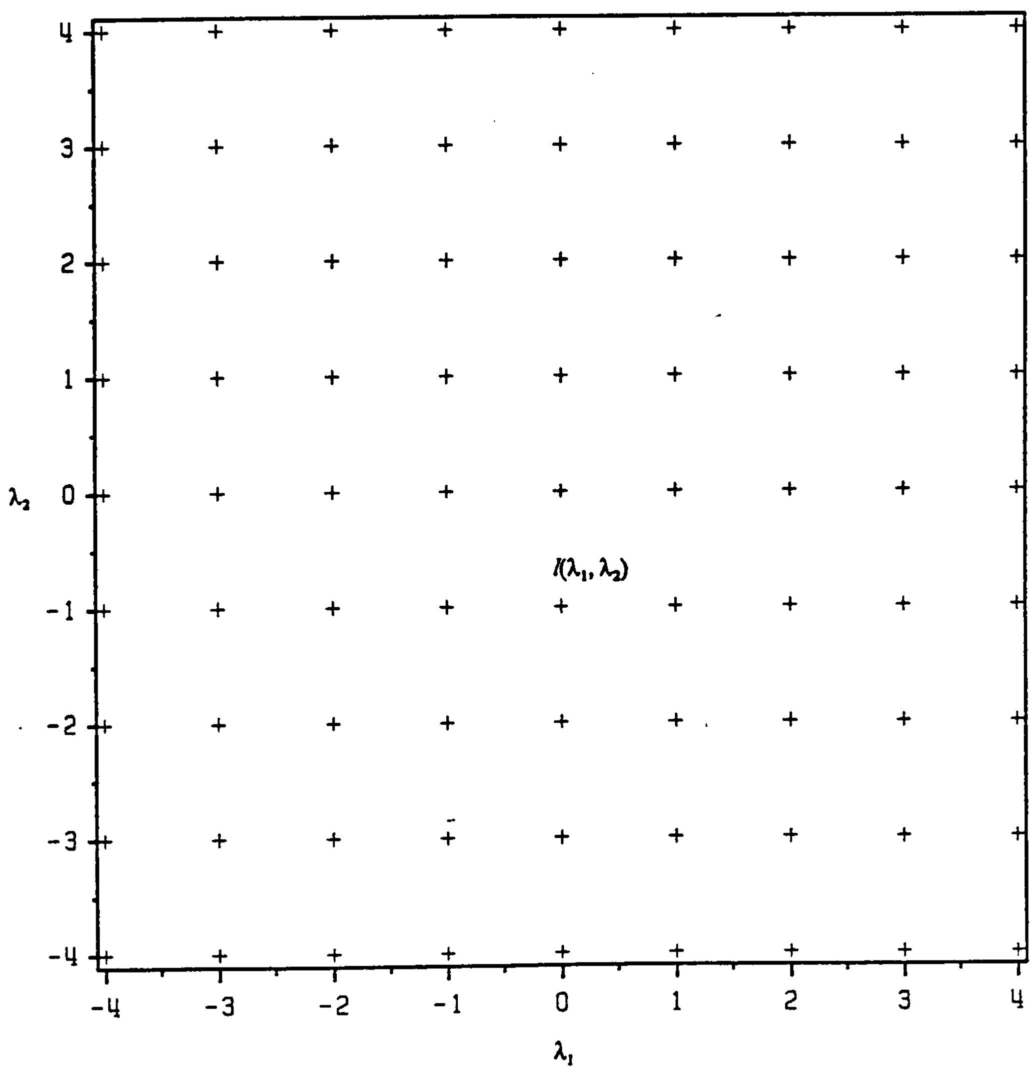

Figure 11. Coordinate system for the joint distribution

3.3.4 Validation of the Transformation Constants

Figure 12 shows the results from this procedure for the Rappahannock River. By using the joint distribution procedure for the Rappahannock River, the transformation constants were found to be $\lambda_1 = 0.03$ for the streamflow and $\lambda_2 = 0.13$ for the tidal height. If a set of variables have a joint normal distribution, then the marginals also have a normal distribution. Therefore, one would expect that the marginal and joint distributions should have the same λ values, but in this case, the results are different. Although the results do differ, it is possible that such differences may occur, and in this situation, the differences are very small. For this study, it is arbitrarily decided that only the λ values computed by the joint distribution will be used.

To be assured that the λ values calculated by the joint distribution do indeed give the transformed data points a normal distribution, the transformed data is plotted against the standard normal quantiles (Johnson and Kotz, 1972). To draw this graph, the transformed data values are arranged in ascending order and ranked $i = 1$ through n, and the probability level, or cumulative probability, for each value is calculated. Knowing the probability level for each transformed value, the standard normal quantile is computed using the inverse normal distribution subroutine MDNRIS from the International Mathematical and Statistical Language (IMSL). A complete explanation on the use of this subroutine is found in Appendix B. The program which ranks the data values and computes the standard normal quantiles is listed in Appendix D. Table 2 gives an example of how these values were determined for the streamflows on the Rappahannock River.

The procedure shown in Table 2 for the streamflows is also followed for the tidal data on the Rappahannock River. Having made these calculations for both the streamflow and tidal data, Figs. 13 and 14 are plotted, and the proximity of the transformed data values to a normal distribution is shown. The straight line on each figure is determined by linear regression. It is easily seen by the close match between the data points and the straight line that the transformed streamflows and tidal heights do follow a normal distribution.

		λ_1						
		0.00	0.01	0.02	0.03	0.04	0.05	0.06
	0.10	-4292.18	-4291.86	-4291.71	-4291.71	-4291.84	-4292.10	-4292.50
	0.11	-4292.14	-4291.84	-4291.70	-4291.69	-4291.82	-4292.08	-4292.48
	0.12	-4292.09	-4291.81	-4291.67	-4291.66	-4291.79	-4292.05	-4292.45
λ_2	0.13	-4292.09	-4291.81	-4291.66	-4291.55	-4291.79	-4292.05	-4292.44
	0.14	-4292.09	-4291.81	-4291.66	-4291.66	-4291.79	-4292.05	-4292.44
	0.15	-4292.10	-4291.82	-4291.67	-4291.66	-4291.79	-4292.05	-4292.45
	0.16	-4292.11	-4291.83	-4291.68	-4291.68	-4291.80	-4292.06	-4292.46

Figure 12. Determination of the transformation constants for the joint distribution

Table 2. Determining standard normal quantiles for streamflows on the Rappahannock River (n = 628)

Rank	Ordered Streamflows Observations	Probability Levels	Standard Normal Quantiles
i	$Q_{(i)}$	$(i - \frac{1}{2})/n$	$q_{(i)}$
1	44	0.0008	-3.1573
2	44	0.0024	-2.8217
3	55	0.0040	-2.6537
...	...	...	...
628	37800	0.9992	3.1573

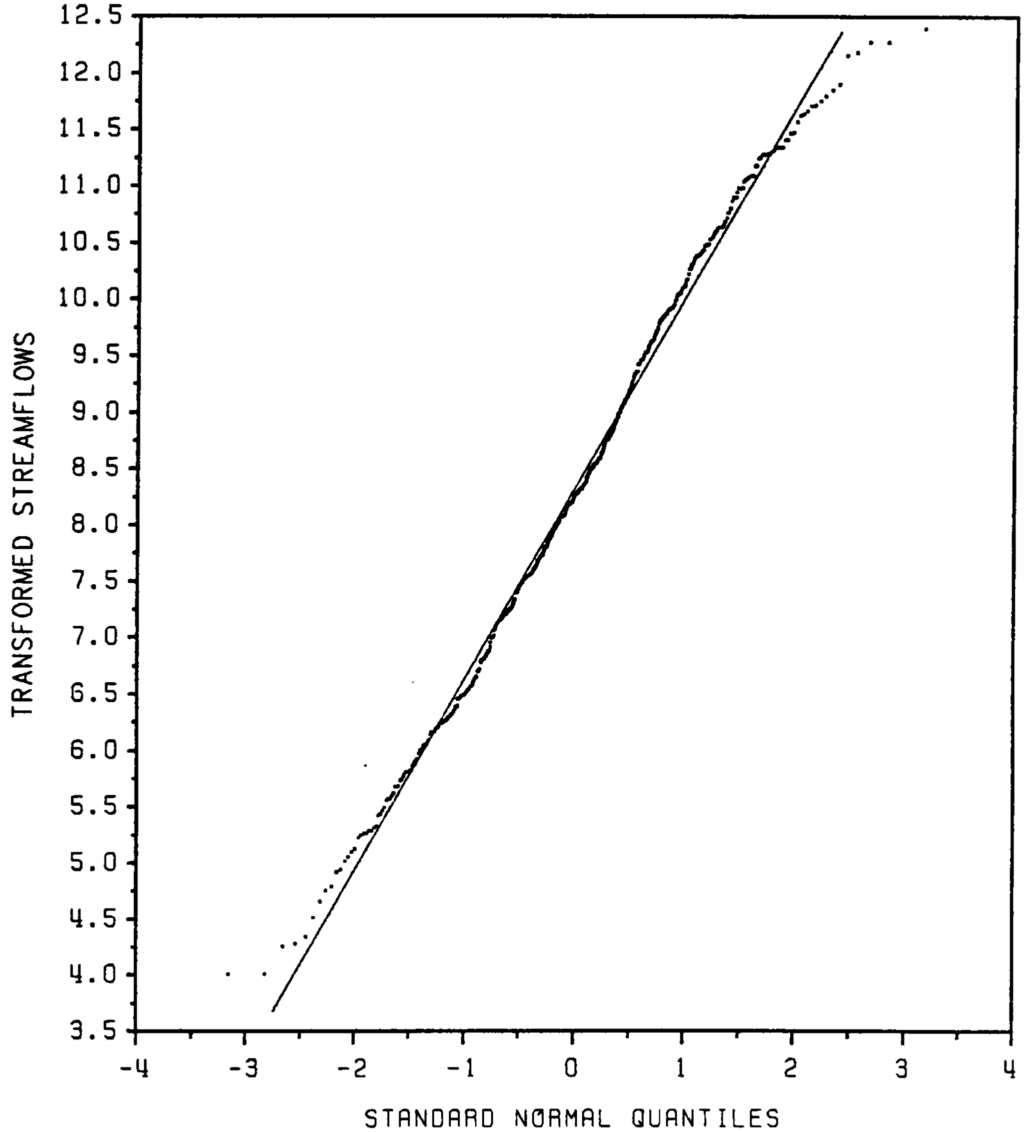

Figure 13. Comparison of the empirical distribution of the streamflows on the Rappahannock River with a normal distribution

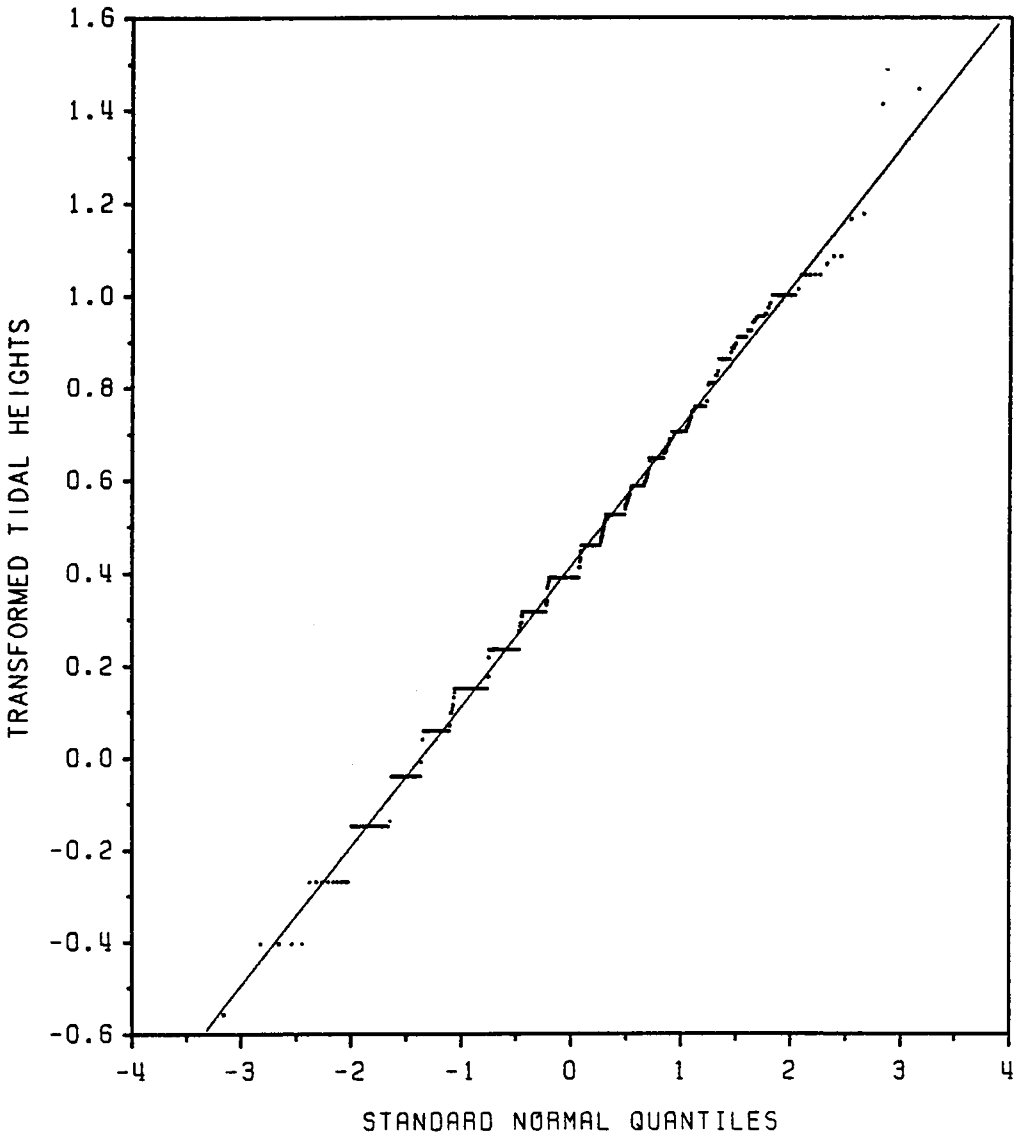

Figure 14. Comparison of the empirical distribution of the tidal heights on the Rappahannock River with a normal distribution

3.3.5 Computation of the Joint Probabilities of Exceedence

Now that the λ values are determined for the Rappahannock River, the statistical quantities for the transformed tidal heights and streamflows are calculated:

$$\bar{x}^{(\lambda)} = \frac{1}{n} \sum_{j=1}^{n} x_j^{(\lambda)} \tag{3.11}$$

$$(\hat{s}^{(\lambda)})^2 = \frac{1}{n-1} \sum_{j=1}^{n} (x_j^{(\lambda)} - \bar{x}^{(\lambda)})^2 \tag{3.12}$$

$$\hat{s}^{(\lambda)} = \sqrt{\frac{1}{n-1} \sum_{j=1}^{n} (x_j^{(\lambda)} - \bar{x}^{(\lambda)})^2} \tag{3.13}$$

$$a^{(\lambda)} = \frac{n}{(n-1)(n-2)} \sum_{j=1}^{n} (x_j^{(\lambda)} - \bar{x}^{(\lambda)})^3 \tag{3.14}$$

$$C_s = \frac{a^{(\lambda)}}{(\hat{s}^{(\lambda)})^3} \tag{3.15}$$

Equations (3.11) through (3.15) represent the expressions for the mean, variance, standard deviation, skew and skew coefficient respectively.

Another statistic to be found is the sample correlation-coefficient ρ, between the transformed streamflows and the transformed tidal heights. A consistent estimate of ρ, is made with the coefficient of correlation r and it is expressed as:

$$r = \frac{R}{\sqrt{WZ}} \tag{3.16}$$

W and Z are consistent estimates of the variances of the transformed streamflows and tidal heights respectively. The values of W and Z are calculated with Eq. (3.7) where $x_1^{(\lambda_1)}$ is the transformed streamflow and $x_2^{(\lambda_2)}$ is the transformed tidal height. R is a consistent estimate of the covariance of the transformed streamflows and tidal heights, and it is calculated by Eq. (3.8). All of the statistical quantities for the Rappahannock River are listed in Table 3.

Knowing that the transformed streamflows and tidal heights each follow a normal distribution, the two variables are combined to form a bivariate normal distribution, $g(q,s,\rho_r)$. To determine the probability of exceeding a specified streamflow and tidal height simultaneously, the following double integral must be evaluated:

$$P[Q \geq h, S \geq k] = \int_h^\infty dq \int_k^\infty g(q,s,\rho_r) ds \qquad (3.17)$$

where h and k are the standardized values of the specified streamflow and tidal height respectively, and Q and S are the transformed streamflows and tidal heights.

The procedure for finding the joint probability requires the choice of a streamflow and tidal height. The values are transformed according to Eq. (3.3) or Eq. (3.4) using the appropriate λ values. Now, the statistics in Table 3 are used to standardize the transformed values and get h and k:

$$h = \frac{q^{(\lambda_1)} - \bar{q}^{(\lambda_1)}}{\hat{s}_q^{(\lambda_1)}} \qquad (3.18)$$

$$k = \frac{s^{(\lambda_2)} - \bar{s}^{(\lambda_2)}}{\hat{s}_s^{(\lambda_2)}} \qquad (3.19)$$

where

$q^{(\lambda_1)}$ = transformed streamflow value

$\bar{q}^{(\lambda_1)}$ = mean of the transformed streamflow data

$\hat{s}_q^{(\lambda_1)}$ = standard deviation of the transformed streamflow data

$s^{(\lambda_2)}$ = transformed tidal height value

Table 3. Statistical quantities for the Rappahannock River

	Streamflow (λ_1 = 0.03)	Tidal Height (λ_2 = 0.13)
Mean	8.32	0.412
Variance	2.88	0.0918
Standard Deviation	1.70	0.303
Skew	0.230	0.000788
Skew Coefficient	0.0472	0.0283

ρ_r = 0.185

$\bar{s}^{(\lambda_1)}$ = mean of the transformed tidal height data

$\hat{s}_s^{(\lambda_1)}$ = standard deviation of the transformed tidal height data

Once again, the IMSL package provides a very useful subroutine called MDBNOR which calculates the bivariate normal distribution for the following expression:

$$P[Q \leq h, S \leq k] = \int_{-\infty}^{h} dq \int_{-\infty}^{k} g(q,s,\rho) ds \tag{3.20}$$

Once again, Q and S are the transformed streamflows and tidal heights respectively. Equation (3.20) does not compute the same probability as Eq. (3.17), therefore Eq. (3.21) is required to get the joint probability of exceedence shown in Eq. (3.17):

$$P[Q \geq h, S \geq k] = 1 - P[Q \leq h] - P[S \leq k] + P[Q \leq h, S \leq k] \tag{3.21}$$

The second and third terms on the right hand side of Eq. (3.21) are the cumulative probabilities of the univariate normal distributions for Q and S . The logic of Eq. (3.21) is best visualized by a Cartesian coordinate system (Fig. 15) where h is the x-axis and k is the y -axis, and the total area of the four quadrants equals one. For the case where $h = 0$ and $k = 0$, $P[Q \geq h, S \geq k]$ would correspond to the first quadrant of the coordinate system, and $P[Q \leq h, S \leq k]$ would correspond to the third quadrant. The combined area of the second and third quadrants represents $P[Q \leq h]$, and the combined area of the third and fourth quadrants represents $P[S \leq k]$. To calculate these univariate normal distributions, the MDNOR subroutine of IMSL package will be used. If $P[Q \leq h]$ and $P[S \leq k]$ are subtracted from the total area, the area of the third quadrant is subtracted twice. Adding the value of $P[Q \leq h, S \leq k]$ to this difference will correct for this error and give the joint probability of exceedence $P[Q \geq h, S \geq k]$.

Figures 16 and 17 show the relationship between the streamflow and the tidal height for different joint probabilities of exceedence. To develop these figures, a set of paired streamflow and tidal height values must be determined for each joint probability of exceedence. The procedure begins

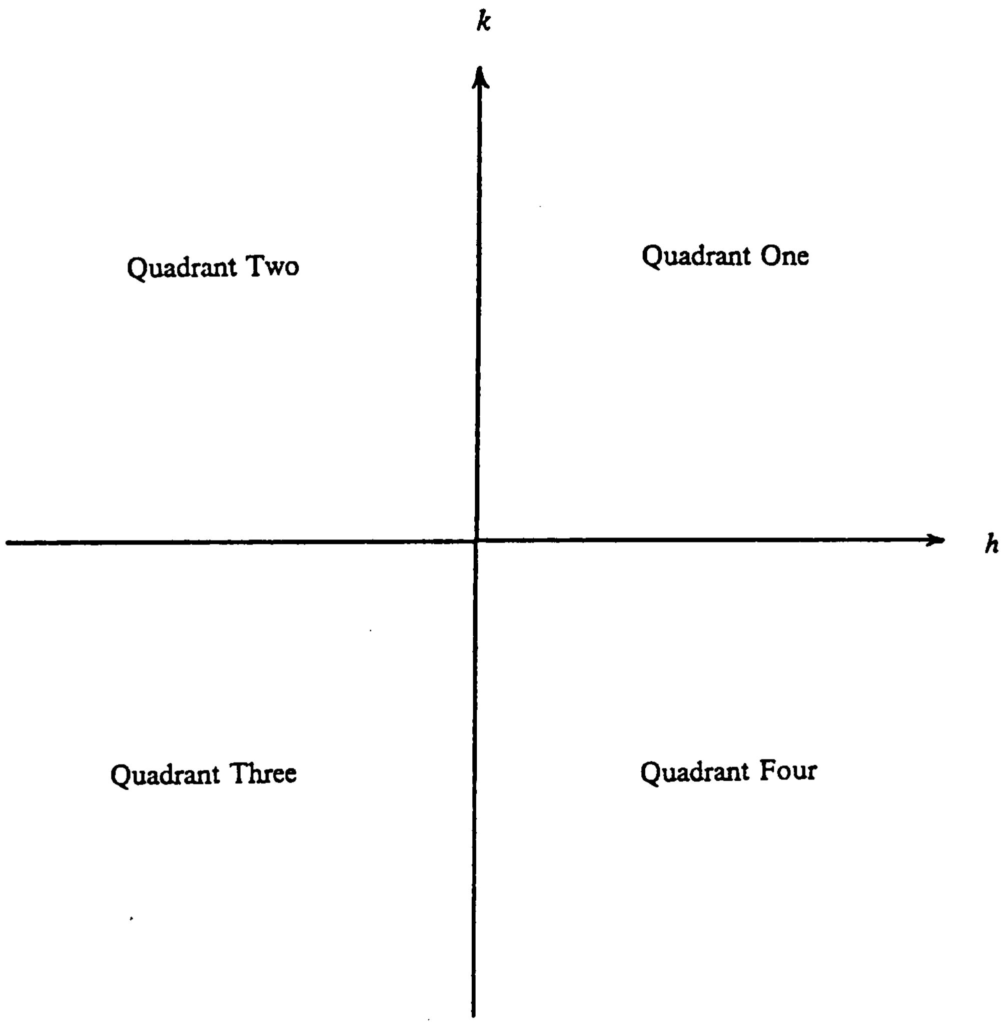

Figure 15. Cartesian coordinate system used to derive Eq. (3.21)

by specifying a particular joint probability of exceedence. The appropriate streamflow and tidal height which when combined will give this joint probability of exceedence are found by trial and error. Different transformed streamflows and tidal heights are substituted into Eq. (3.21) until a solution equalling the specified joint probability of exceedence is found. A computer program was written which would perform this iterative procedure, and a listing of the program is in Appendix D. The probabilities in Eq. (3.21) are calculated with the IMSL subroutines MDBNOR and MDNOR. The use of these subroutines is explained in Appendix B.

It should be remembered that when the solution to Eq. (3.21) equals the desired joint probability of exceedence, the computed streamflow and tidal height values are standardized values of the transformed data. Therefore, an inverse transformation is necessary. First, to convert these standardized values back to the transformed values, Eqs. (3.18) and (3.19) are solved for $q^{(\lambda_1)}$ and $s^{(\lambda_2)}$ respectively. Now to return to the original data form, either Eq. (3.3) or Eq. (3.4) is solved for the nontransformed streamflow and then the tidal height. Selection of the proper equation depends on whether or not λ equals zero.

3.3.6 Application and Interpretation of the Joint Probability

This chapter has concentrated on the development of a method which will calculate the joint probability of exeedence of a particular streamflow and tidal height which are dependent upon one another. This is unlike some other methods which have assumed independence between the two variables (Jenkins and Johnson, 1978). Due to the dependence of the streamflow and the tidal surge on one another, though, formulation of the new method presented here was necessary. Further complicating the computation of these joint probabilities was the fact that the streamflows and tidal heights each follow an unknown distribution. The procedure developed here takes the original streamflow and tidal data and converts both sets of data into normal distributions. Since both variables now follow a normal distribution, a bivariate normal distribution is used to calculate the joint probability of exceedence.

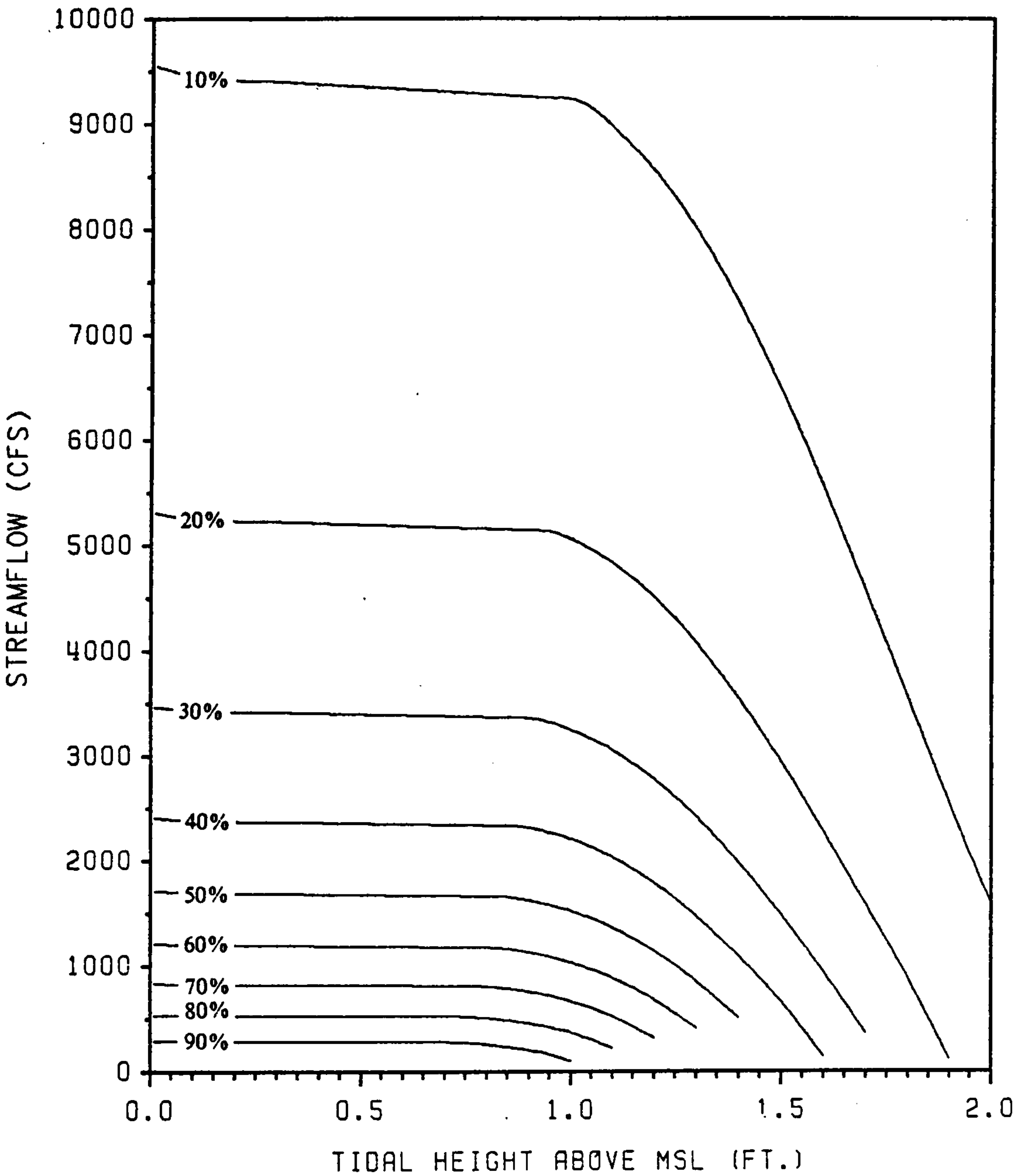

Figure 16. Joint probabilities on the Rappahannock River (10% to 90% probability of exceedance)

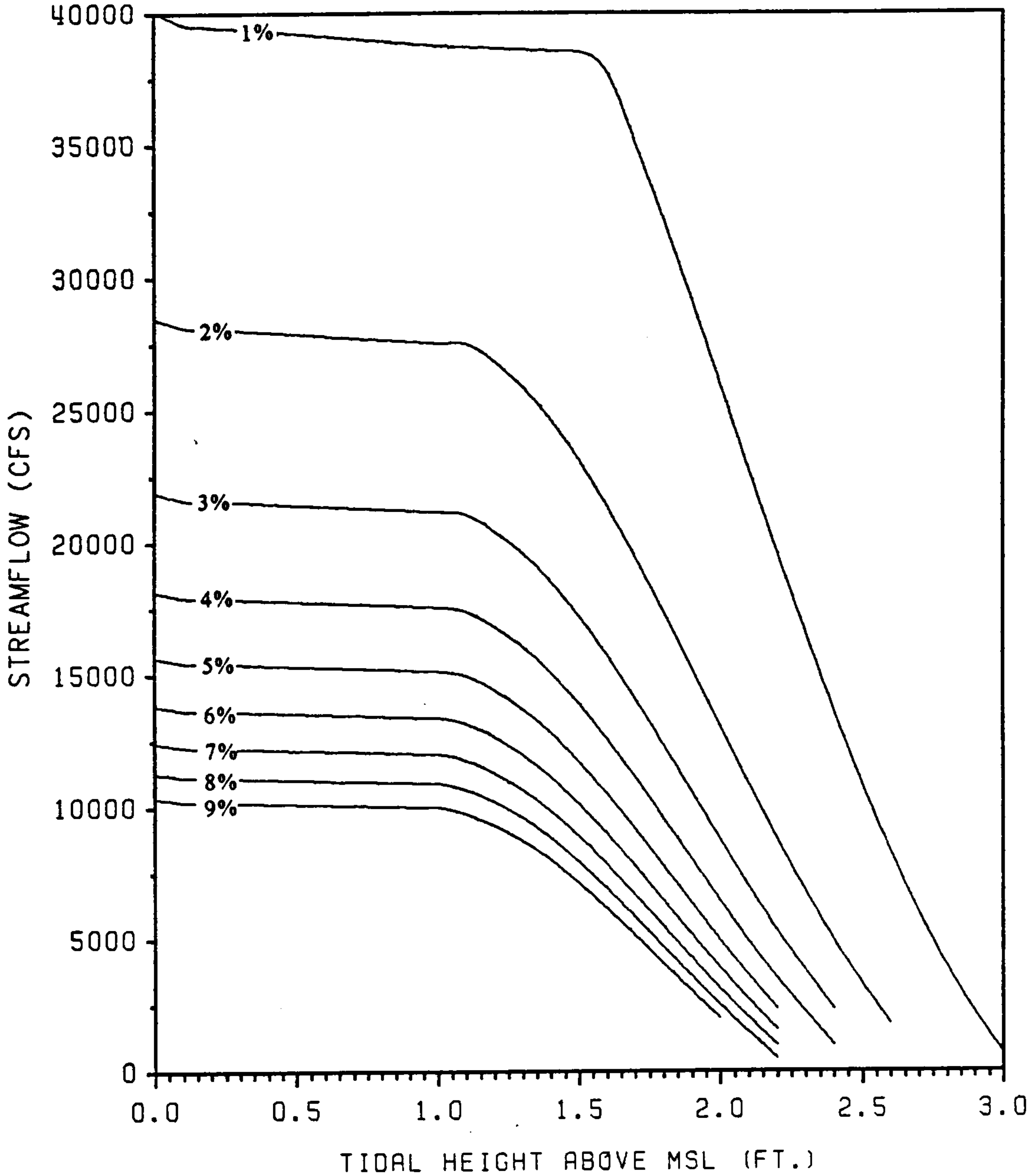

Figure 17. Joint probabilities on the Rappahannock River (1% to 9% probability of exceedance)

While pairs of streamflows and tidal heights were used here, this method may be applicable to other variable pairs which are dependent and have unknown distributions. An example of such a pair would be a large rainstorm moving in from the sea which might also bring with it an associated storm surge. Here again, it is unlikely that the heavy rainfall and the storm surge are independent of one another, yet the unknown distributions of the precipitation and tidal data would make evaluation of the joint probabilities difficult. With the method developed in this study, though, the joint probability of exceedence for any paired set of precipitation and tidal height may be easily calculated. In addition, this procedure provides a method by which boundary conditions may be properly matched. If, for instance, a specific joint probability of exceedence and streamflow are given, the matching tidal height can be determined. Likewise, one can use a given joint probability and tidal height to find the appropriate streamflow.

Although a value indicating the joint probability of exceedence is calculated by the method presented here, the interpretation of this value is not made as readily as it is made for the flood flow or tide frequencies. For these frequency analyses only one flood or one tide has a particular probability of exceedence. On the other hand, many streamflow-tidal height pairs will give a particular joint probability of exceedence. A low flow with a high tidal surge may have the same joint probability as a high flow and a low tidal surge. In between, there would be innumerable combinations of streamflow and tidal surge which also have the same joint probability. The salinity, horizontal velocity and suspended sediment concentration are all affected by the estuary's boundary conditions: streamflow and tidal height. Therefore, the streamflow-tidal height pairs for a particular joint probability of exceedence may affect the estuarine processes in several different ways due to the variability of the boundary conditions.

When considering a flood or tide with a one percent probability of exceedence, it is commonly interpreted to mean that the event has a return period of 100 years. Since the joint probability lacks the uniqueness of the flood flow or tide frequencies, it is not immediately apparent that the same interpretation of the return period is valid. In defining the rate of recurrence of a particular streamflow-tidal height pair, though, the concept of a return period is useful. Care must be taken when calculating this return period for the tidal heights which are used here are monthly extreme high tides not yearly values. Therefore, the inverse of the joint probability of exceedence will give a monthly return period. Dividing this inverse value by twelve will give the yearly return period. When discussing the effects upon the estuarine processes such as the intrusion of saltwater, though, the use of the return period may not be applicable. For example, a low flow and a high tidal surge may have an one percent joint probability of exceedence. The return period for this particular pair is 8.3 (= 100/12) years. Due to this low flow and high tidal surge, the may saltfront shift 15 miles upstream. It would not be proper to assume that a saltwater intrusion of this magnitude has a 8.3 year return period. A low flow paired with a lower tidal surge may have a shorter return period, but the saltwater limit may also be observed to move 15 miles upstream. This situation is very apparent if one looks at the one percent joint probability of exceedence curve in Fig. 17. It is not reasonable to assume the same salinity distribution will be observed over the wide range of streamflows and tidal heights this curve covers. While salinity is used in this example, the same situation might be seen with the horizontal velocity and the suspended sediment concentration.

CHAPTER 4

MODEL SIMULATIONS

To study the effects of sea level rise on the estuarine environment, the boundary conditions of the numerical model are changed to simulate several scenarios. These changes include drought and flood flows at the upstream boundary, and storm surges and sea level rise at the downstream boundary. As a point of reference for the other scenarios, one simulation will have normal streamflow with only the normal astronomic tide. For each of these simulations, streamflow, suspended sediment and tidal records must be used to prepare the input data.

The final three simulations to be presented will show how the joint probability method developed in Chapter 3 can be used to determine the boundary conditions for the model simulations. A single joint probability of exceedence is selected and three sets of boundary conditions are chosen. Although each pair has the same joint probability, the boundary conditions affect the estuarine processes differently. These results reinforce the hesitancy to apply the calculated joint probabilities to specific estuarine conditions.

4.1 BOUNDARY CONDITIONS FOR THE MODEL SIMULATIONS

4.1.1 Upstream Boundary

The conditions at the upstream boundary of the Rappahannock River will determine the river stage, longitudinal velocity, and the concentration of the incoming suspended sediment entered into the numerical model. A general discussion of how this information is derived is contained in Section 2.3.2. What is presented here is based specifically on the Rappahannock River.

First, the values for the normal, drought, and flood flow conditions must be determined. Normal flow is taken as the mean flow recorded at a USGS stream gauging station over the period of record. For the Rappahannock River, the gauging station closest to the upstream boundary is located near Fredericksburg. Over a period extending back to September, 1907, the average discharge has been approximately 1660 cfs (47.0 m^3/s). Information on this stream gaging station is contained in Appendix A.

For the simulation of drought flows, the 10-year, 7-day average low flow is chosen, because it is a commonly used definition of drought conditions. In a study of instream flow analysis methods, 7-day low flows of varying return periods were calculated for 115 Virginia stream gauging stations using the log-Boughton distribution. This study computes the 10-year, 7-day low flow at Fredericksburg to be 53.79 cfs (1.52 m^3/s) (Loganathan, Kuo, and McCormick, 1985).

The opposite extreme to a drought is a flood, and the flood frequency analysis done by HISARS for the Fredericksburg station is shown in Fig. 6. To insure that the streamflow is of a magnitude comparable to the storm surge and sea level rise, a 100-year flood event is chosen. From the flood frequency analysis, a flood of this size would be approximately 123,000 cfs (3480 m^3/s).

These streamflows are converted to their corresponding river stages using a stage-flow diagram plotted from the USGS streamflow data. Figure 18 shows the stage-flow relationship at Fredericksburg over a wide range of flows. As indicated on Fig. 18, the river stage for the 100-year flood flow is 23.3 feet (7.1 m). Figure 19 provides a better idea of the stage-flow relationship for low flows at Fredericksburg. Besides showing the river stage at normal flow to be 2.46 feet (0.75m), a river stage of 0.16 feet (0.05 m) at the 10-year, 7-day average low flow is also shown.

It is assumed that the river cross-sections provided by Kuo *et al.* (1978) are for the Rappahannock River under normal flow conditions. Therefore, the river stage at normal flow will be used as a point of reference. For model simulations of normal flow, the river cross-sections are used as given. During a drought, the river stage falls by 0.70 meters. Since this is less than the two meter thickness of the top layer, no changes are made to the cross-sectional data. Not making these changes maintains the constant layer thickness which exists throughout the depth of the estuary.

For floods, more complicated adjustments are made. Section 2.3.3 discusses the subroutine UPDATE which is used to modify the model's boundary conditions for flood flows. UPDATE not only changes the longitudinal velocity, but it also will add new layers to the top of the estuary to reflect the rising river stage due to the incoming flood waters. These new layers have the same thickness as one another, and for the Rappahannock River, this thickness is set at two meters. This thickness is determined mainly by trial and error. It is important that the new layer thicknesses not be too small for this tends to create computational problems for the model. Since the normal flow stage is 0.75 meters and the incremental layer thickness is two meters, the streamflows at river stages of 2.75 meters, 4.75 meters, and 6.75 meters are determined with Fig. 18. These streamflows are recorded in Table 4.

To know at what time these streamflows occur, a hydrograph is required which will represent the river's response to a 100-year flood flow. Such a flood event did occur in October, 1942. During that flood, the Rappahannock River near Fredericksburg carried a peak flow of 127,000 cfs (3600 m^3/s). Since the 100-year flood is 123,000 cfs, the ordinates of the hydrograph for for the October,

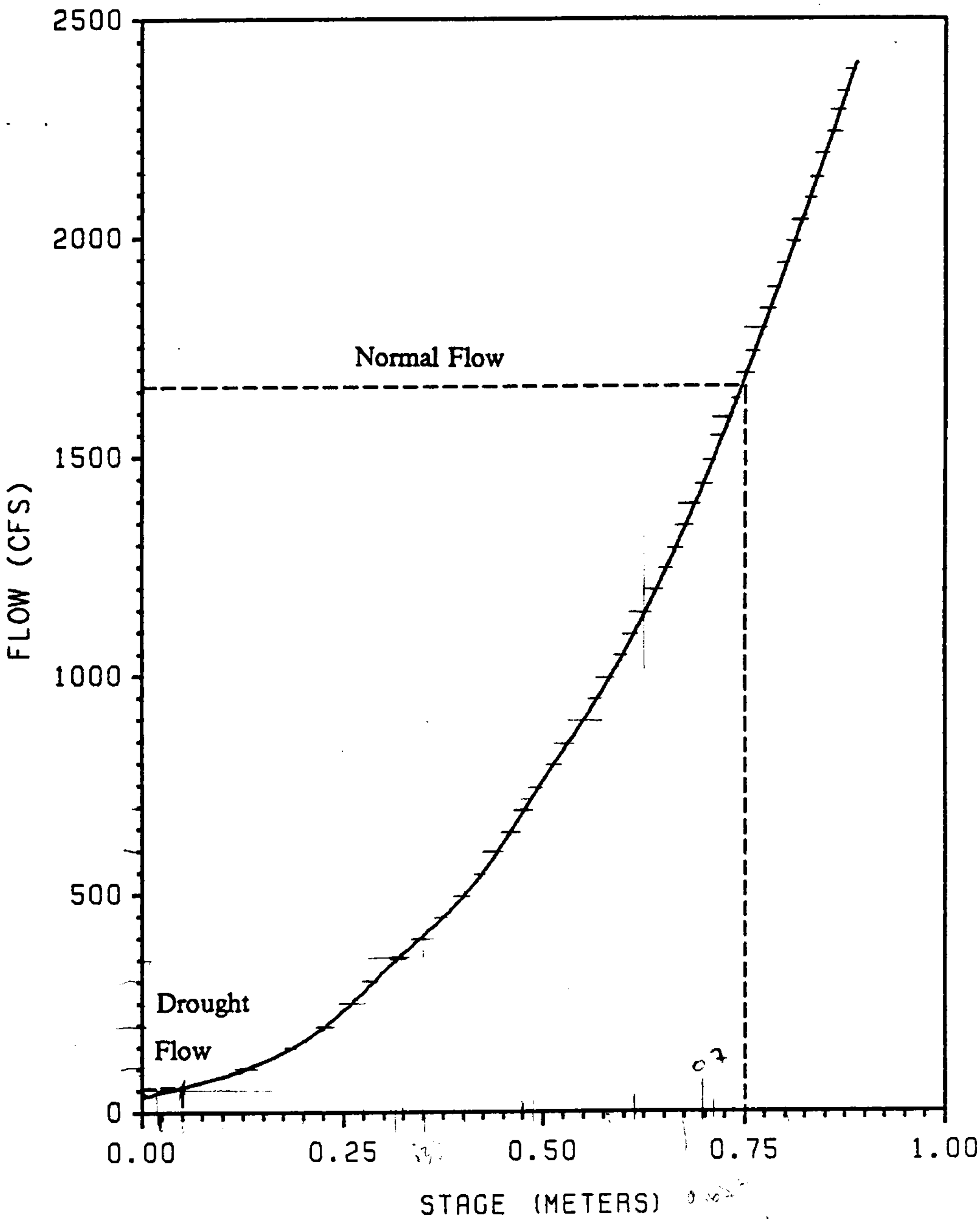

Figure 18. Stage-flow relationship for the Rappahannock River

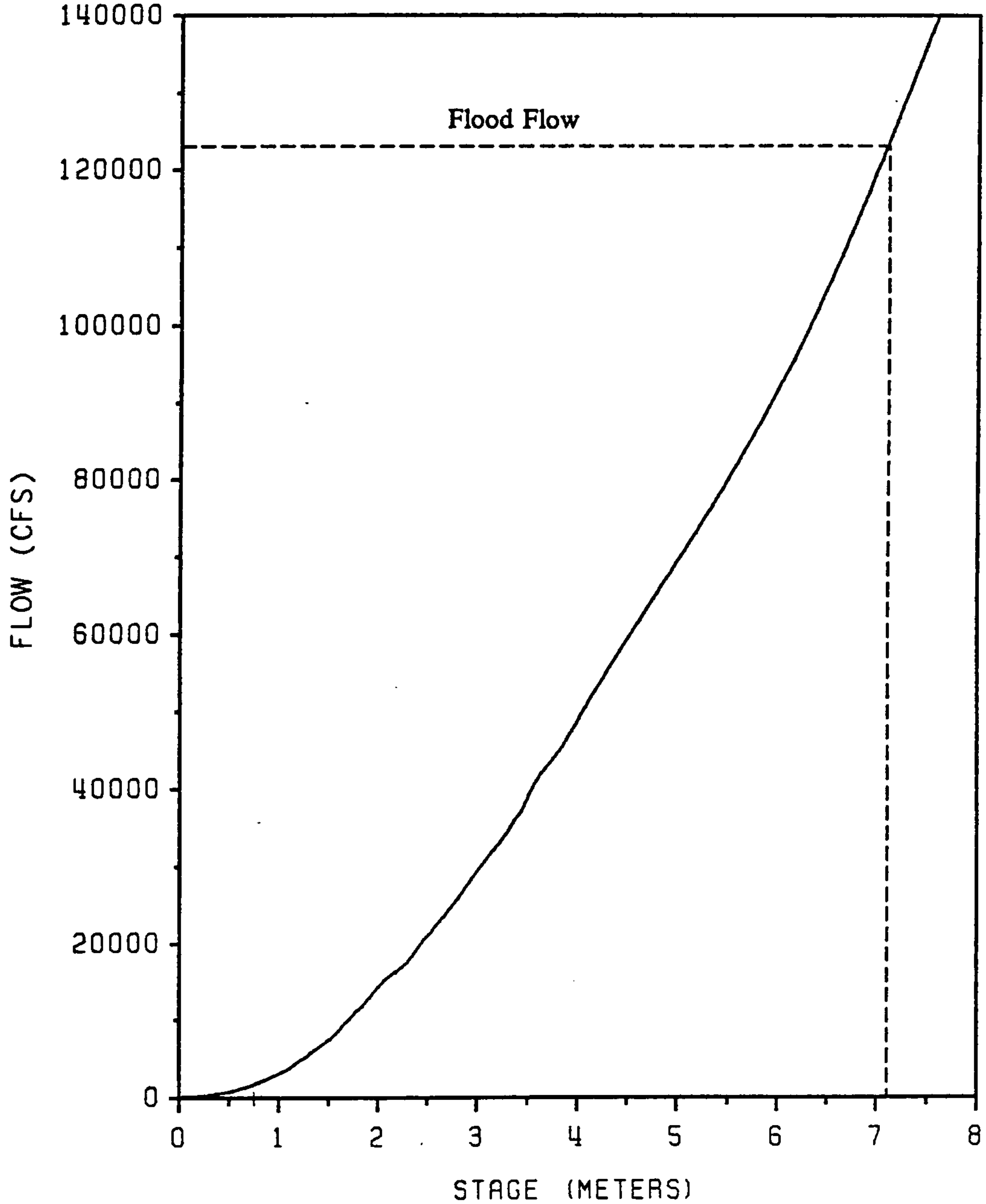

Figure 19. Stage-flow relationship for low flows on the Rappahannock River

1942, flood are reduced by a proportional amount. This results in the hydrograph shown by the dashed line in Fig. 20.

The solid line in Fig. 20 represents the hydrograph used in the model simulation. At t = 0 hours, the river carries a normal flow. At t = 163.6 hours, the hydrograph indicates that the flow has increased to 25,000 cfs (708 m^3/s). Figure 18 shows that at a flow of 25,000 cfs, the river stage is 2.75 meters. Since this is a two meter increase over the original stage, it is time to update the model's upstream boundary condition. The process of locating the time of occurrence for each two meter change in the river stage continues all along the hydrograph. Although the simulation hydrograph has a lower peak than the original hydrograph, this compensated by the fact that this lower peak is maintained for a longer period of time.

The actual data entered into the numerical model is not the incoming streamflow however, but it is the longitudinal velocity at the upstream boundary. To convert the streamflow into a velocity, the changing cross-sectional area at the boundary must be taken into account. As the river rises, the assumption made in Section 2.3.2 for the new top layer is that the riverbanks slope up and away from the river at a 10:1 slope. For a two meter layer thickness, this means the top of the layer will be 40 meters wider that the bottom of the layer to form a trapezoidal cross-section. The numerical model assumes the layers to be rectangular, so instead, the new top layer is made only 20 meters wider than the second layer to give the same cross-sectional area as the trapezoid. As the river stage changes by two meter increments, the streamflow and cross-sectional area are calculated, and the streamflow is divided by the area to give the new longitudinal velocity.

It is assumed that the suspended sediment load also changes each time the flow changes. This requires an estimation of the suspended sediment concentration corresponding to each new streamflow. The stream gauge near Fredericksburg is also a National Stream-quality Accounting Network Station. Since 1977, the suspended sediment concentration in the Rappahannock River has been measured at this station six to eleven times each year. With USGS records available only through 1984, this means that there are only 46 suspended sediment data points. Figure 21 plots

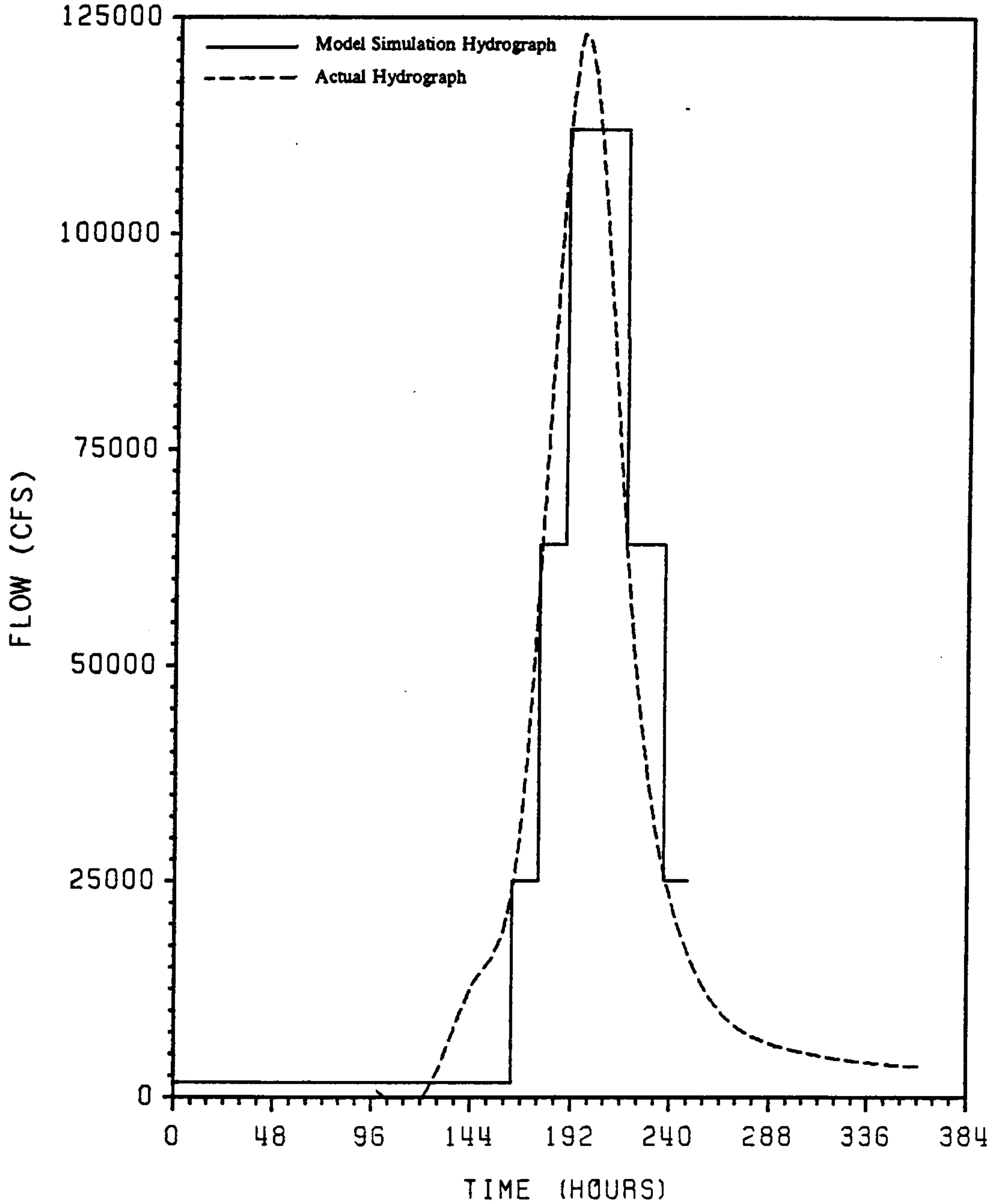

Figure 20. Storm hydrograph for the Rappahannock River

the suspended sediment concentration versus the river's mean flow on the day the sediment sample was taken. The data is widely scattered, and it is nearly impossible to find a satisfactory relationship.

Due to the difficulty in using Fig. 21, certain assumptions are made. A review of the sediment data shows that at the lowest flows the suspended sediment concentration was 1 mg/l, so during a drought flow, the incoming suspended sediment concentration is taken as 1 mg/l. For flows near the normal flow of 1660 cfs, the sediment concentration is approximately 30 mg/l, and this is the upstream boundary condition during normal flows. The highest sediment concentration measured was 718 mg/l at a flow of 2750 cfs (77.9 m^3/s). This data point is so far at of line with the general trend of the data that it is discarded. The next highest measured sediment concentration was 357 mg/l with a flow of 11,500 cfs (325.6 m^3/s). This value is rounded down to 350 mg/l and assumed to correspond to the 100-year peak flow. The rationale here is that the highest sediment load will correspond to the highest streamflow. Between 30 mg/l and 350 mg/l, the sediment concentration is assumed to vary linearly with changes in the streamflow. In other words, a flow which is one-half of the 100-year peak flow will have a suspended sediment concentration one-half of 350 mg/l, or 175 mg/l. It is recognized that these are rough approximations, but the lack of data make the usually difficult task of finding a suspended sediment-streamflow relationship even harder to accomplish. Thus, it is necessary to make some educated guesses.

Complete information on the upstream boundary conditions is listed in Table 4.

4.1.2 Downstream Boundary Conditions

Changes in the downstream boundary condition include the addition of a storm surge and the sea level rise to the astronomic tide already calculated by the numerical model. This astronomic, or normal, tide is computed with the harmonic function presented in Eq. (2.32). As discussed in Section 2.3.1, determination of the tides at the mouth of the Rappahannock River involves the

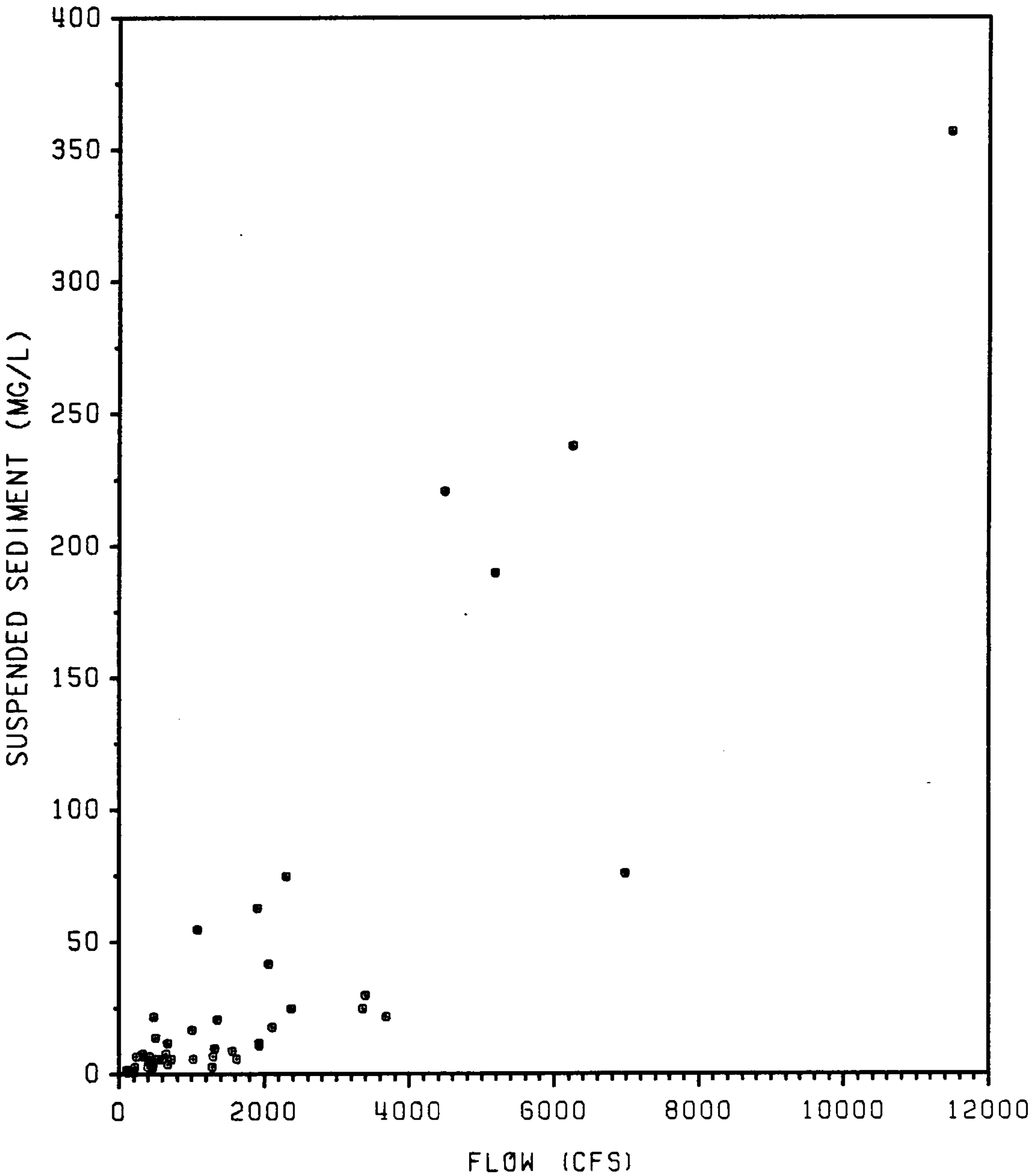

Figure 21. Suspended sediment-streamflow relationship for the Rappahannock River

Table 4. Upstream boundary conditions on the Rappahannock River

a) Normal flow:

Flow (m^3/s)	Longitudinal Velocity (cm/s)	Suspended Sediment (mg/l)
47.0	20.4	30

b) 10-year, 7-day drought flow:

Flow (m^3/s)	Longitudinal Velocity (cm/s)	Suspended Sediment (mg/l)
1.52	0.83	1

c) 100-year flood flow hydrograph and sedimentgraph:

Time (hours)	River Stage (meters)	Flow (m^3/s)	Longitudinal Velocity (cm/s)	Suspended Sediment (mg/l)
0.0	0.75	7.0	20.4	30
163.6	2.75	720.0	180.0	70
175.8	4.75	1891.0	310.0	180
188.3	6.75	3354.0	390.0	320
217.4	4.75	1891.0	310.0	180
236.3	2.75	720.0	180.0	70

substitution of the Hampton Roads tidal constituents into Eq. (2.32) and modifying the result with the tide conversion factor taken from the tide tables. The tidal constituents for Hampton Roads were obtained from NOAA and are listed in Table 5. Information about the Hampton Roads tide gauging station is included in Appendix A.

As for the storm surge, a tide frequency analysis was made for tides at the mouth of the Rappahannock River using a log-Pearson III distribution. Section 3.1 describes the procedure used to make this analysis, and Fig. 7 presents the results of the tide frequency analysis. In order to simulate the most extreme case, a 100-year storm surge was selected. From the frequency analysis, a storm surge of this size would be 4.06 feet (123.75 cm). This is the storm surge value used in Eq. (2.33).

The sea level rise is the third component of the downstream boundary. There are many predictions of the rate of sea level rise from which to choose as boundary conditions. An Environmental Protection Agency (EPA) report, though, reviewed the pertinent literature and developed a consensus opinion among the many projections (Hoffman, Keyes and Titus, 1983). The low and high sea level rise estimates are selected from this report so that a range of situations can be studied. Also, the projected increases in the sea level for the years 2025 and 2075 are chosen to see how conditions in the estuary change over time. These estimates, listed in Table 5, refer to water levels along ocean shorelines. The sea level rise estimates are routed into the Chesapeake Bay by adding the increased sea level to the astronomic tide at Hampton Roads and multiplying this sum by a tide conversion factor. Section 2.3.1 explains this procedure as it is applied in Eq. (2.33).

4.1.3 Selection of the Model Simulations

Table 6 gives a complete review of the boundary conditions for each model simulation made for the Rappahannock River. The number of tidal cycles for which each simulation was run is also

Table 5. Downstream boundary conditions on the Rappahannock River

a) Tidal constituents at Hampton Roads, Virginia:

Constituent	Amplitude (cm)	Phase Angle (degrees)	Tidal Frequency (degrees/hour)
M_2	36.1	262.1	28.9841
S_2	6.9	285.4	30.0000
N_2	7.9	244.8	28.4397
K_1	5.0	127.8	15.0411
O_1	4.3	315.6	13.9470

Multiply the Hampton Road tides by 0.44 to convert to Windmill Point on the Rappahannock River.

b) Storm Surge:

100-year storm surge = 123.75 cm

c) Sea level rise predictions:

Year	Low Estimate	High Estimate
2025	5 in. (13 cm)	22 in. (55 cm)
2075	15 in. (38 cm)	83 in. (211 cm)

Sea level rise predictions refer to the sea level as of 1980.

listed. The numerical model results used for the plots shown later in this chapter are taken from the last tidal cycle of each model run.

In selecting the boundary conditions for the model simulations, there many valid combinations which could be chosen. The simulations selected for this study involve extreme conditions at the upstream and downstream boundaries. This should define the limits of change within the estuary due to sea level rise. Other combinations of streamflow, storm surge, and sea level rise would give results falling within these limits. Another reason for limiting the model runs to extreme cases is the prohibitive costs of the computer time needed to run the numerical model. For a simulation covering ten tidal cycles, the CPU time averaged three minutes. Twenty tidal cycles required six minutes of CPU time, and the extended simulation took over ten minutes to complete 35 tidal cycles.

4.1.4 Other Input Data

Besides the upstream and downstream boundary conditions, other information is needed to run the numerical model. This information includes the characteristics of the suspended sediment, the geometry of the estuary, and the hydraulics of the channel. This data was provided by the Virginia Institute of Marine Science (VIMS), and it is presented in Tables 7, 8 and 9.

Table 7 gives the values for many of the variables needed to calculate the density, salinity and suspended sediment concentration. Table 8 lists the value of the Manning's friction coefficient n and the surface storage area in millions of square meters for each transect. The surface storage area as

Table 6. Model simulations for the Rappahannock River

Model Simulation Number	Upstream Boundary Condition	Downstream Boundary Condition	Number of Tidal Cycles Simulated
1	Normal flow	Normal tide	10
2	10-yr.,7-day drought flow	Normal tide, 100-yr. storm surge, 13 cm sea level rise	10
3	10-yr.,7-day drought flow	Normal tide, 100-yr. storm surge, 38 cm sea level rise	10
4	10-yr.,7-day drought flow	Normal tide, 100-yr. storm surge, 55 cm sea level rise	10
5	10-yr.,7-day drought flow	Normal tide, 100-yr. storm surge, 211 cm sea level rise	10
6	100-yr. flood flow	Normal tide, 100-yr. storm surge, 13 cm sea level rise	20
7	100-yr. flood flow	Normal tide, 100-yr. storm surge, 38 cm sea level rise	20
8	100-yr. flood flow	Normal tide, 100-yr. storm surge, 55 cm sea level rise	20
9	100-yr. flood flow	Normal tide, 100-yr. storm surge, 211 cm sea level rise	20
10	10-yr.,7-day drought flow	Normal tide, 13 cm sea level rise	35
11	1580 cfs (44.7 m^3/s) inflow	2.00 foot (61.0 cm) tide	10
12	5540 cfs (157 m^3/s) inflow	1.60 foot (48.8 cm) tide	10
13	9270 cfs (262 m^3/s) inflow	0.85 foot (25.9 cm) tide	10

illustrated in Fig. 22 includes coves and shoals along the estuary which are set off from the flow of the river. The numerical model assumes that these areas are shallow and have a depth equal to the thickness of the top layer. Table 9 lists the width of each layer in each transect of the Rappahannock River.

4.2 RESULTS AND DISCUSSION

Using the boundary conditions and other data discussed in Section 4.1, the numerical model is run for each of the scenarios listed in Table 6. For each computer simulation, distributions are plotted for three quantities: salinity, horizontal velocity, and suspended sediment concentration. Appendix E contains the output results from the last tidal cycle of the model run, and it is this data which is used in these graphs. Since it is difficult to make comparisons from the individual plots, one salinity and one horizontal velocity value are selected for comparison. No similar comparison is made for the suspended sediment because different sediment loads are carried by the normal, drought, and flood flows.

4.2.1 Normal Case

The normal case studies the estuary's response to a normal streamflow and a normal astronomic tide. To give one an idea of the frequency of such a condition, the joint probability of exceedence computed by the method shown in Chapter 3 is 0.495. This gives a return period of 0.2 years. Figures 23, 24 and 25 show the salinity, horizontal velocity and sediment concentration respectively. These figures illustrate the estuarine conditions at the end of the tenth tidal cycle. At that time, the flood tide is entering the estuary. This case is used as a point of reference, and it shows that the saltwater intrudes approximately 35 miles (56 km) up the Rappahannock River. The horizontal velocities in Fig. 24 show the effects of the density difference between the freshwater and

Table 7. Input data for the model simulation for the Rappahannock River

a) Time Step, Δt = 46 seconds

b) Water Temperature, T = 20° C

c) Wind Speed = 0.0

d) Wind Wave Characteristics

Wave height = 0.
Wave period = 0.
Wave length = 0.

e) Initial Salinities

Upstream boundary = 0 ppt
Downstream boundary = 24 ppt
Saltwater intrusion ends at transect number 25

f) Suspended Sediment:

Suspended sediment concentration at downstream boundary = 0 mg/l
Critical shear stress of deposition τ_d = 0.3 dyne/cm^2
Critical shear stress of resuspenion τ_e = 0.5 dyne/cm^2
Resuspension constant M = 0.3 μg/cm^2/sec

g) After the flood tide begins, ocean conditions are reached at the mouth of the estuary after 5 hours.

Table 8. Manning's friction coefficients and surface storage areas

Transect Number	Mannings Coefficient	Surface Storage Area(x 10^6 m^2)
2	0.0200	0.000
3	0.0200	0.000
4	0.0200	0.000
5	0.0200	0.000
6	0.0200	0.000
7	0.0200	0.000
8	0.0200	0.500
9	0.0200	0.800
10	0.0150	0.600
11	0.0150	0.900
12	0.0150	5.060
13	0.0150	1.280
14	0.0150	0.790
15	0.0150	1.000
16	0.0150	1.300
17	0.0150	3.300
18	0.0150	3.680
19	0.0150	3.890
20	0.0150	9.770
21	0.0150	12.830
22	0.0150	10.000
23	0.0150	6.130
24	0.0150	2.900
25	0.0150	5.800
26	0.0150	2.000
27	0.0150	9.400
28	0.0150	4.000
29	0.0150	0.000
30	0.0150	2.550
31	0.0150	3.570
32	0.0150	33.100
33	0.0150	3.450
34	0.0150	6.160
35	0.0150	6.100
36	0.0150	0.000

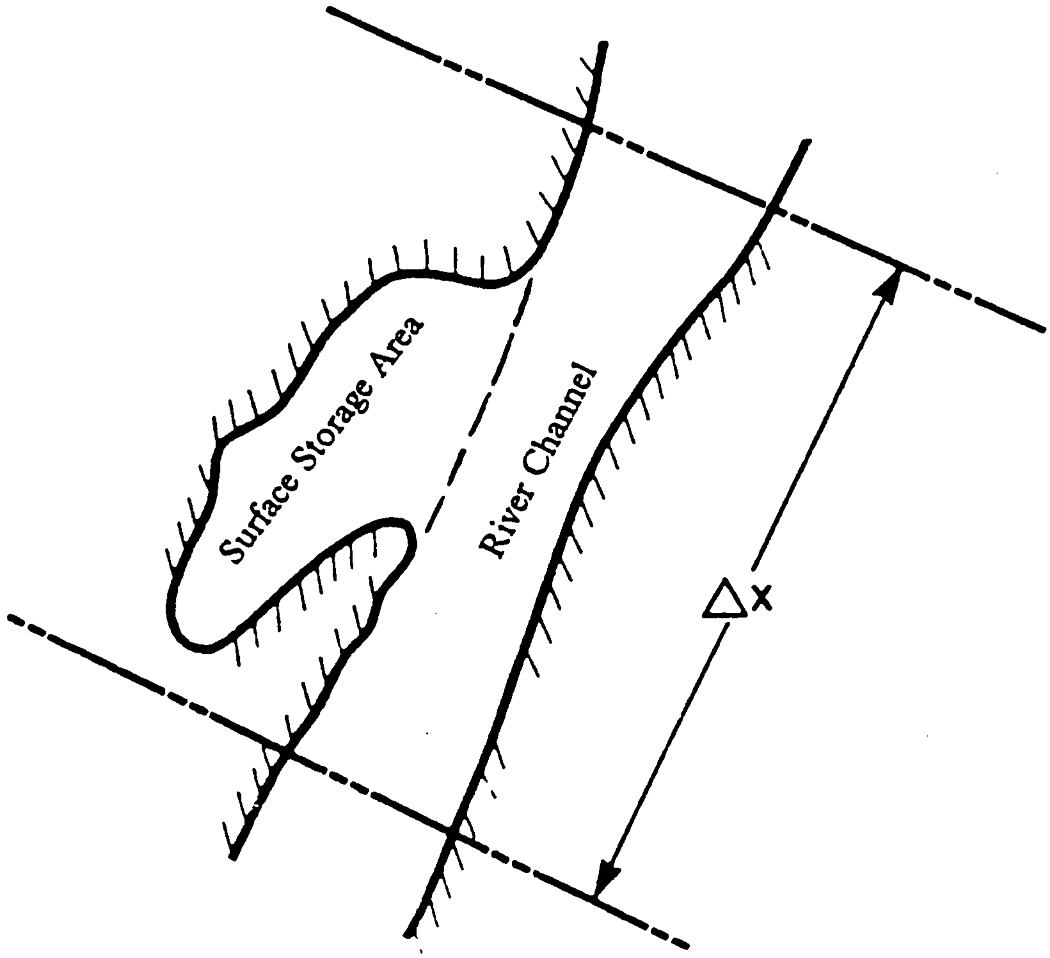

Figure 22. Illustration of the surface storage area

Table 9. Estuary widths for the Rappahannock River in meters

Transect	Layer									
	1	2	3	4	5	6	7	8	9	10
2	65	50								
3	82	50								
4	89	49								
5	103	57								
6	119	69								
7	109	70	35							
8	117	91	47							
9	153	118	39							
10	146	119	68							
11	197	140	45							
12	210	154	42							
13	383	201	23							
14	235	199	143	78						
15	306	268	142	68						
16	510	291	132	24						
17	291	239	200	145	104					
18	475	306	196	132	90					
19	430	342	250	122						
20	567	396	238	57						
21	897	461	185							
22	1199	500	111							
23	1361	546	205							
24	1879	685	234	78						
25	2347	924	345	255						
26	3617	1270	587	357						
27	3102	1410	739	511	128					
28	4043	2209	864	642	498					
29	4038	2914	1372	835	768	606	296			
30	4230	3382	2113	1329	1071	703	433			
31	3566	3068	2016	1742	1596	791	589			
32	2720	2309	1810	1501	1120	974	793	602	396	198
33	4390	3734	3190	2347	1195	491	395	357	299	251
34	4167	3073	2475	2230	1793	1280	944	704	475	256
35	4417	3431	2989	2059	1593	1198	902	747	506	278
36	4400	2730	1585	1378	686	216	72			

the saltwater. The lighter freshwater rises over the denser saltwater, and this causes the streamflow to ride over the water carried in by the tide. In Fig. 24, this effect is shown by the intrusion of negative velocities into the lower layers of the estuary near the mouth of the river.

The point of zero horizontal velocity, the null point, is located far downstream from the limit of saltwater intrusion. For this study, the saltwater limit is defined as the 1 ppt isochlor, that line along which the salinity is 1 ppt. The null point and saltwater limit are generally observed to be located at the same spot, but in their study, Kuo *et al.* (1978) noticed this same discrepancy. According to their explanation, the estuary bed quickly rises as one moves upstream from the river mouth. This sudden contraction of the estuary's depth retards the upstream net movement of water. To check their hypothesis, they ran the model for a river of constant depth and found that the model does indeed simulate the coincidence of the null point and saltwater limit.

From Fig. 25, the suspended sediment concentration is shown to fall below 1 mg/l about one-third of the way down the estuary. At a point about 35 miles (56 km) from the river mouth, the suspended sediment concentration increases. This point is near the null point where the river flow moving downstream meets the incoming saltwater from the Chesapeake Bay. This increases the vertical velocities and causes the resuspension of the sediment.

4.2.2 Drought Case

The figures for the drought scenarios are taken from the computer results at the end of the tenth tidal cycle. Just as for the normal case, a flood tide is entering the estuary at this time. Judging by the joint probability of exceedence (0.0001), a drought flow paired with 100-year storm surge is a very rare event, but it useful in that it represents the worst case for saltwater intrusion. Figures 26, 27, 28 and 29 show the salinity distribution for each of the four sea level rise scenarios. Comparing the figures with the normal case (Fig. 23), it is seen that there is an upstream movement of the limit of saltwater intrusion. With the decreased streamflow that occurs with a drought, and the

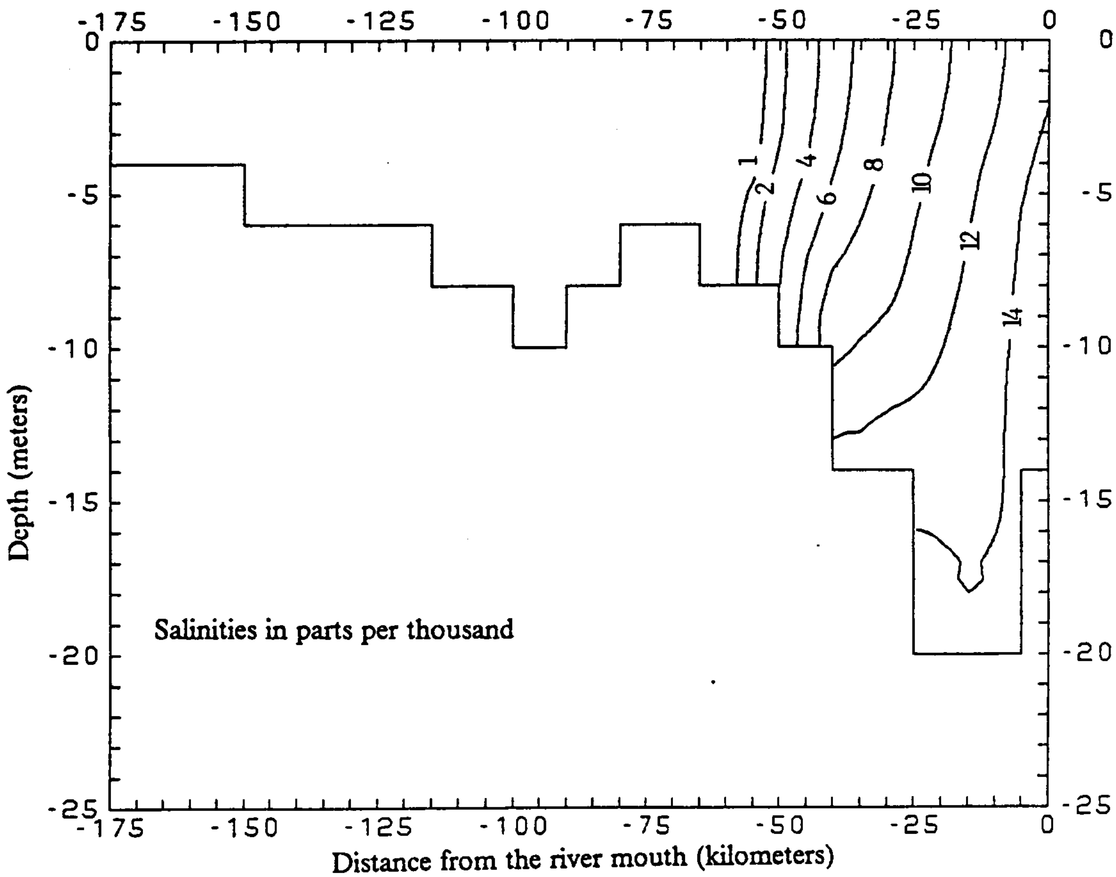

Figure 23. Salinity distribution for normal flow and normal tide

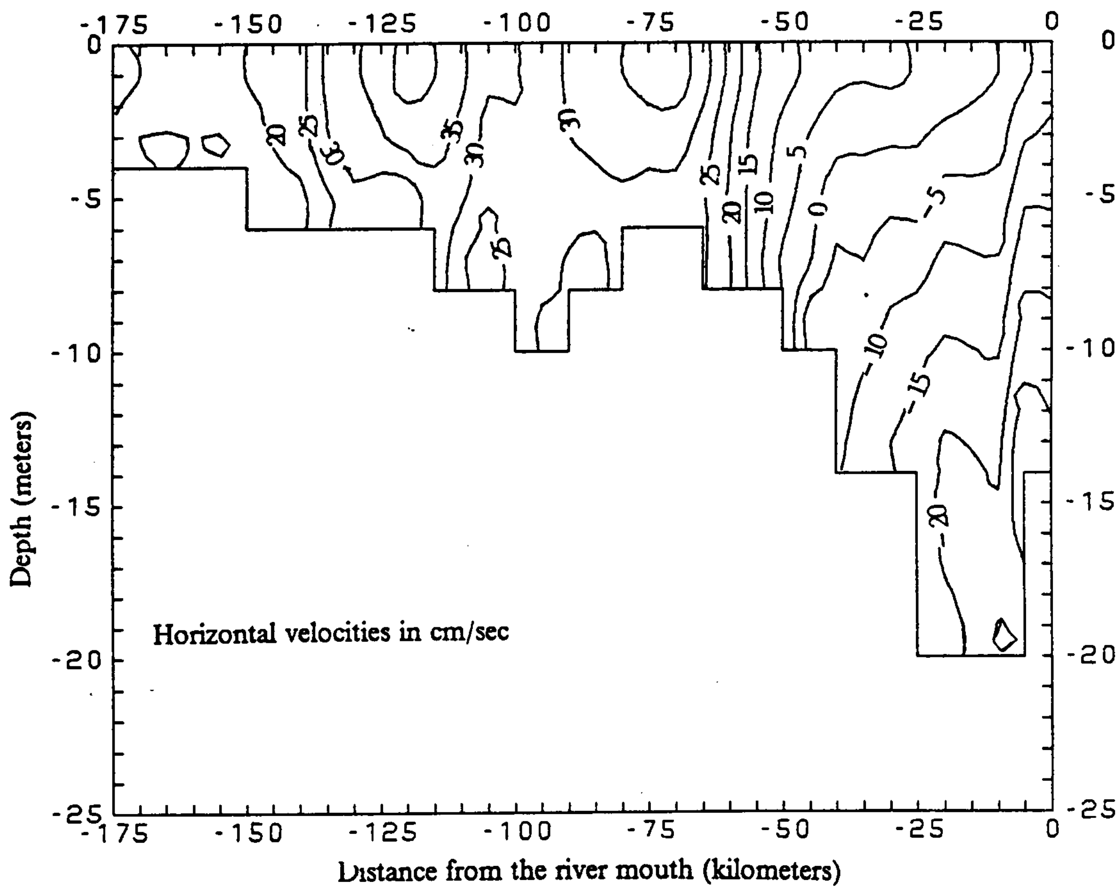

Figure 24. Horizontal velocity distribution for normal flow and normal tide

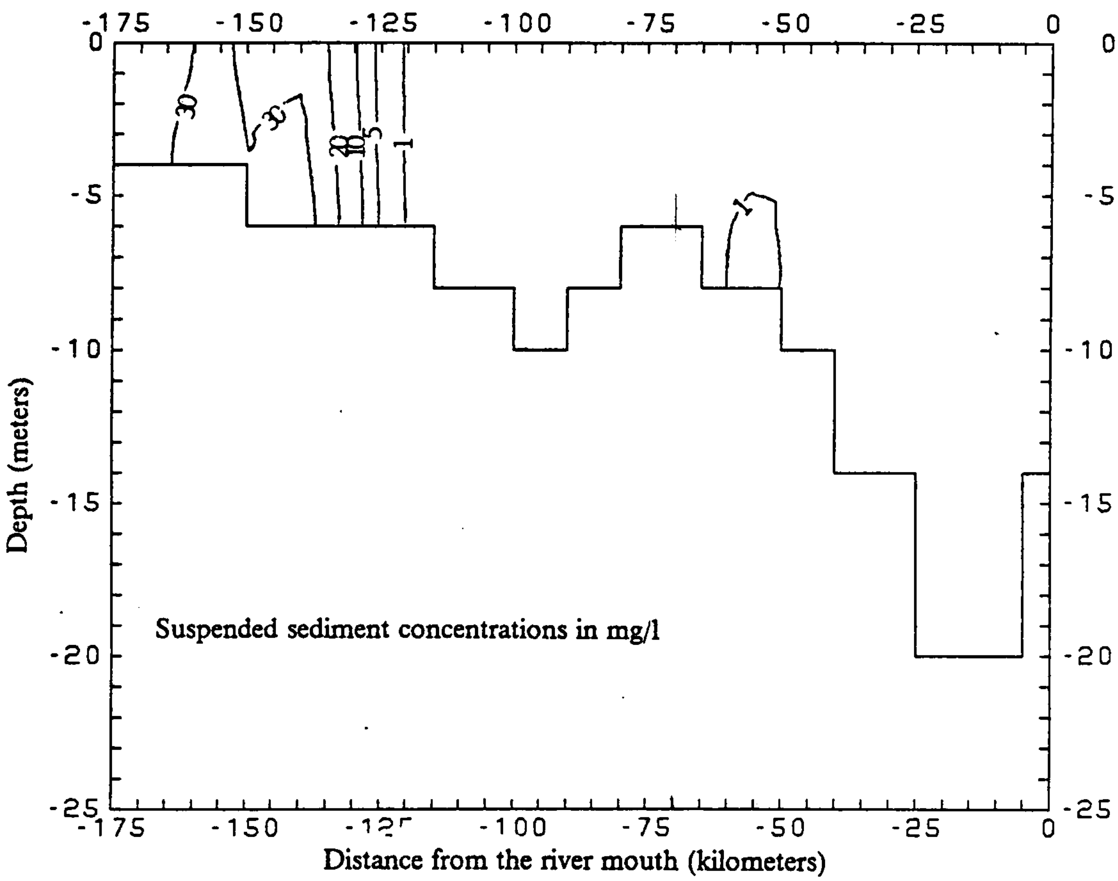

Figure 25. Suspended sediment distribution for normal flow and normal tide

storm surge and the sea level rise, it is expected that the saltwater would move further into the estuary. While the saltwater limit move further upstream as the sea level increases, there is little difference in the salinity distributions for the 13 cm, 38 cm ,and 55 cm sea level rise cases. The largest movement of the saltwater front occurs with.the 211 cm sea level rise. In this scenario, the saltwater limit moves 18 miles (30 km) beyond the limit shown in Fig. 23.

Looking at the velocity distributions in Figs. 30, 31, 32 and 33, a similar situation takes place. The null point does shift upstream during a drought, but little difference is seen between the 13 cm, 38 cm, and 55 cm sea level rise simulations. Again, the biggest movement comes with the 211 cm sea level rise. Most of the movement of the null point observed during a drought occurs near the estuary bed. At the free surface, the null point shifts upstream by only a couple of miles, but at the streambed, the null point moves as much as 7 miles (11 km) upstream in the case of the 211 cm sea level rise. This is attributable to the upstream movement of the denser saltwater through the lower layers of the estuary.

Because the suspended sediment loads are different, it is impossible to compare the suspended sediment concentrations from the normal and drought cases. Instead, some remarks can be made on the general pattern of the suspended sediment distributions shown in Figs. 34, 35, 36 and 37. The sediment concentration generally decreases as the flow moves downstream. An exception can be seen at a point about 35 miles (56 km) from the river mouth. Just as in the normal case, this area is near the null point where the increased turbulence can cause the sediment to be resuspended.

4.2.3 Flood Case

The flood case considers the results of a 100-year flood matched against a 100-year storm surge and heightened sea level. The first ten tidal cycles of the model simulation are run with a constant in-flow. Between the tenth and twentieth tidal cycles, a hydrograph is used to simulate the inflow. The results shown in the figures are taken at the end of the twentieth tidal cycle. At that time, the

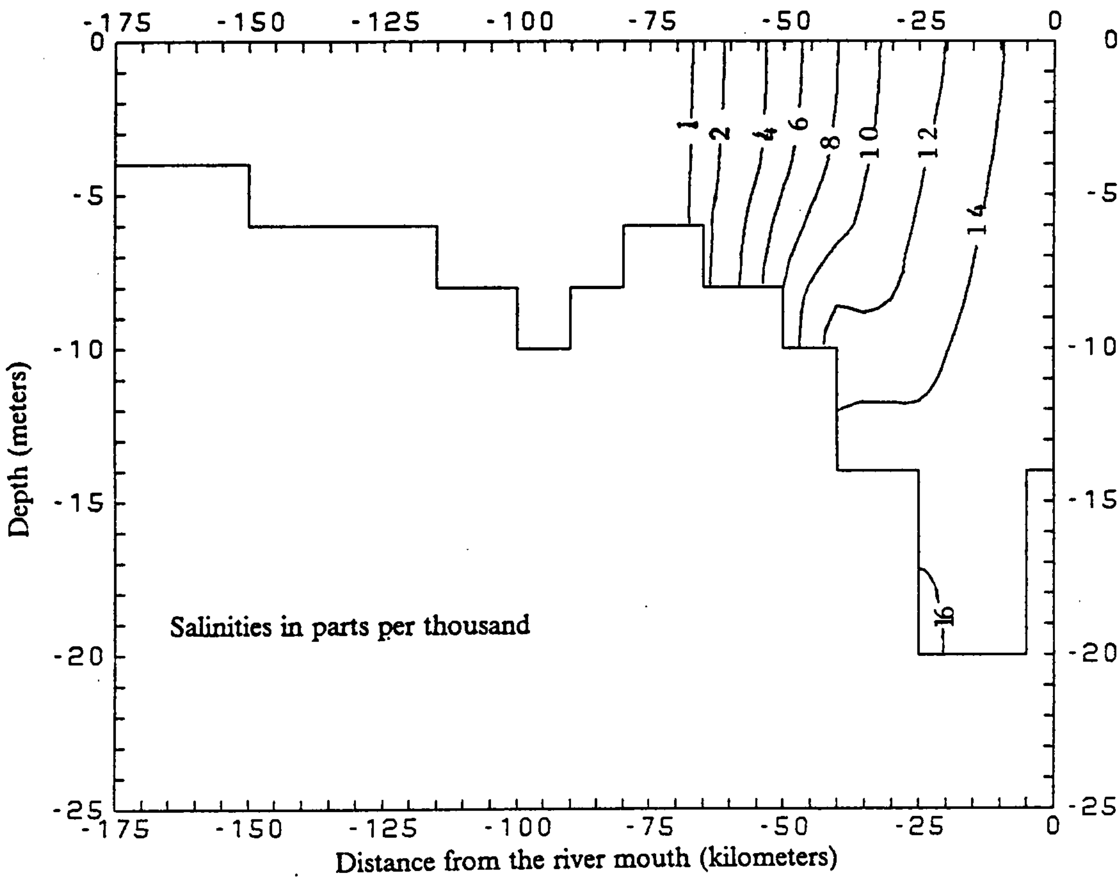

Figure 26. Salinity distribution: drought with storm surge and 13 cm sea level rise

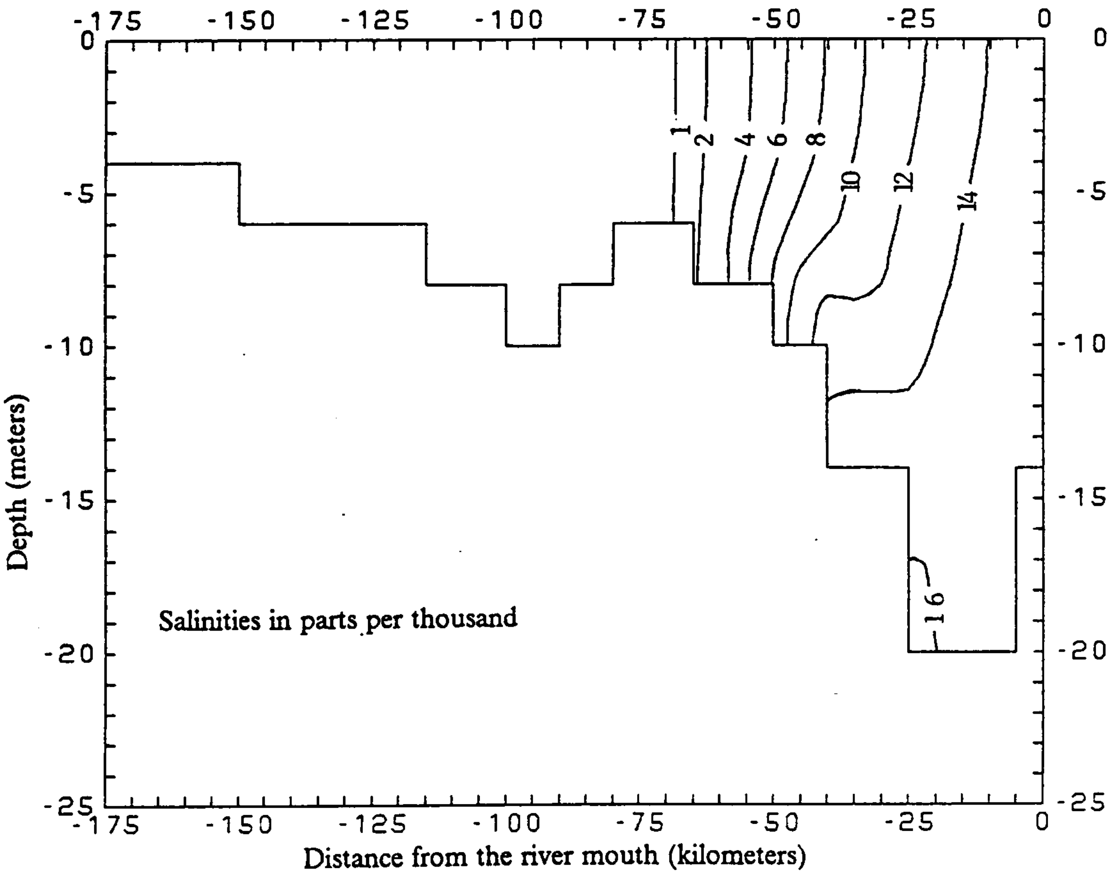

Figure 27. Salinity distribution: drought with storm surge and 38 cm sea level rise

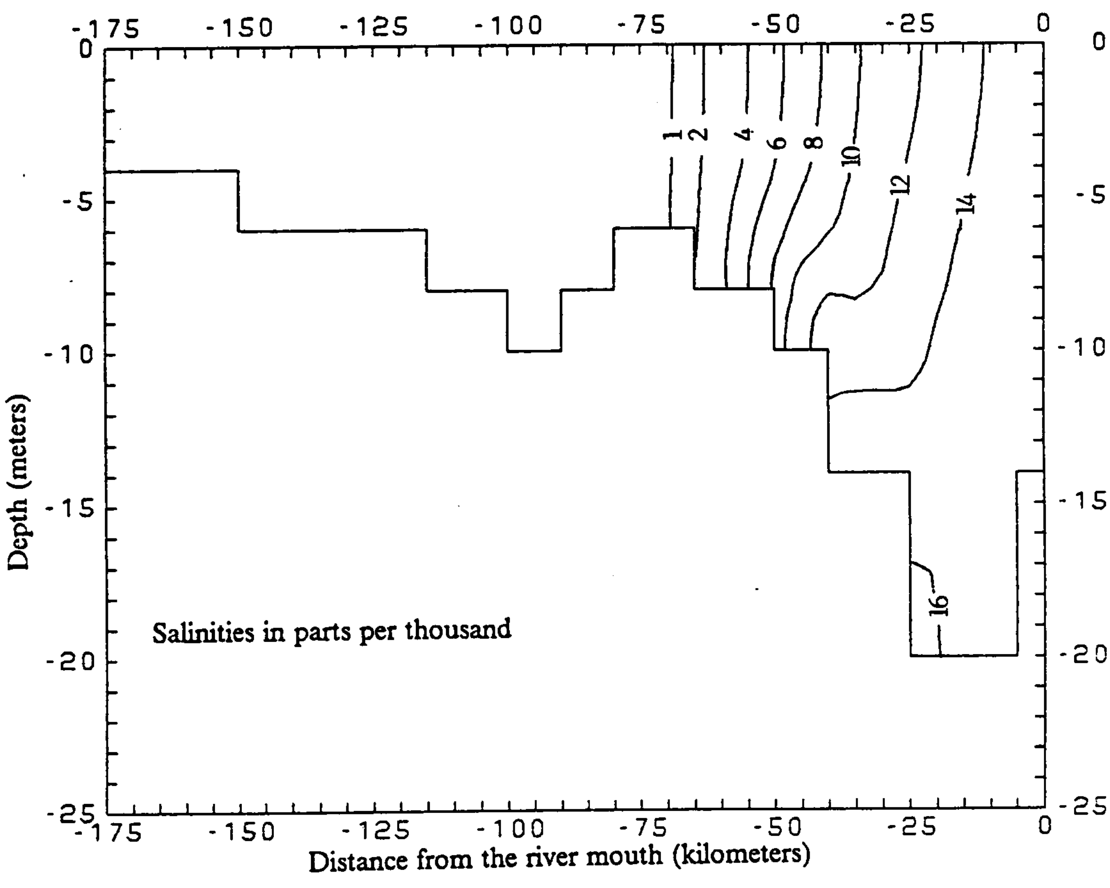

Figure 28. Salinity distribution: drought with storm surge and 55 cm sea level rise

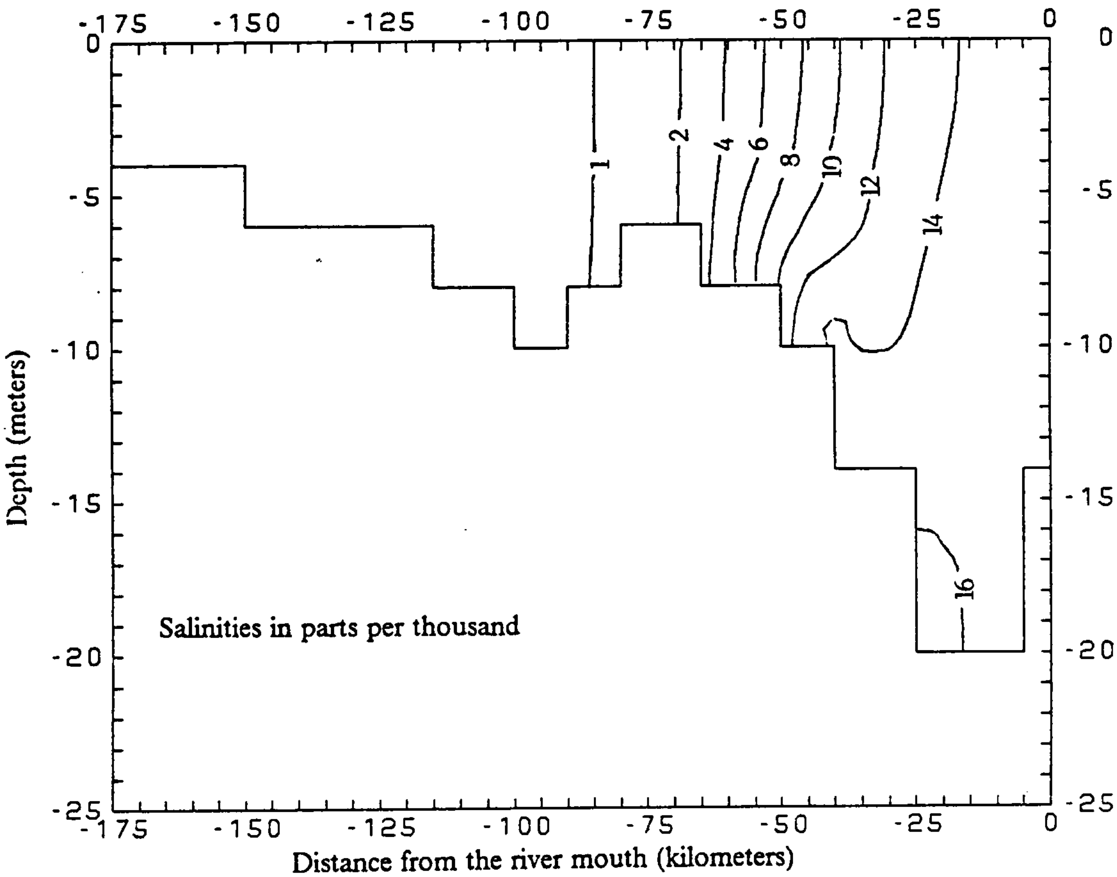

Figure 29. Salinity distribution: drought with storm surge and 211 cm sea level rise

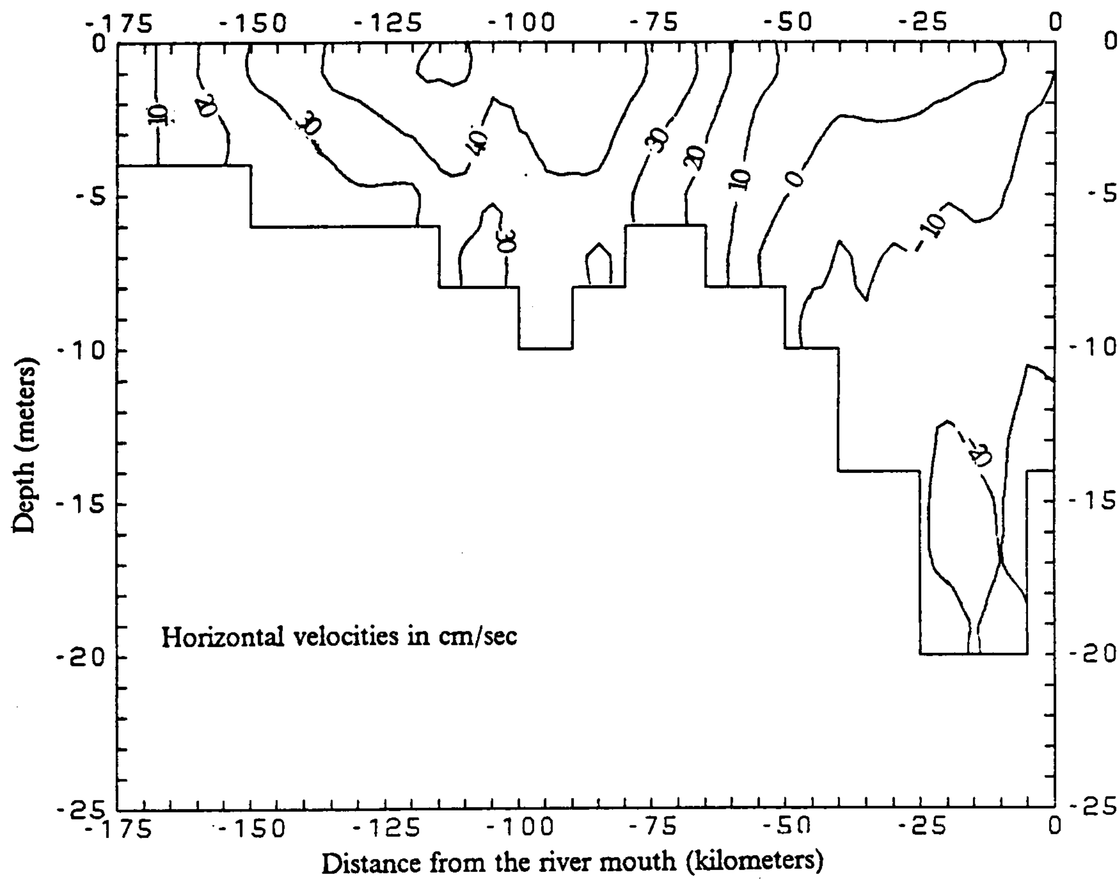

Figure 30. Horizontal velocities: drought with storm surge and 13 cm sea level rise

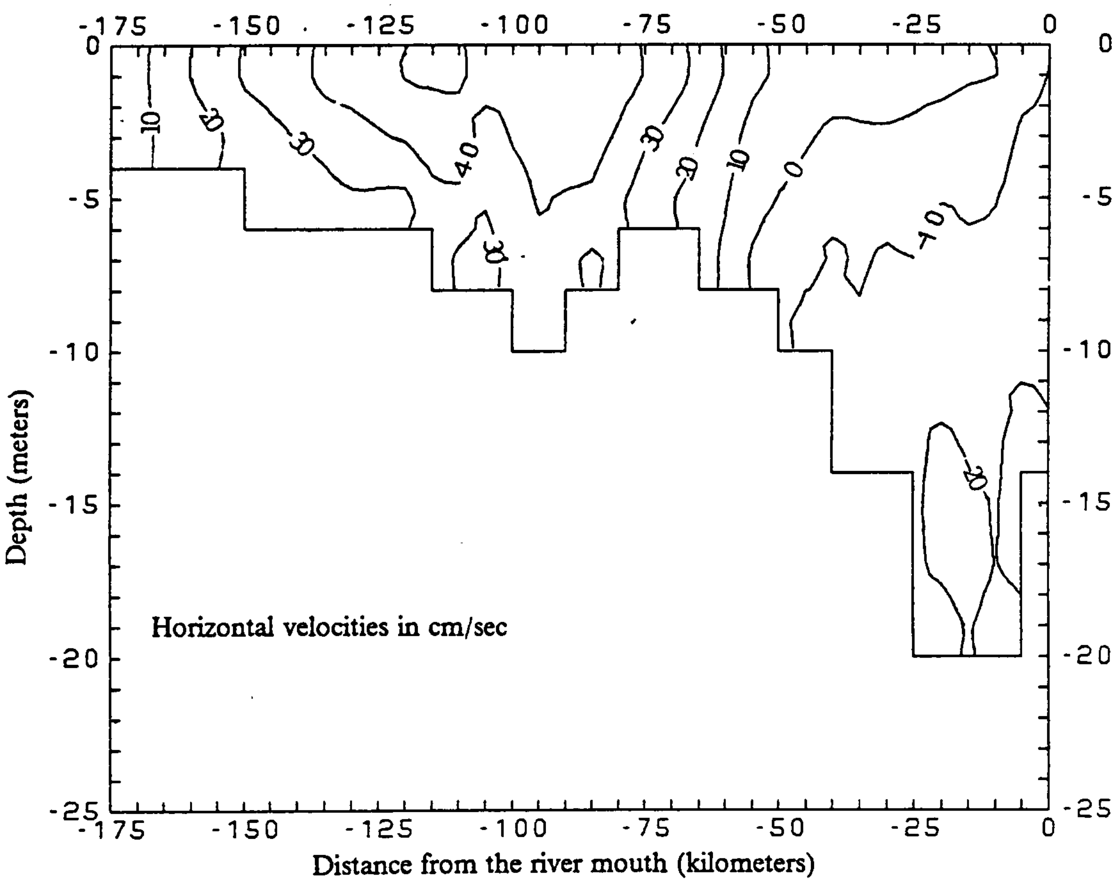

Figure 31. Horizontal velocities: drought with storm surge and 38 cm sea level rise

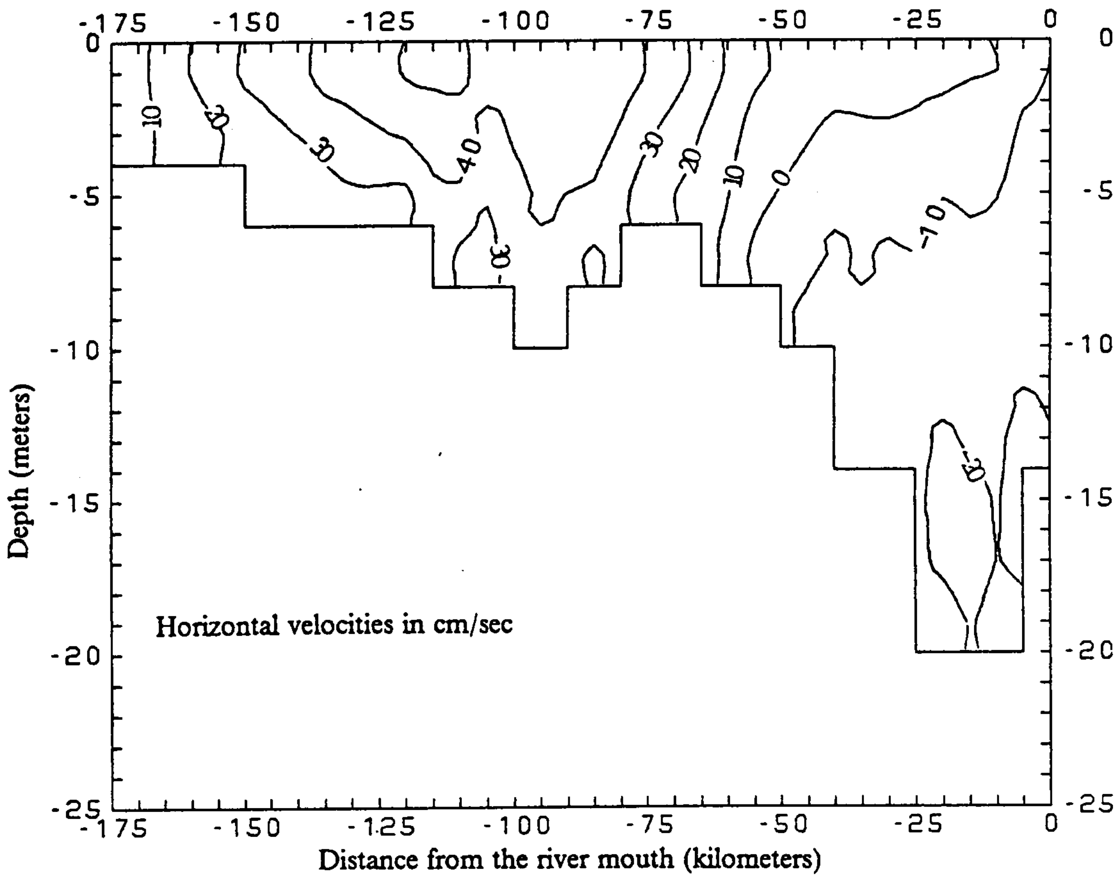

Figure 32. Horizontal velocities: drought with storm surge and 55 cm sea level rise

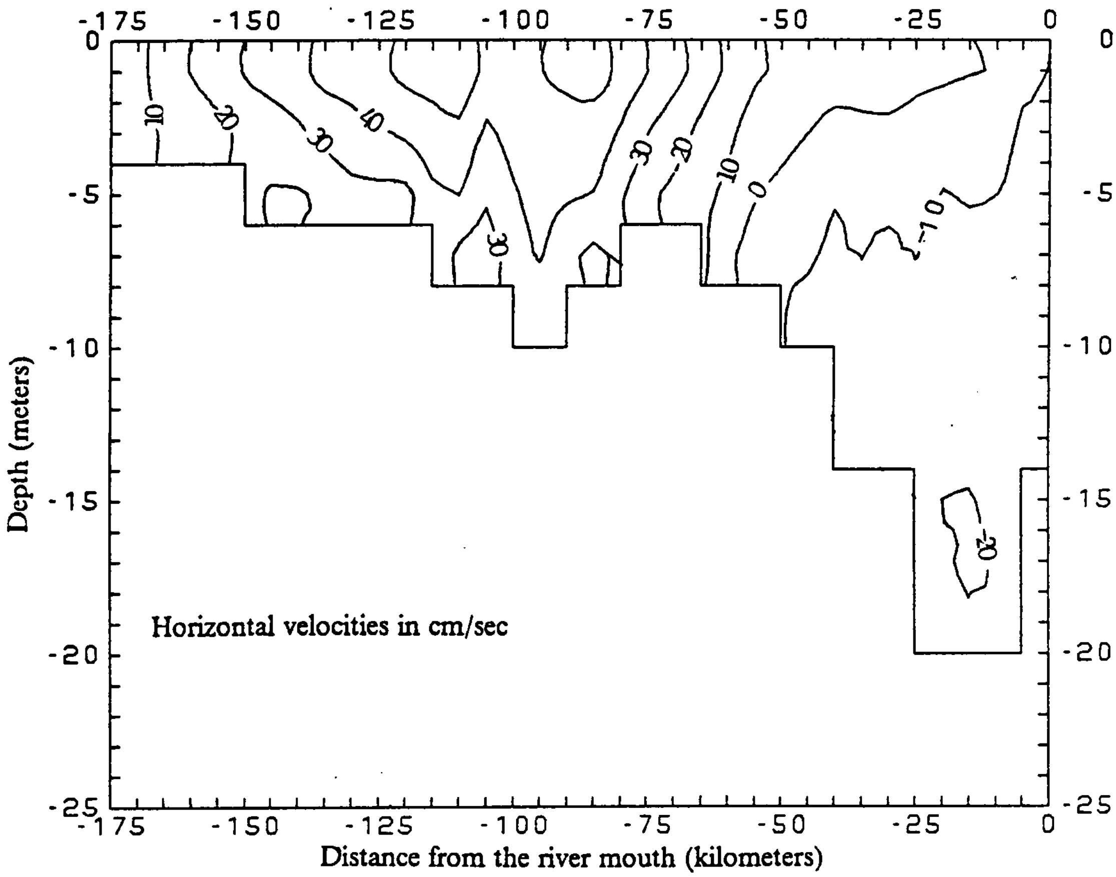

Figure 33. Horizontal velocities: drought with storm surge and 211 cm sea level rise

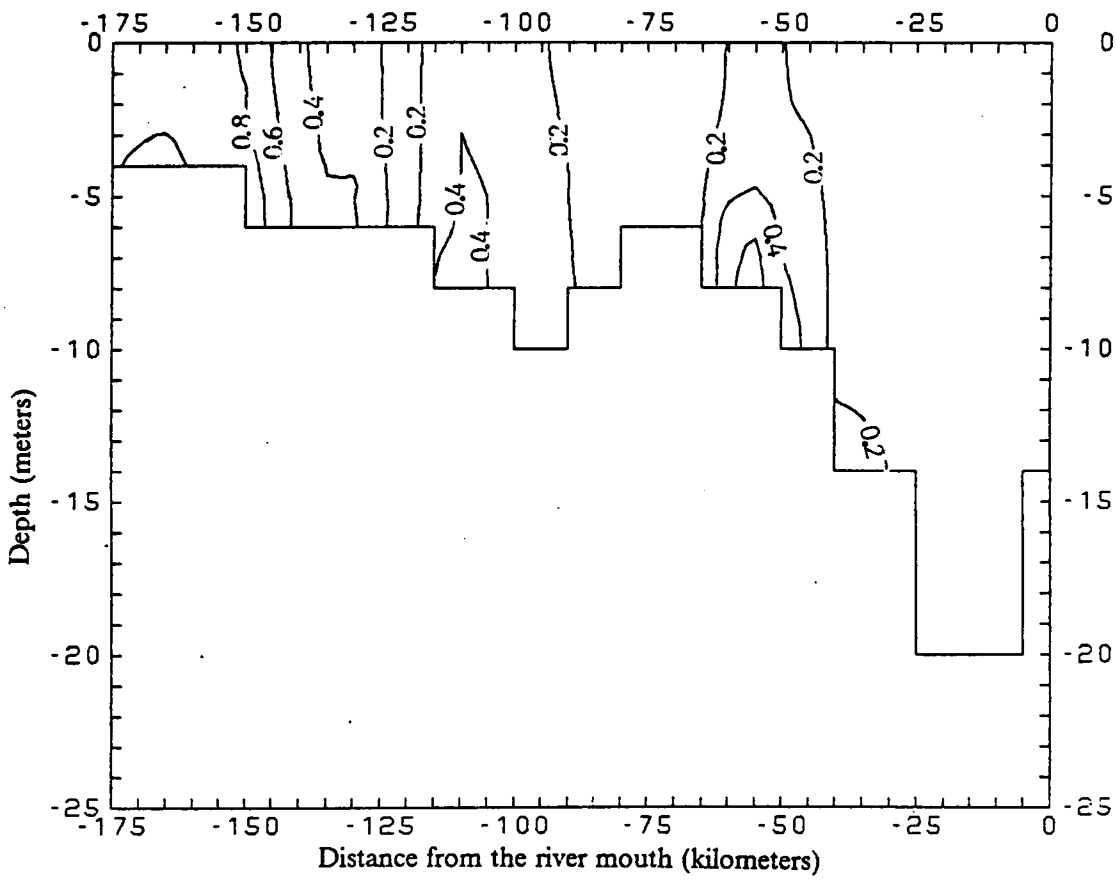

Figure 34. Sediment concentrations: drought with storm surge and 13 cm sea level rise

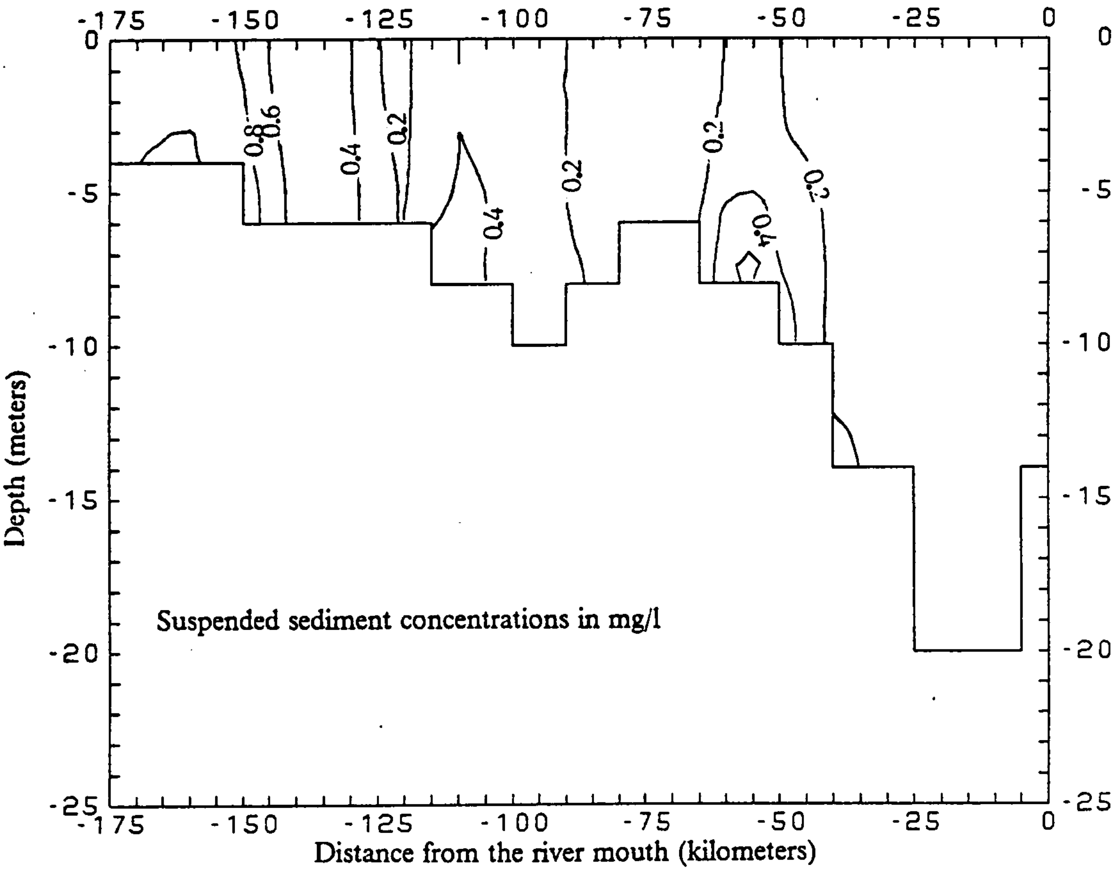

Figure 35. Sediment concentrations: drought with storm surge and 38 cm sea level rise

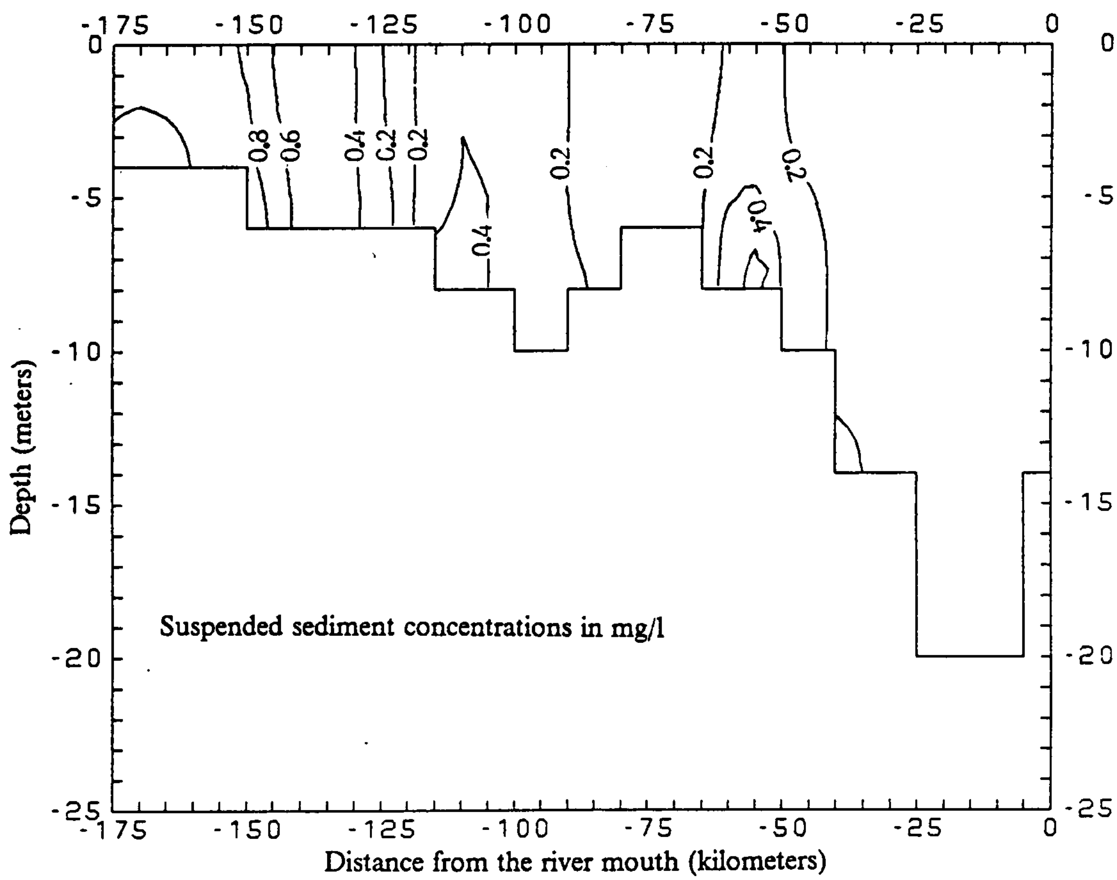

Figure 36. Sediment concentrations: drought with storm surge and 55 cm sea level rise

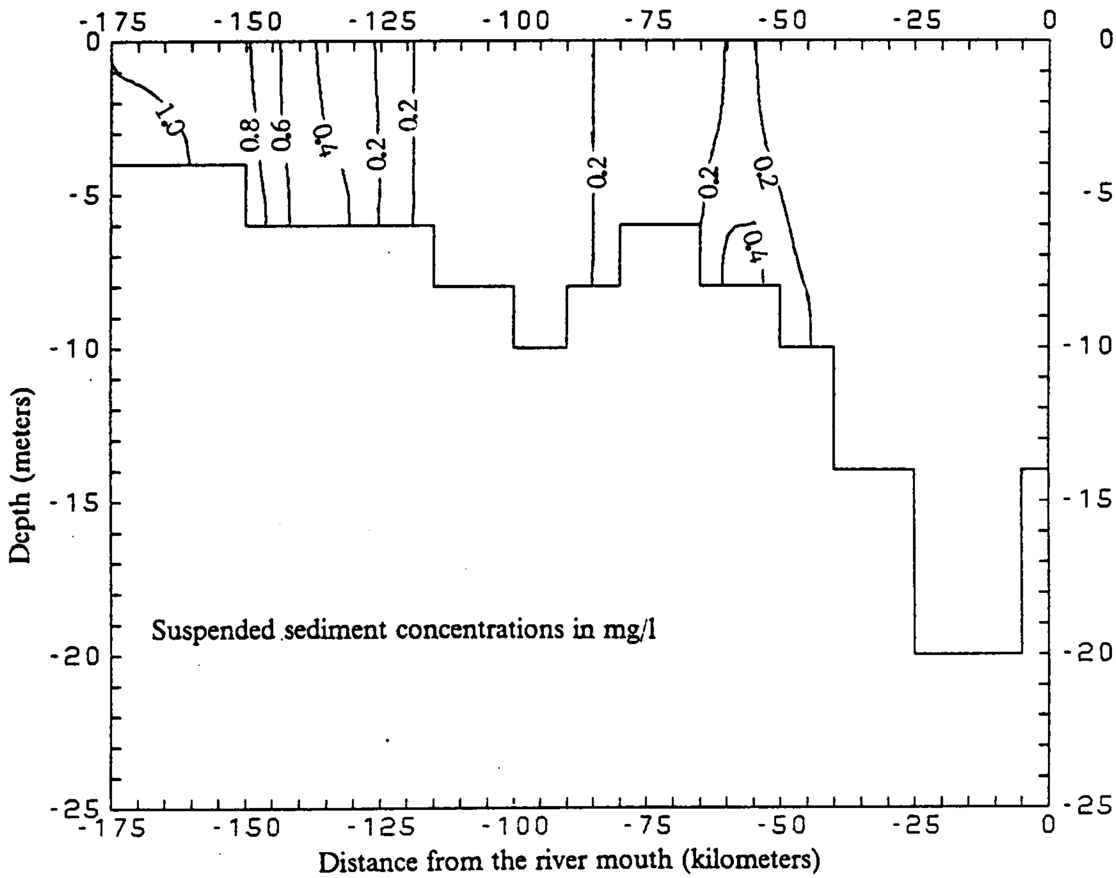

Figure 37. Sediment concentrations: drought with storm surge and 211 cm sea level rise

flood tide is moving into the estuary. The coincidence of a 100-year flood and a 100-year storm surge is an exceedingly rare event with a joint probability of exceedence of $0.596\,(10)^{-7}$. This translates into a return period of $1.4\,(10)^{6}$ years. Again, while this is a unlikely situation, the results from the flood cases with the those from the drought cases should include the most extreme results one might expect.

Figures 38, 39, 40 and 41 show the salinity distributions for each sea level rise scenario. With the high flood flow, the saltwater limit moves about 5 miles (8 km) downstream in comparison with the normal case, and this result is to be expected. As with the drought case, there is little difference between the results of the 13 cm, 38 cm, and 55 cm sea level rise cases. Unlike the drought case, though, the 211 cm sea level rise shows no great variation from the three other sea level rise cases. One trend that is noted is the bulging of the saltwater limit near the estuary bed as the lighter freshwater pushes downstream at the free surface.

The horizontal velocity distributions pictured in Figs. 42, 43, 44 and 45 show that the null point is pushed past the mouth of the river at the free surface. One anomaly shown is the upstream movement of the null point near the estuary bed. While this movement is very slight for the 13 cm, 38 cm, and 55 cm sea level rise scenarios, it is more obvious for a sea level rise of 211 cm. This is apparently contradictory, but it may have an explanation. It may be due to a numerical aberration in the program. A physical reason might possibly explain the results. The downstream boundary includes the storm surge and the sea level rise. This large volume of water tries to move into the estuary, but it is resisted by the lighter freshwater flood flow. So instead, the denser saltwater pushes its way up the estuary through the lower layers.

Reviewing the sediment data, pockets of high suspended sediment concentrations are scattered throughout the length of the estuary. Figures 46, 47, 48 and 49 show these areas to be about 35 miles (56 km), 60 miles (97 km), 70 miles (113 km), and 90 miles (145 km) from the mouth of the estuary. These pockets of high suspended sediment concentration generally occur at points where

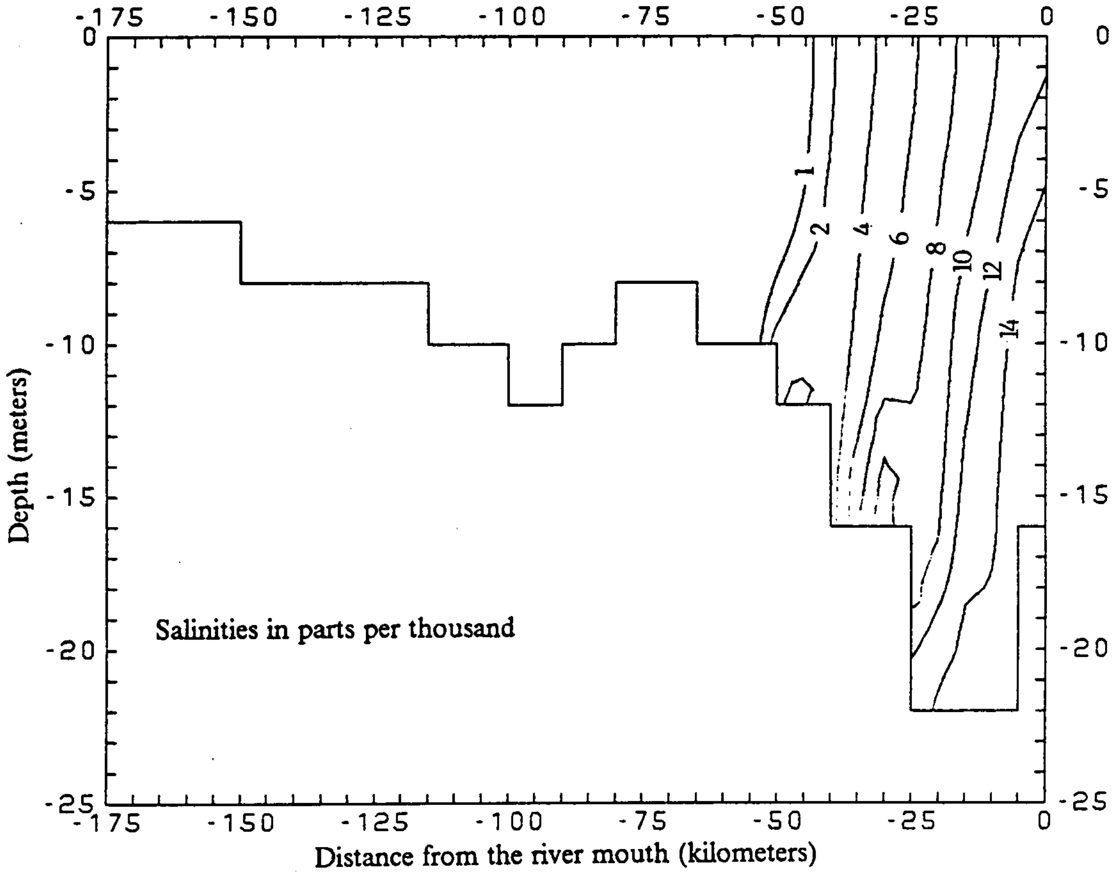

Figure 38. Salinity distribution: flood with storm surge and 13 cm sea level rise

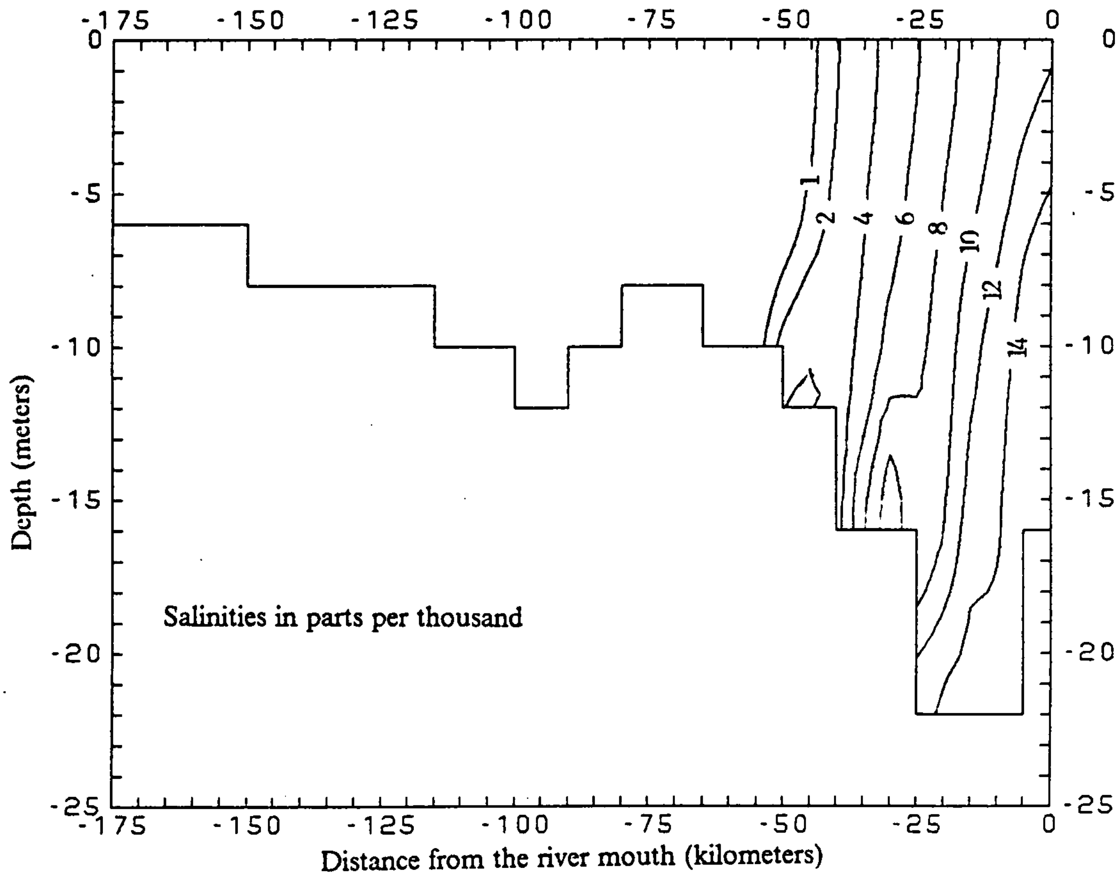

Figure 39. Salinity distribution: flood with storm surge and 38 cm sea level rise

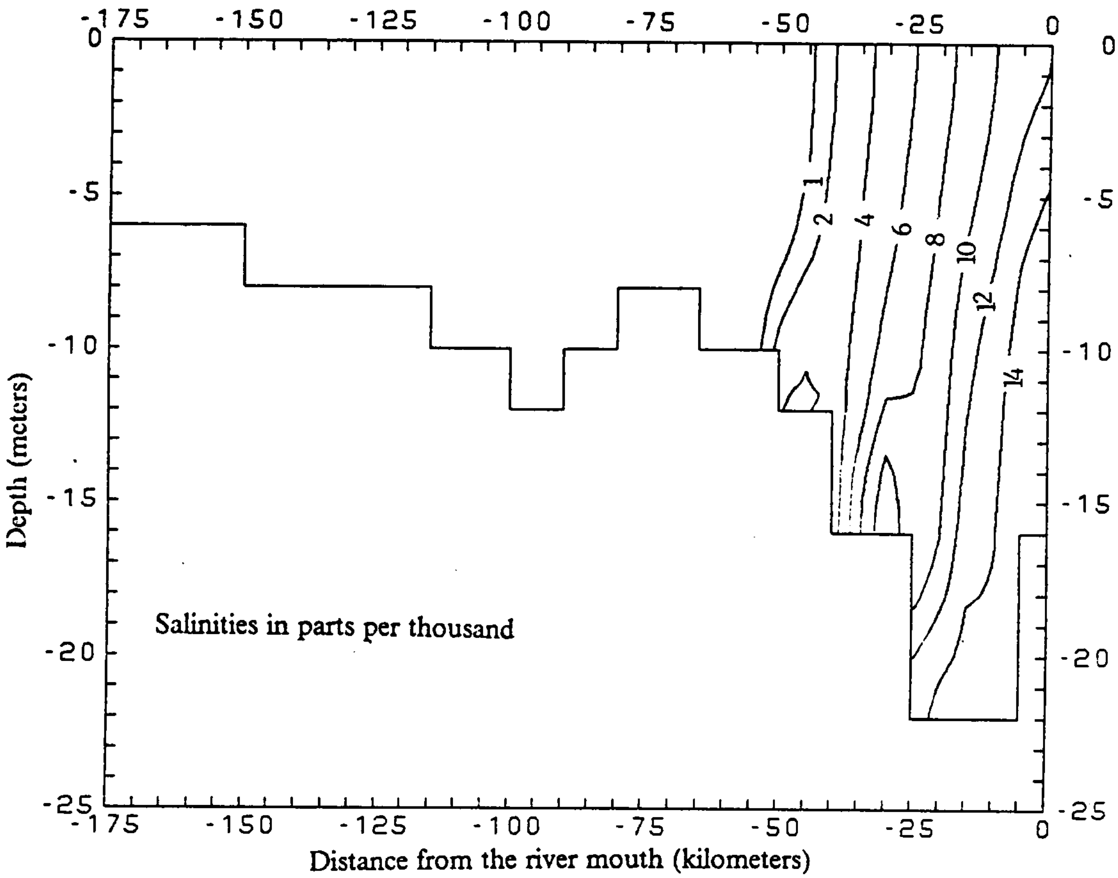

Figure 40. Salinity distribution: flood with storm surge and 55 cm sea level rise

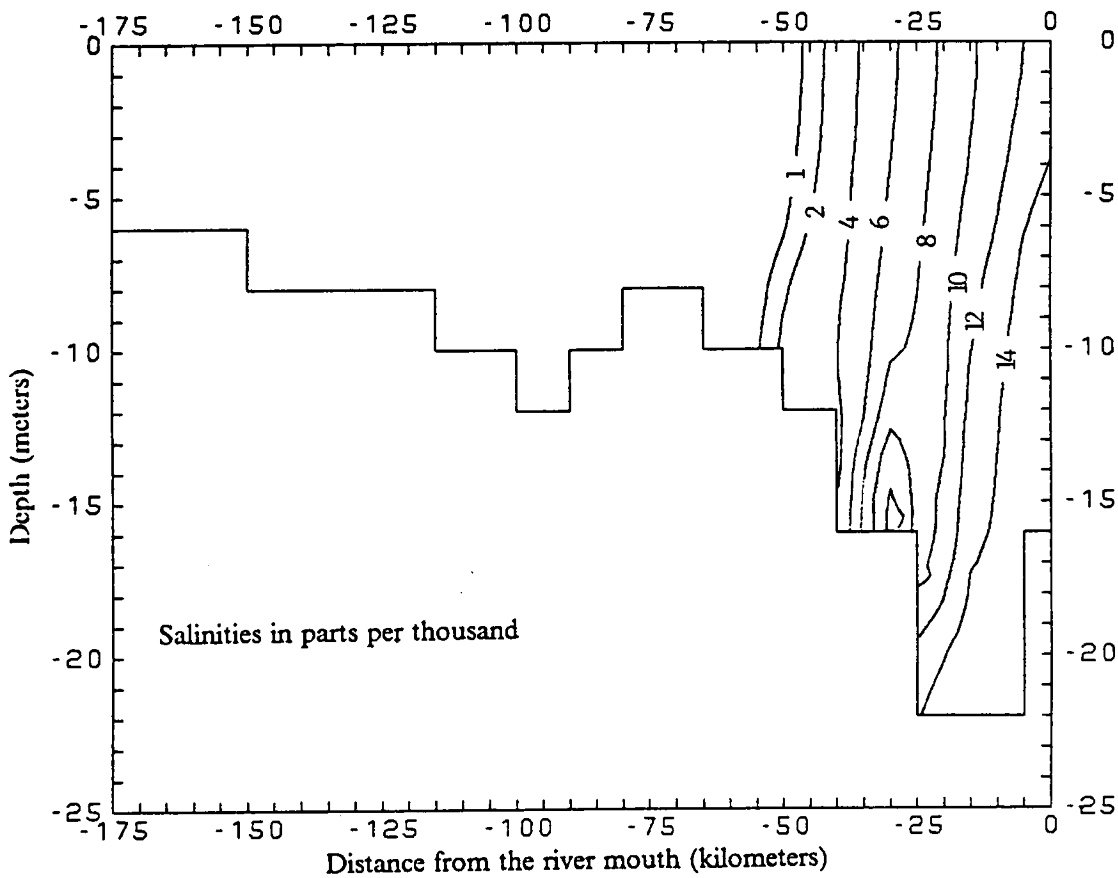

Figure 41. Salinity distribution: flood with storm surge and 211 cm sea level rise

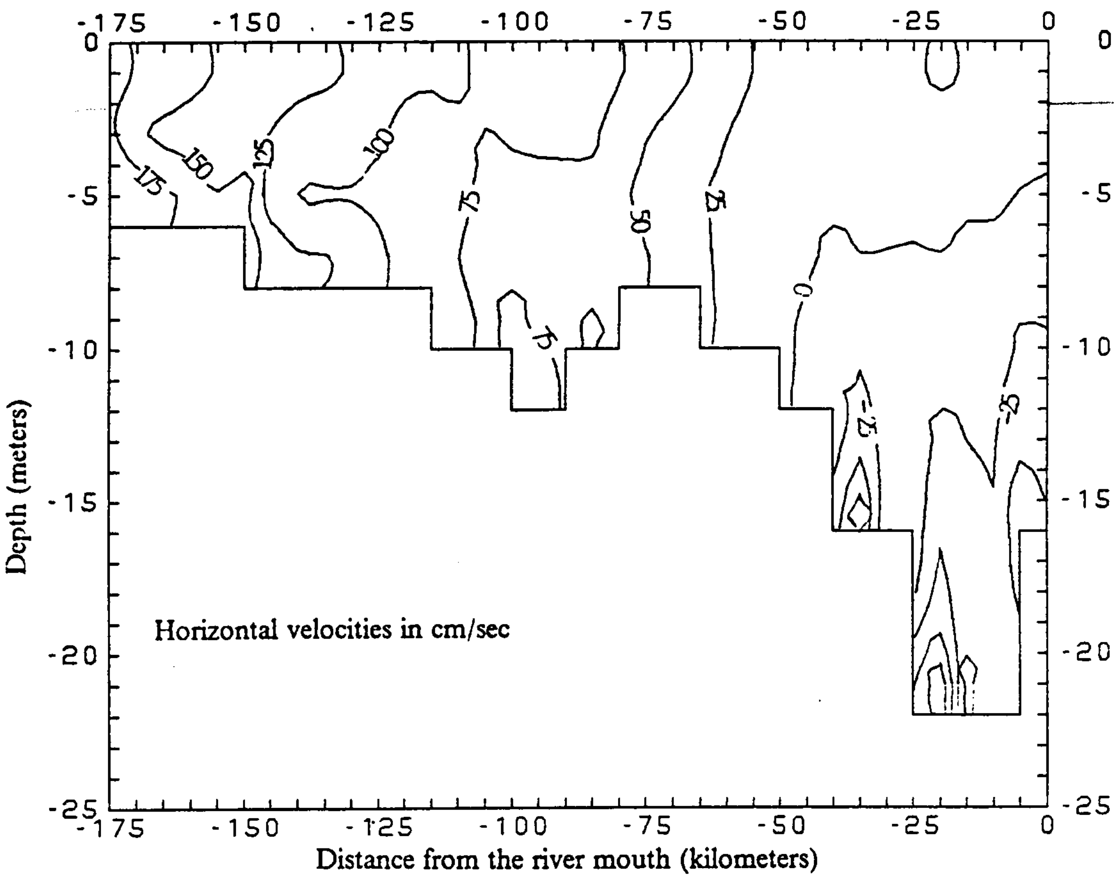

Figure 42. Horizontal velocities: flood with storm surge and 13 cm sea level rise

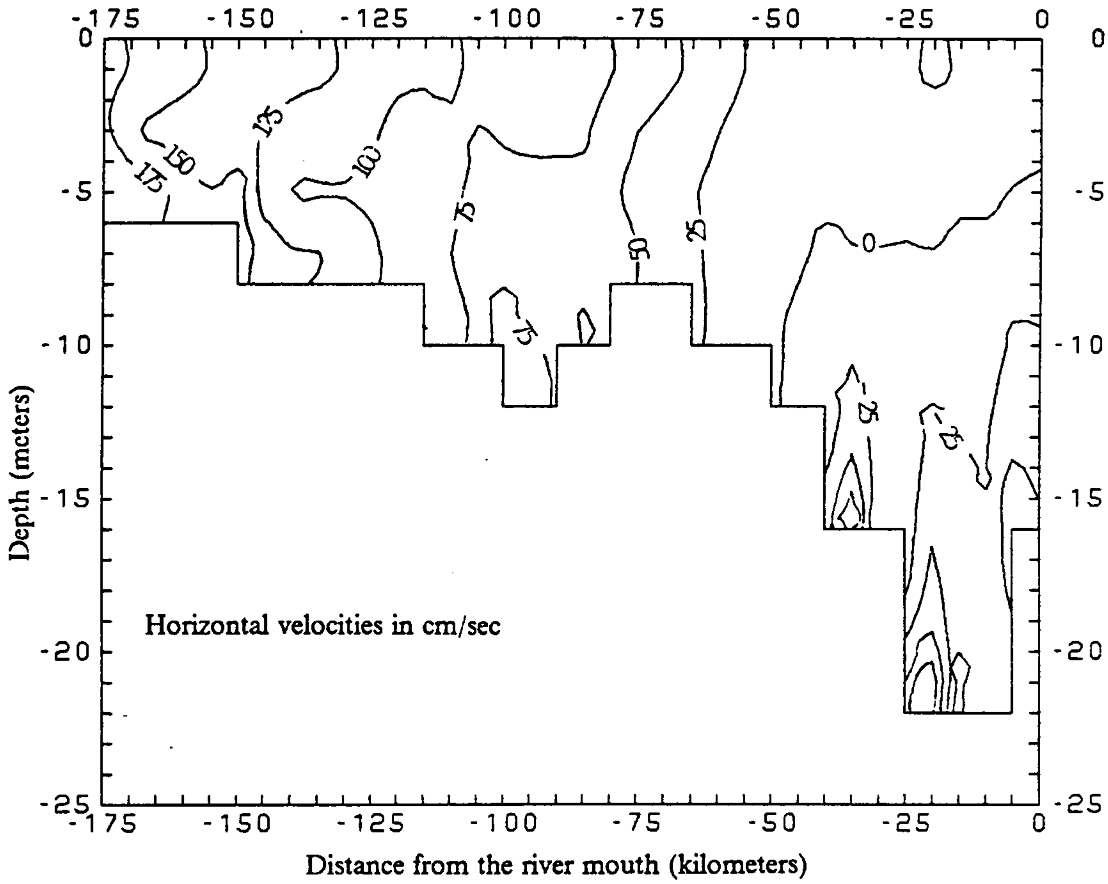

Figure 43. Horizontal velocities: flood with storm surge and 38 cm sea level rise

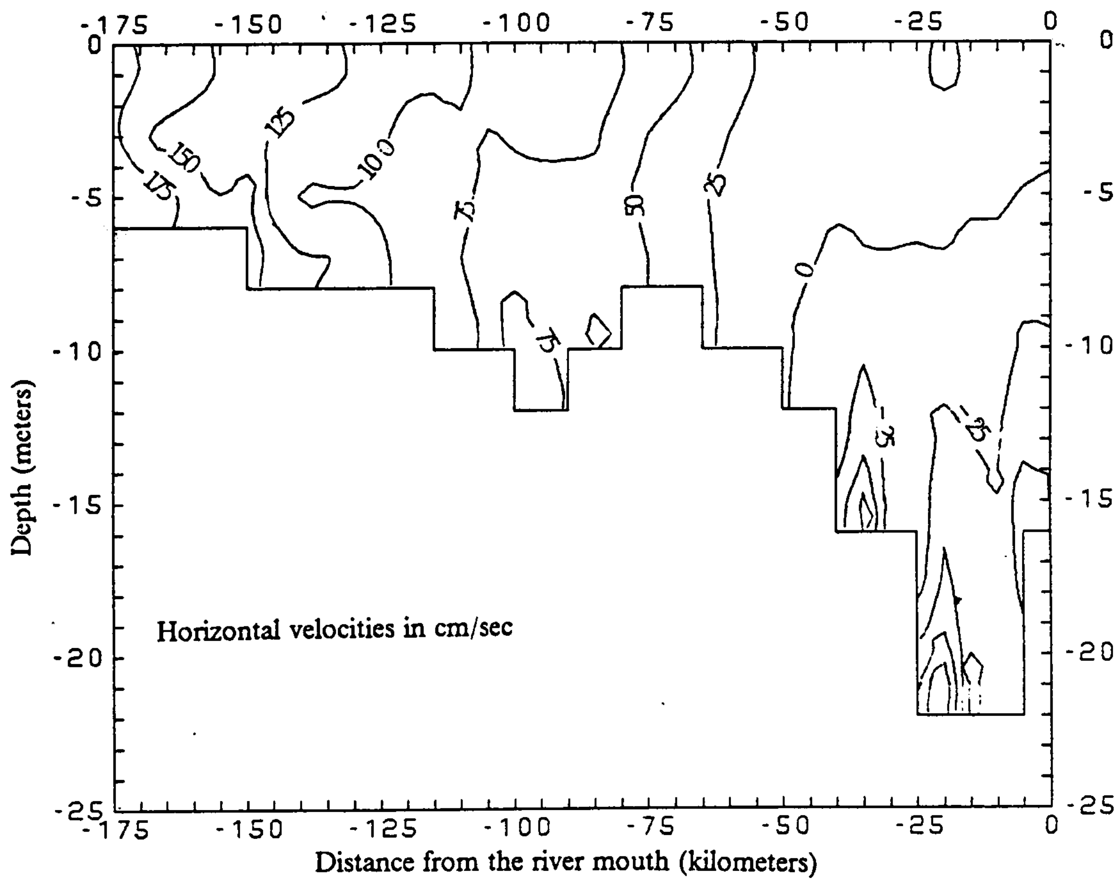

Figure 44. Horizontal velocities: flood with storm surge and 55 cm sea level rise

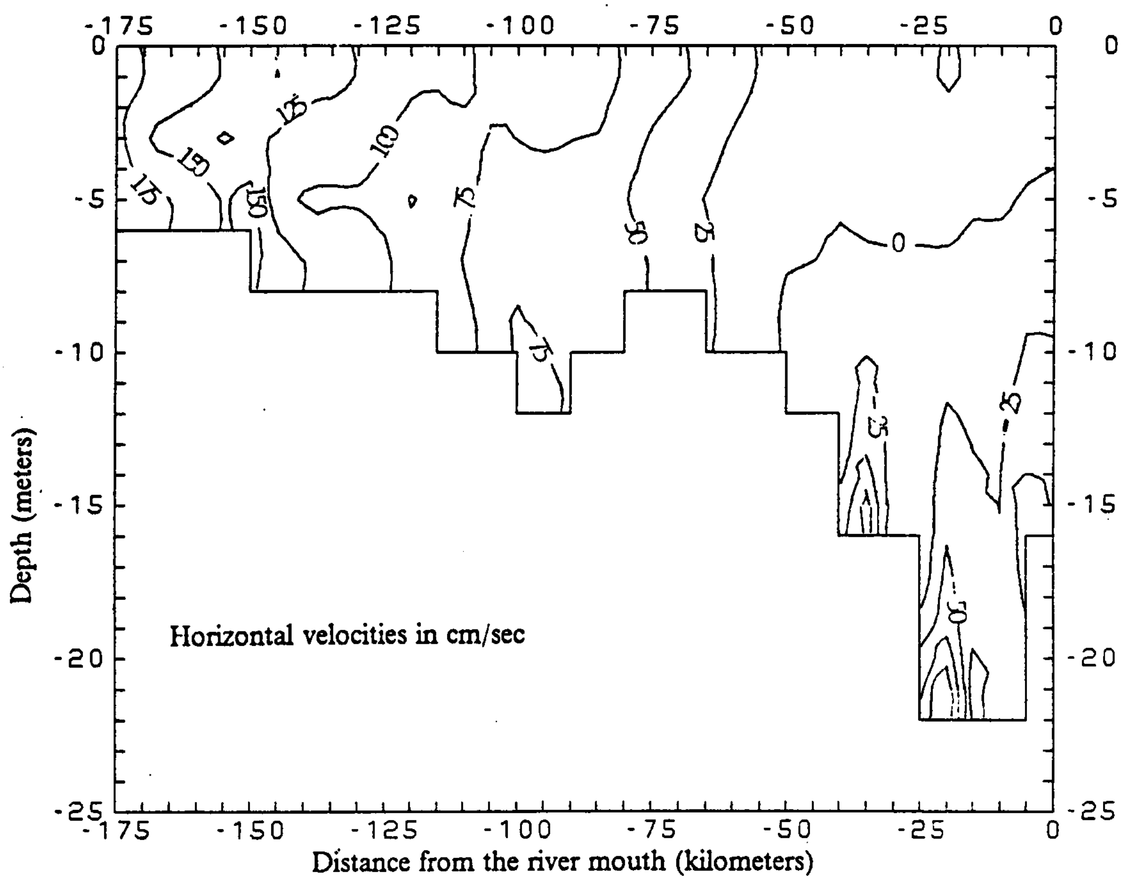

Figure 45. Horizontal velocities: flood with storm surge and 211 cm sea level rise

the depth of the estuary increases. Such changes in the riverbed's longitudinal profile may create turbulence which causes the resuspension of the sediment.

4.2.4 Extended Simulation

For the extended simulation, a drought flow is paired with the normal tide and a 13 cm sea level rise. This combination is run through the numerical model for 35 tidal cycles, about 18 days. As with the other simulations discussed here, a flood tide is entering the estuary at the time that these results are taken. The interest here is the effect the sea level rise would have in a severe and long-term drought. By running the model for a long period of time, a steady state situation for the salinity distribution is reached. Figure 50 shows the salinity distribution. The salt front has intruded 12 miles (20 km) further into the estuary than in the normal case (Fig. 23). Even compared to the drought flow with a storm surge and a 13 cm sea level rise (Fig. 26), the salt front for the extended simulation intrudes further upstream. The horizontal velocities (Fig. 51) are much different from those in Figs. 24 and 30. The null point for the extended simulation retreats upstream. Not only does the line representing the null point shift by as much as 26 miles (42 km), but it becomes more vertical. In fact, the bulge created by the negative velocities in the other model simulations is lessened as the negative velocities increase not only along the streambed but also at the free surface.

The extended simulation brings out the importance of considering the sea level rise. As was stated, the salt front in this case advances twelve miles upstream compared with an intrusion of 18 miles for a drought with a storm surge and a 211 cm sea level rise. A drought with a storm surge and a large rise in the sea level may not be likely, but a sea level rise of 13 cm with a drought of approximately two weeks is possible. Using the joint probability method developed in Chapter 3, the joint probability of exceedence for the former case is 0.0001, and for the latter case, it is 0.967. Comparing Figs. 50 and 51 with Figs. 29 and 33, it can be seen that for long periods of low flow, a small sea level rise can have effects nearly as significant as those found for more extreme short term cases.

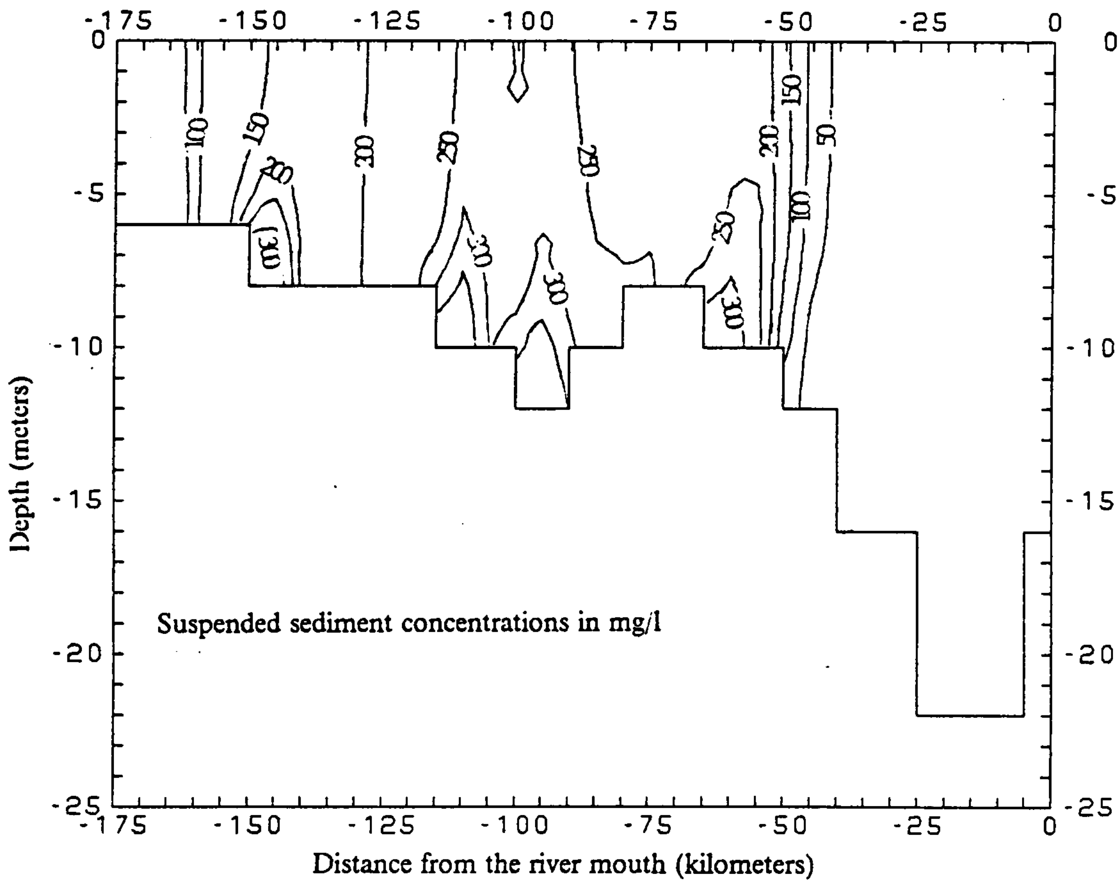

Figure 46. Sediment concentrations: flood with storm surge and 13 cm sea level rise

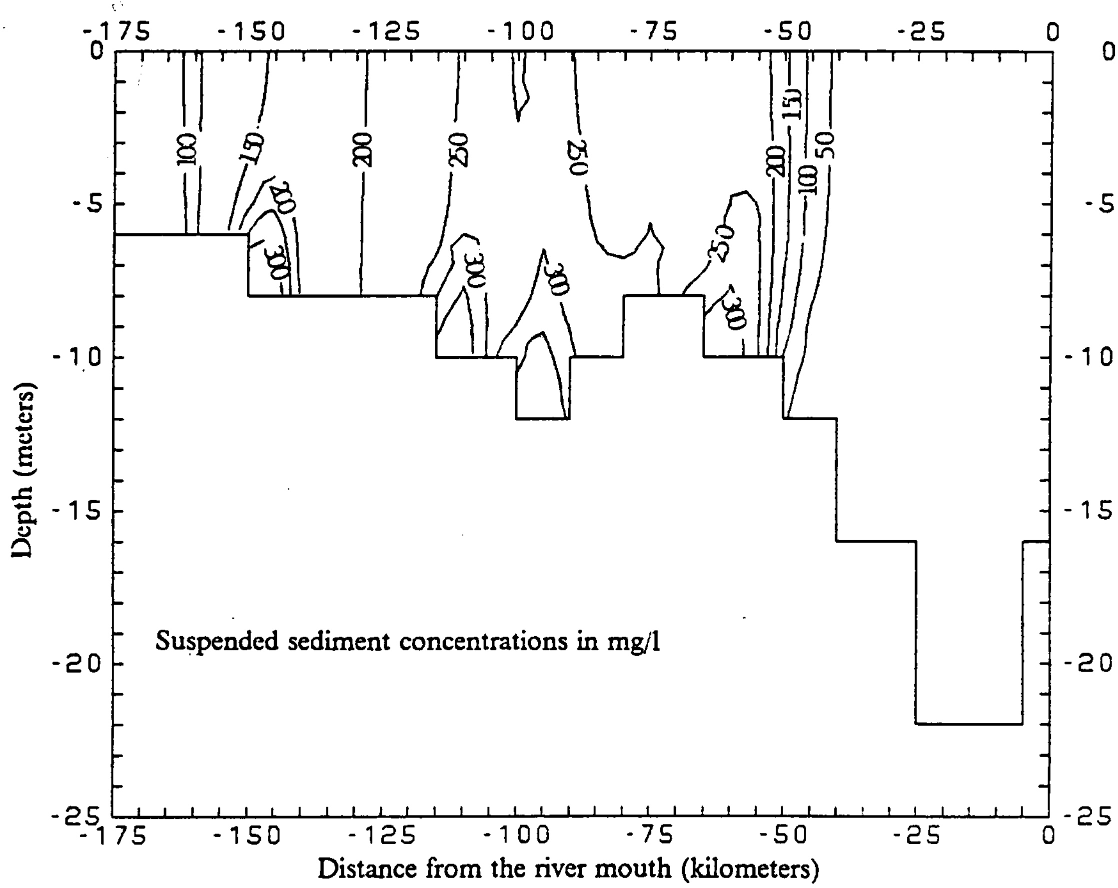

Figure 47. Sediment concentrations: flood with storm surge and 38 cm sea level rise

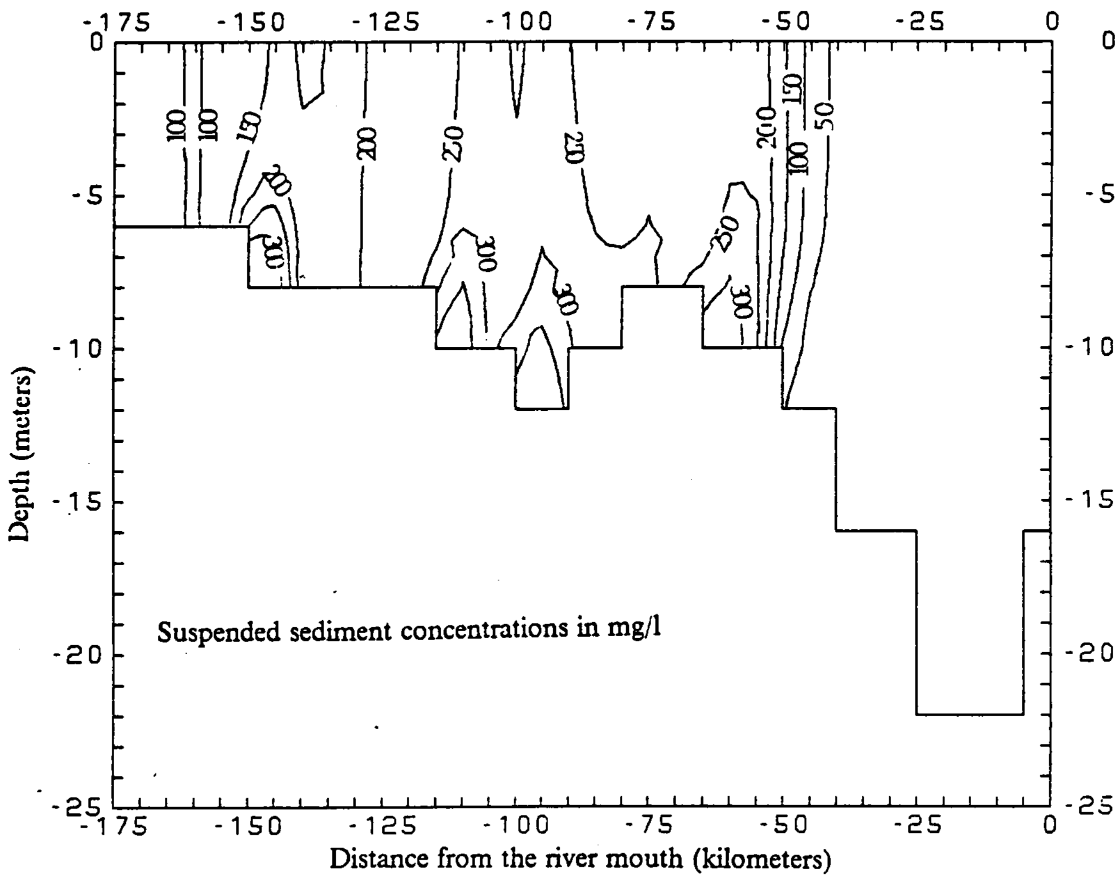

Figure 48. Sediment concentrations: flood with storm surge and 55 cm sea level rise

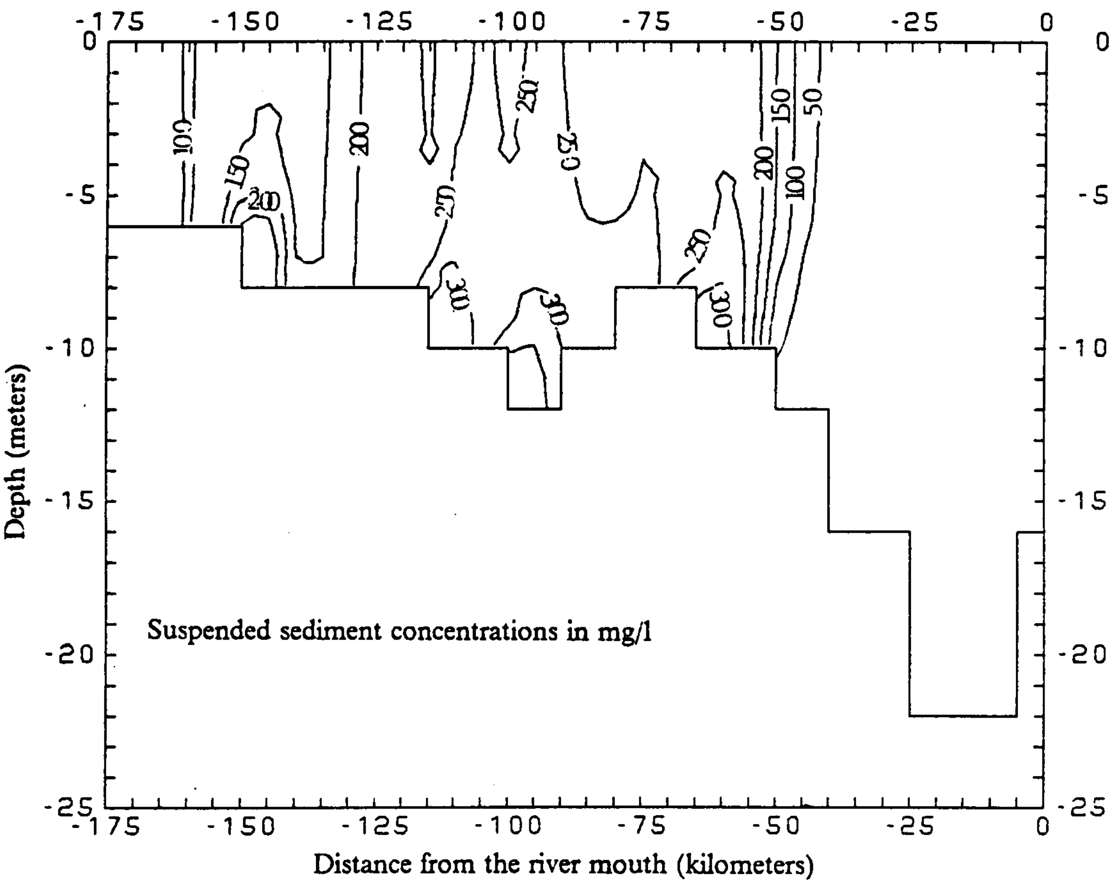

Figure 49. Sediment concentrations: flood with storm surge and 211 cm sea level rise

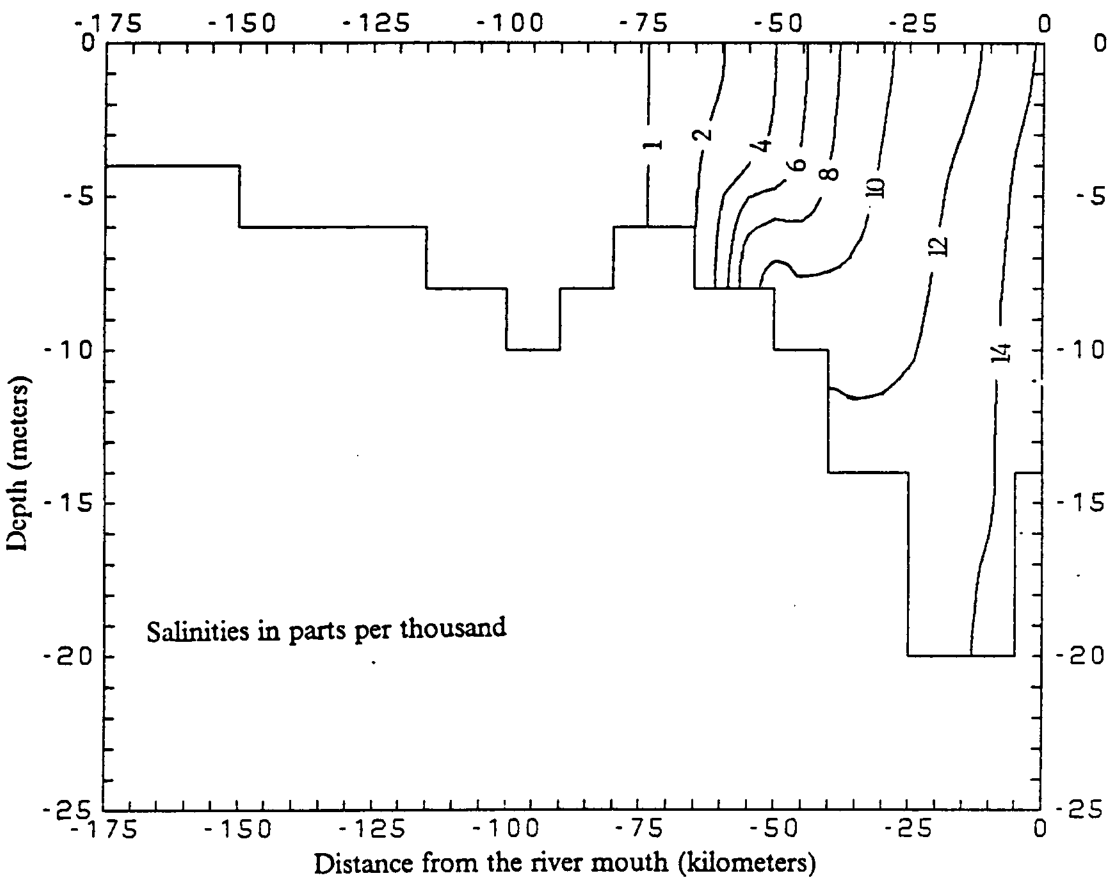

Figure 50. Salinity distribution: extended simulation with a drought and a 13 cm sea level rise

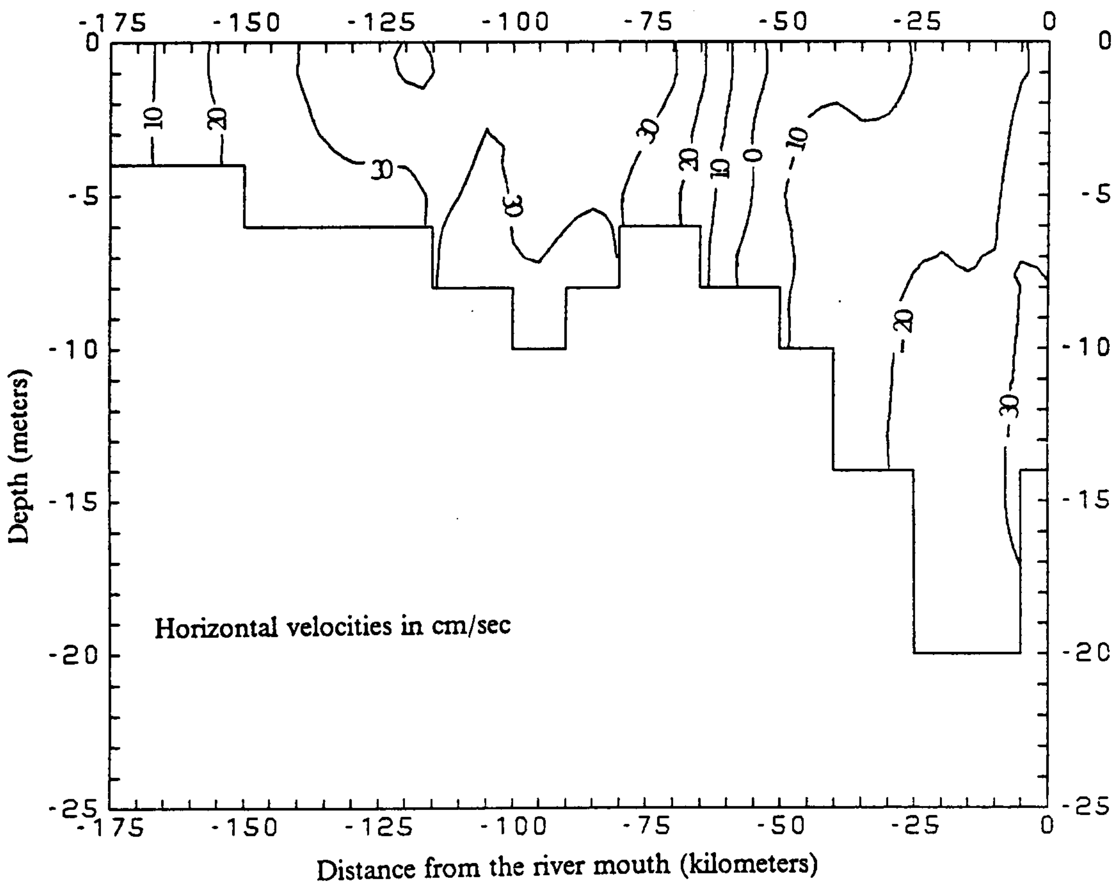

Figure 51. Horizontal velocities: extended simulation with a drought and a 13 cm sea level rise

4.2.5 Comparisons

Figures 52 and 53 provide a better comparison of the model results for the salinity and horizontal velocity, respectively. In each figure, one value is chosen for comparison. In Fig. 52, a salinity of 10 ppt is studied, and in Fig. 53, the null point where there is no horizontal velocity is examined. Since results for the 13 cm, 38 cm, and 55 cm sea level rise scenarios are very similar, the results for a 13 cm sea level rise are taken as representative of the other two scenarios in Figs. 52 and 53. The effects of the most drastic increase in the height of the sea level, 211 cm, are also shown in these figures. The final case to be compared in Figs. 52 and 53 is the extended simulation.

The shifting of the salinity distribution is quite evident in Fig. 52. The largest shifts are seen for the drought cases. In these cases, the movement is especially clear in the lower layers where the denser saltwater causes the 10 ppt isochlor to migrate as far as 15 miles (25 km) upstream. For the flood cases, a downstream shift of the salinity distribution is shown, and again, the largest movement is seen in the lower layers. Here, the 10 ppt isochlor shifts 12 miles (20 km). The effects of flooding on the salinity distribution might be expected to provide some relief from the saltwater intrusion due to the sea level rise. Floods, though, are very short events, and this relief would soon pass. On the other hand, droughts may extend over a period of days or weeks, and this longer time period allows the effects of the increased salinity to be felt by the estuarine life and nearby communities which depend upon the river for their water supplies.

The large salinity changes seen in the lower layers have been mentioned often in reviewing the numerical model results. These changes occurring at or near the riverbed should be noted. While the shifting of the saltwater front may be slight near the free surface, this should not be interpreted as meaning that the threat of saltwater intrusion is small. Many forms of life such as oysters live near the bottom of the estuary, and small salinity increases at the free surface may mean large increases detrimental to these lifeforms are occurring near the riverbed. This is especially evident in for the extended simulation. At a depth of eight meters, the 10 ppt isochlor moves 15 miles (25 km) upstream compared to an upstream shift of 6 miles (10 km) at the free surface.

In contrast to the salinity, the horizontal velocity comparison made in Fig. 53 provides a rather muddled picture. For drought flows, the null point moves upstream at all depths in the estuary. During flood flows, the null point at the free surface is pushed beyond the river mouth. In the lower layers, the null point instead moves upstream during the flood flow. As explained in Section 4.2.3, this may be due to a numerical aberration in the computer program, or it may be due to the large volume of saltwater which is trying to move into the estuary but is impeded at the surface by the freshwater flow. Unlike the other five curves in Fig. 53, the extended simulation has a zero horizontal velocity profile which is nearly vertical.

As the figures show, the intrusion of saltwater and the changing pattern of the horizontal velocities are two implications of the sea level rise. Of concern, also, is the effect the heightened sea level will have on the frequency of damaging storm surges. Since it is difficult to predict how weather patterns will be altered with a higher sea level, it is assumed that the tide frequencies will remain the same. Even if the return period of a particular storm surge is not shortened, the magnitude of the storm surge needed to reach a dangerous tide level is not as large when the sea level rises. The tides in the frequency analysis shown in Fig. 7 refer to the present mean sea level, but this mean sea level will rise over time. Table 10 gives an indication of the changes this will bring to the frequency of a surge equivalent to the present 100-year storm surge. For example, the 100-year storm surge reaches a tide level of 4.06 feet (123.75 cm) above the current mean sea level. A 13 cm sea level rise will reduce the surge necessary to reach a tide level of 123.75 cm. Using a tide conversion factor, this 13 cm rise will be about 6 cm at the mouth of the Rappahannock River. Now, only a surge of 3.86 feet (117.75 cm) is required. From Fig. 7, it is found that such a storm surge has a return period of 63 years. The length of the return period falls quickly as further increases in the sea level are seen. The possibility of more frequent storm surges which would threaten development along the water will require a review of current land use patterns.

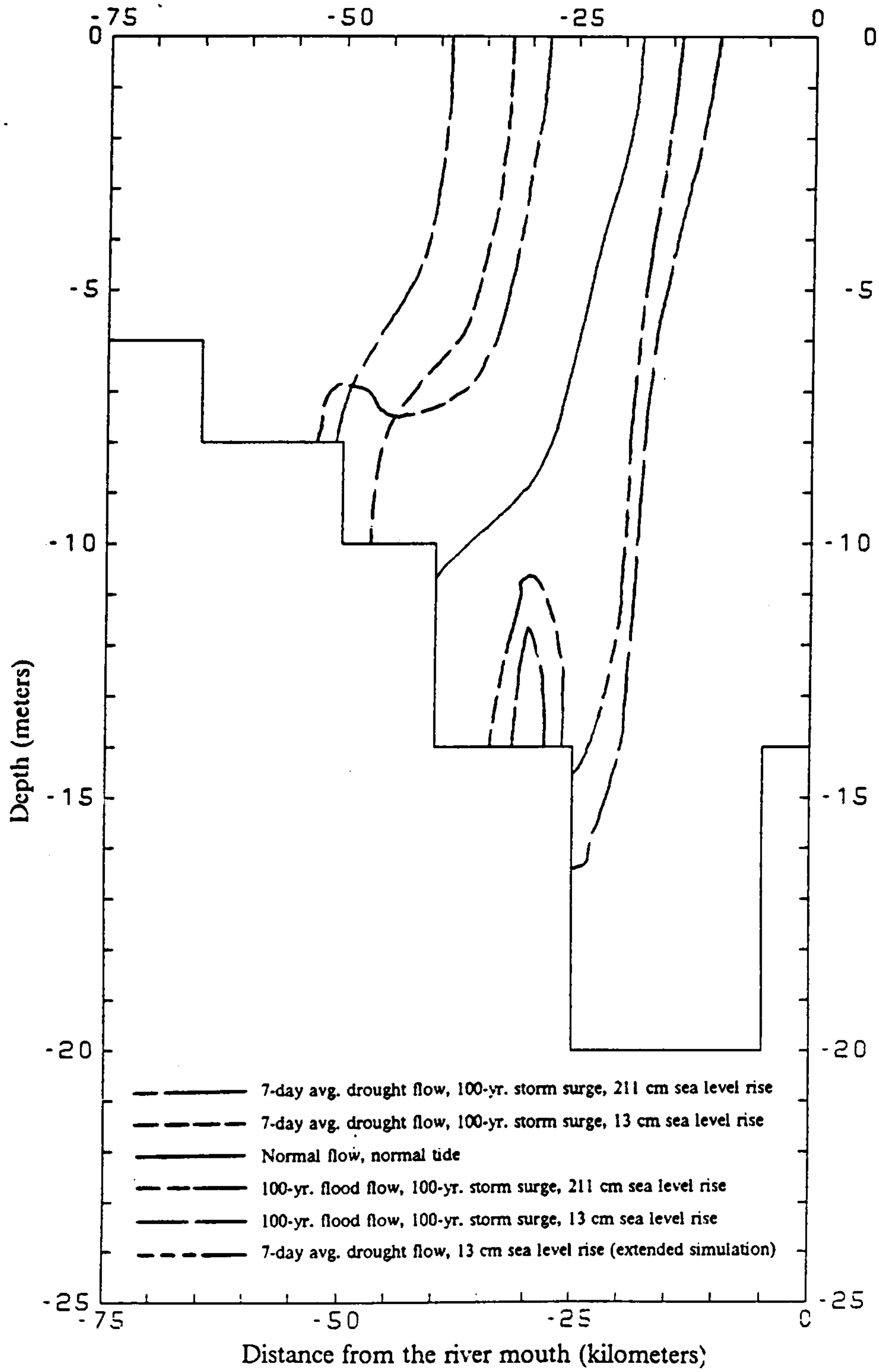

Figure 52. Comparison of the simulation results for various scenarios (salinity = 10 ppt)

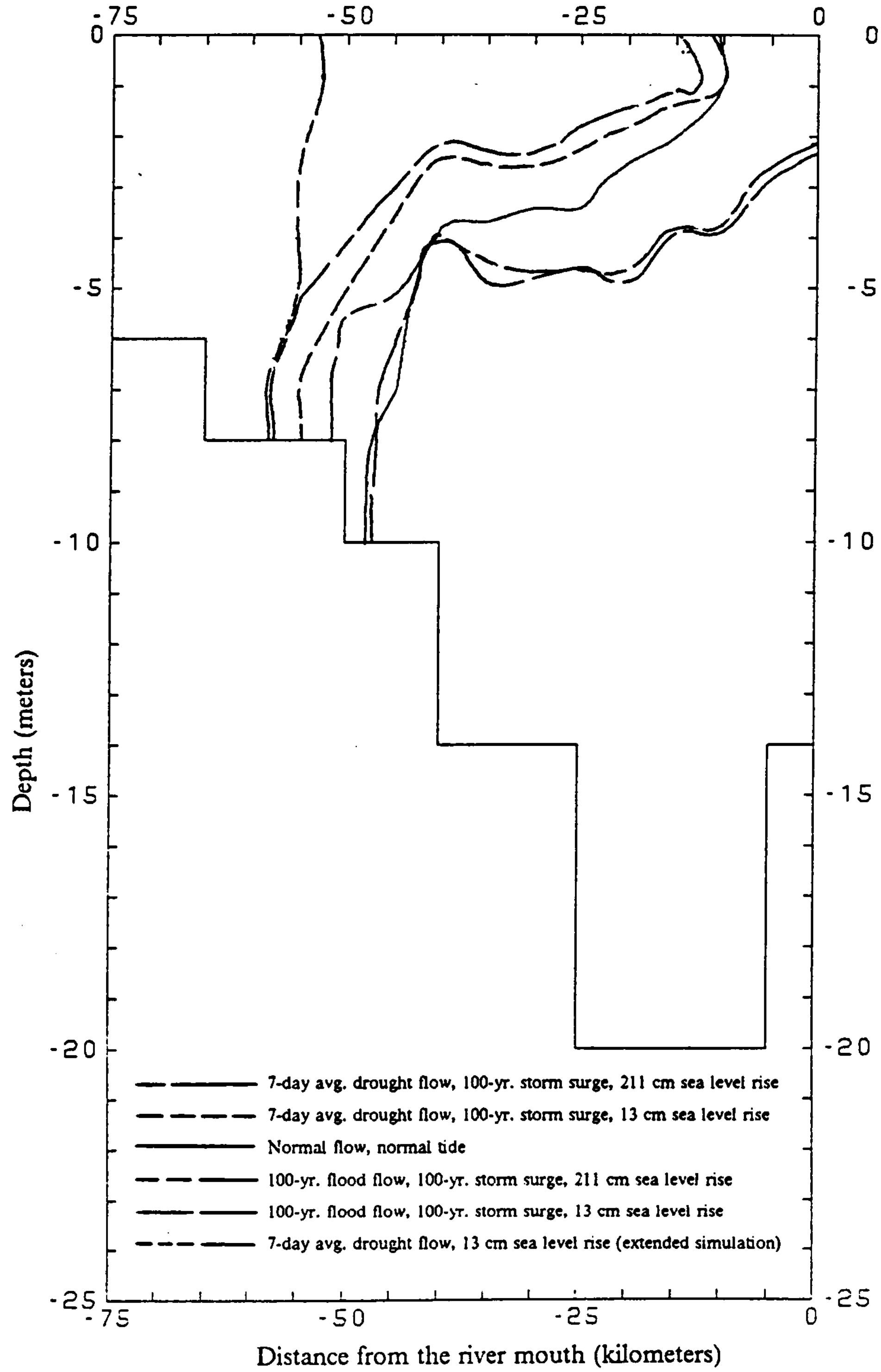

Figure 53. Comparison of the simulation results for various scenarios (horizontal velocity = 0, null point)

Table 10. Effect of sea level rise on storm surge return periods

Sea Level Rise* (cm)	Storm Surge (cm)	Tide Level Above Present MSL (cm)	Probability of Exceedence for Storm Surge (percent)	Return Period of Storm Surge (years)
0	123.75	123.75	1.0	100
13 (6)	117.75	123.75	1.6	63
38 (17)	106.75	123.75	3.8	26
55 (24)	99.75	123.75	6.5	15

* Value in parentheses is the sea level rise at the mouth of the Rappahannock River.

4.2.6 Effects on the Estuarine Processes for a Single Joint Probability of Exceedence

The final three simulations do not include sea level rise. Instead, these three cases illustrate the application of the joint probability method in the selection of the numerical model's boundary conditions. In these examples, the boundary conditions all have a joint probability of exceedence of ten percent. The simulations cover a range of streamflows from 1580 cfs (44.7 m^3/s) to 9270 cfs (262 m^3/s) and tidal heights from 2 feet (61 cm) to 0.85 feet (26 cm) above mean sea level. Each of the simulations was run for ten tidal cycles, and the results shown in the figures are taken from the end of the tenth tidal cycle.

Figures 54,55 and 56 show the salinity distribution in the estuary. Comparing these three figures with one another, it is apparent that the limit of saltwater intrusion represented by the one ppt isochlor shifts noticeably for each case. In Fig. 54, a near normal flow with a storm surge over two times higher than the highest astronomic tide causes the saltfront to advance 2 miles (3.5 km) up-stream from the limit seen for the normal case. For a flow five times greater than normal and near normal tides (Fig. 56), the saltwater limit shifts downstream by 6 miles (10 km). Figure 55 re-presents a case which lies between these two extremes, and here, the one ppt isochlor moves 2 miles (3.5 km) downstream.

As for the horizontal velocities, these are shown in Figs. 57, 58 and 59. Using the isobar repres-enting zero horizontal velocity, it is seen that this line behaves as may be expected. As the flow increases and the tidal height decreases, the null point moves downstream. The null points for the low and high flow cases in (Figs. 57 and 59) generally fall about one or two miles (2-3 km) on either side of the null point for the normal case (Fig. 24).

Since the suspended sediment load at the upstream boundary differs for each case, a comparison of the values shown in Figs. 60, 61 and 62 is not possible. Generally, though, each of the three

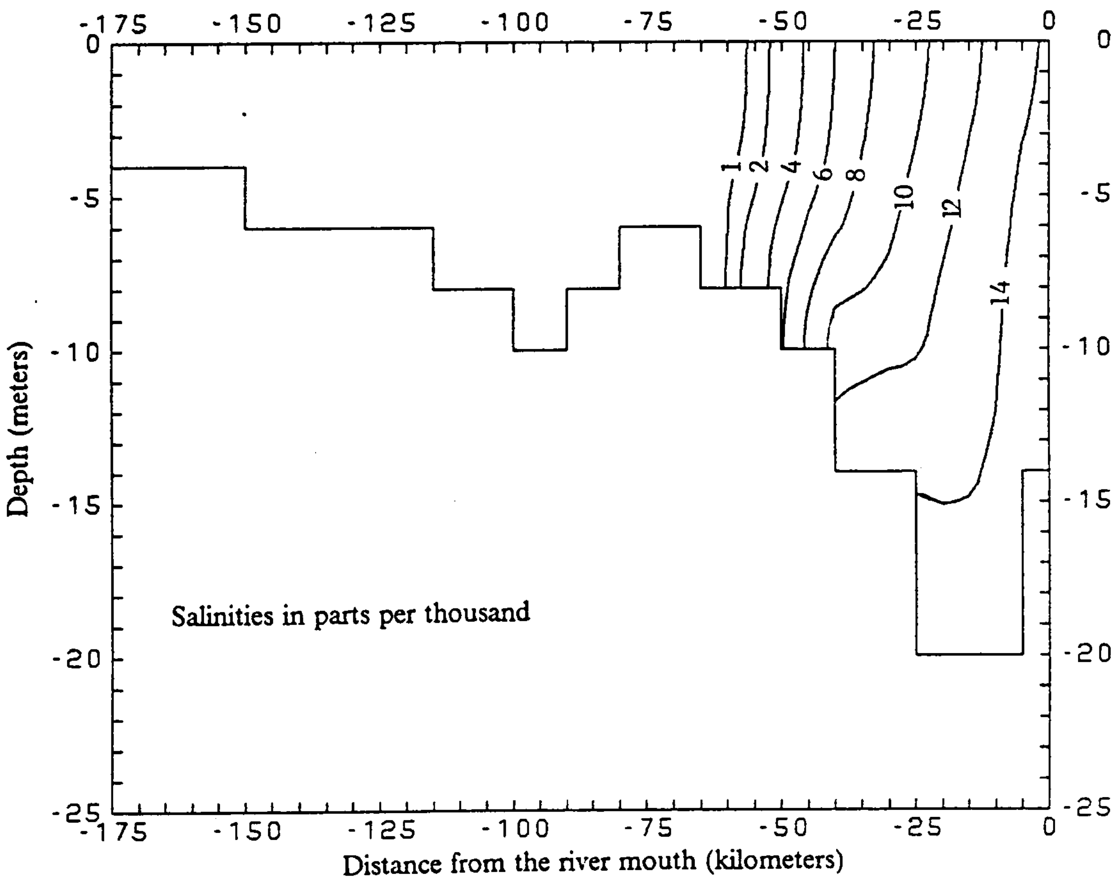

Figure 54. Salinity distribution: 1580 cfs inflow with a 2.00 foot tidal height

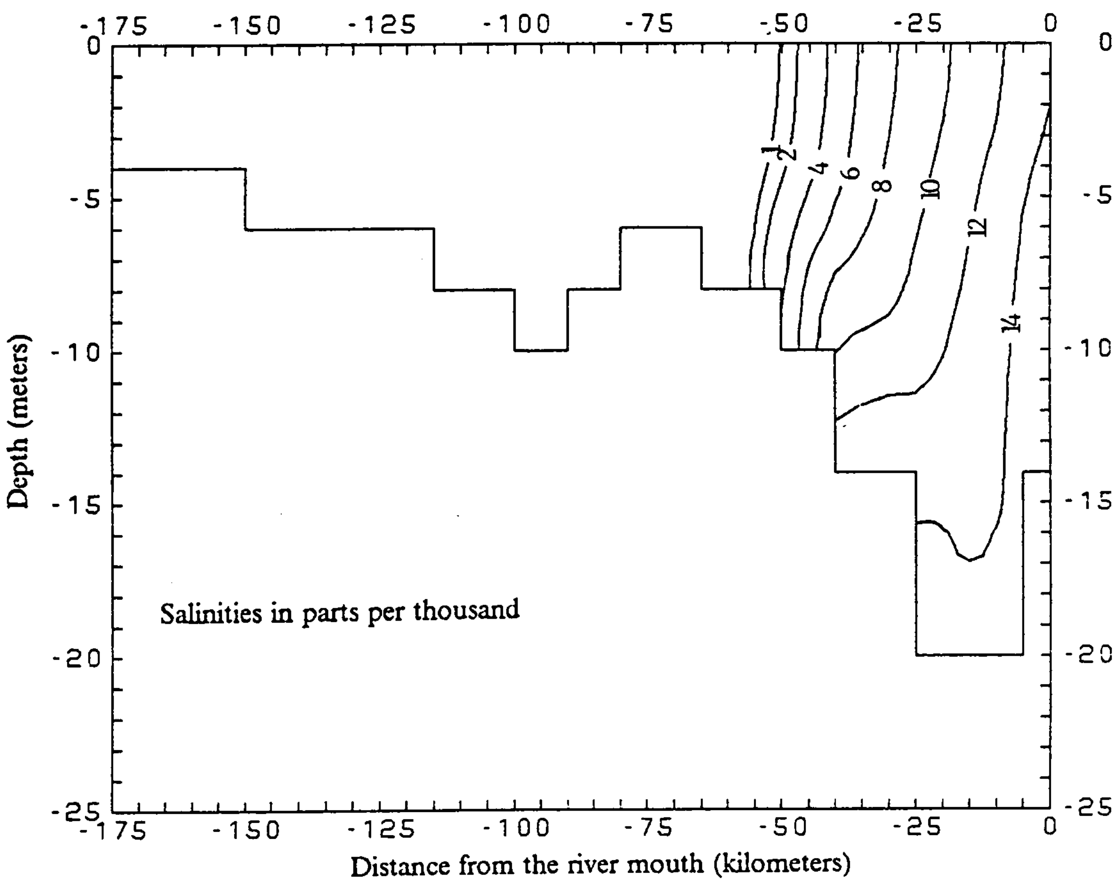

Figure 55. Salinity distribution: 5540 cfs inflow with a 1.60 foot tidal height

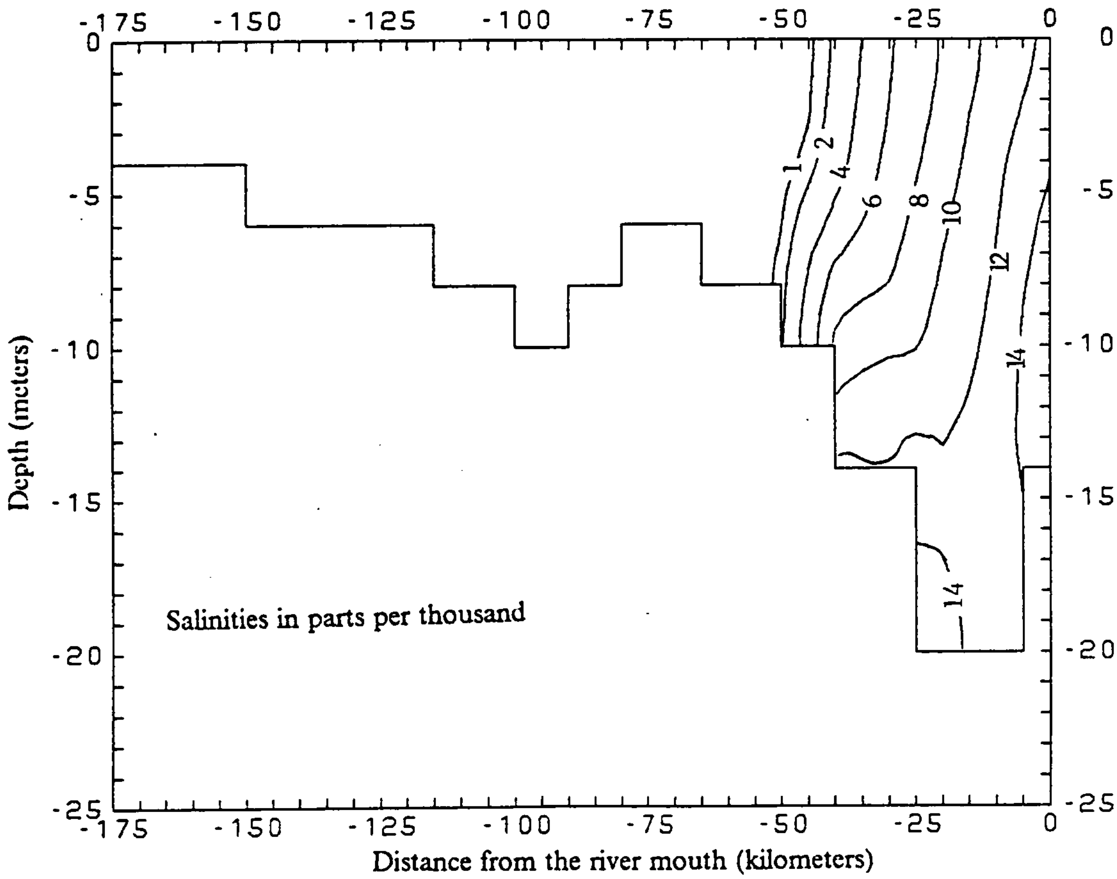

Figure 56. Salinity distribution: 9270 cfs inflow with a 0.85 foot tidal height

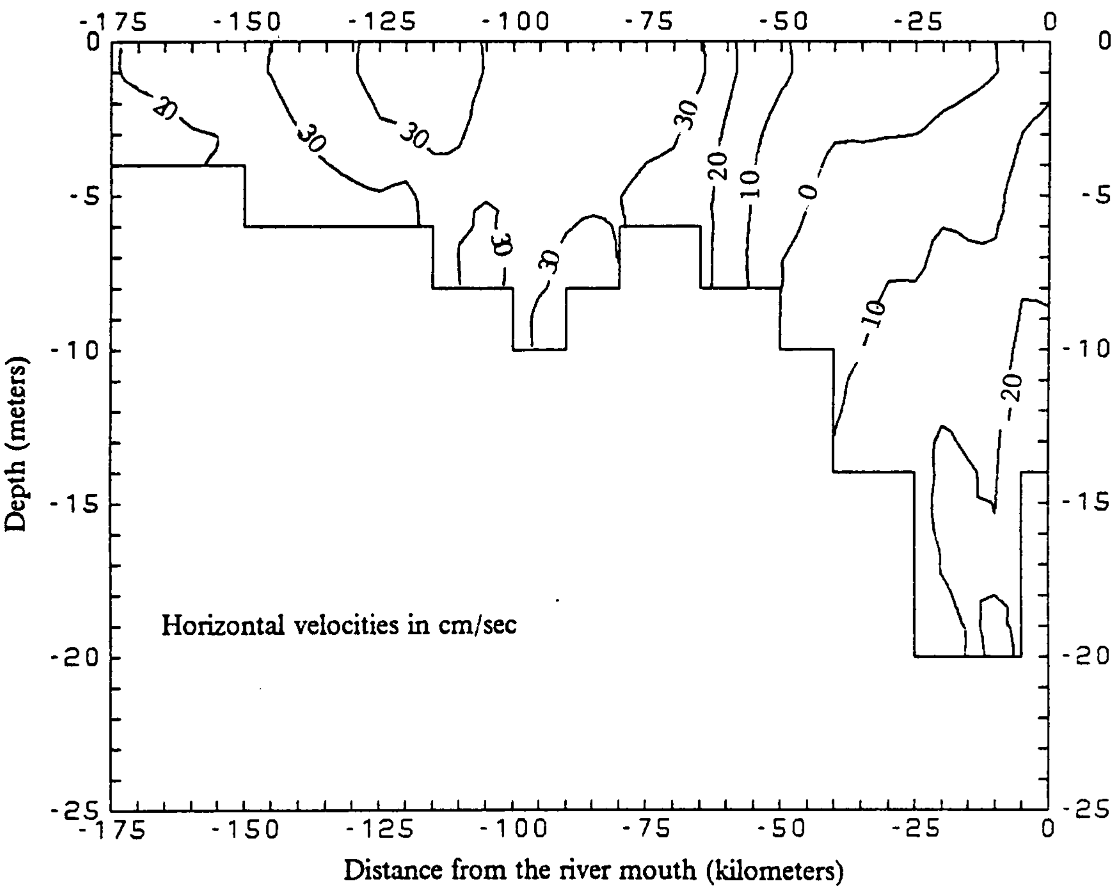

Figure 57. Horizontal velocities: 1580 cfs inflow with a 2.00 foot tidal height

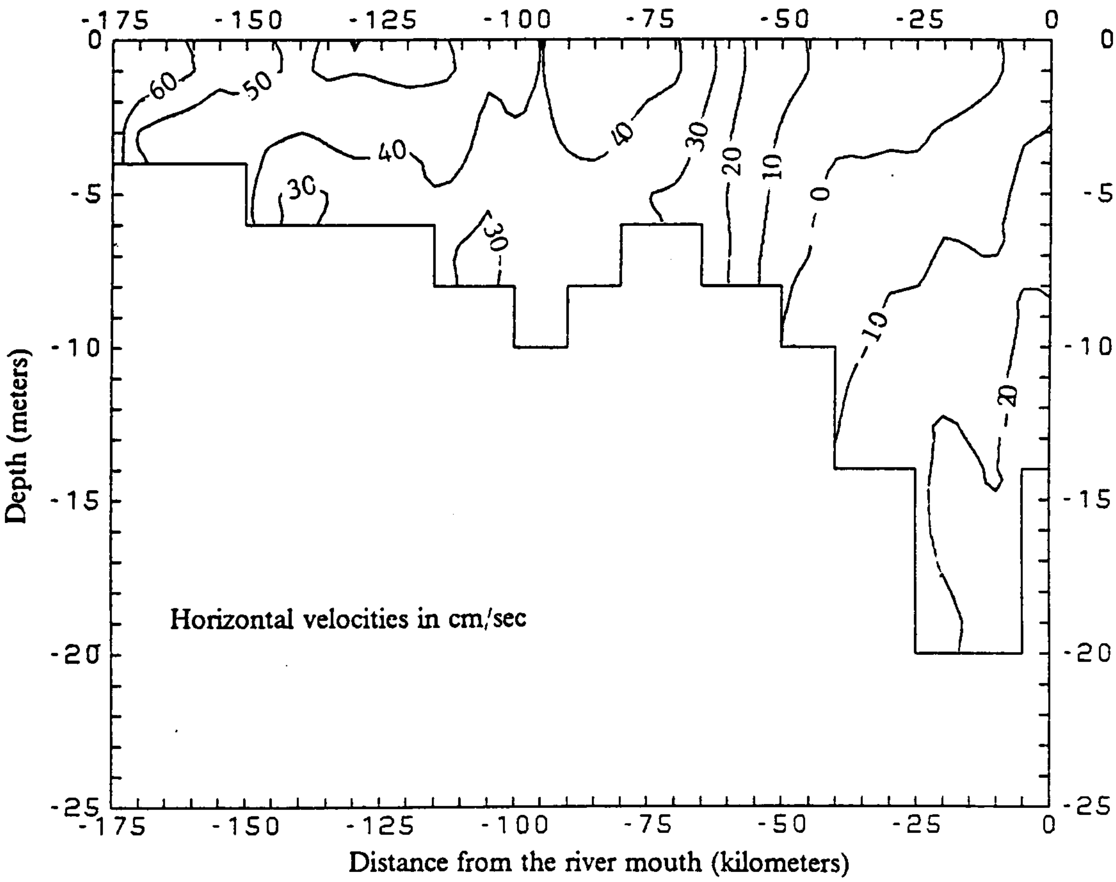

Figure 58. Horizontal velocities: 5540 cfs inflow with a 1.60 foot tidal height

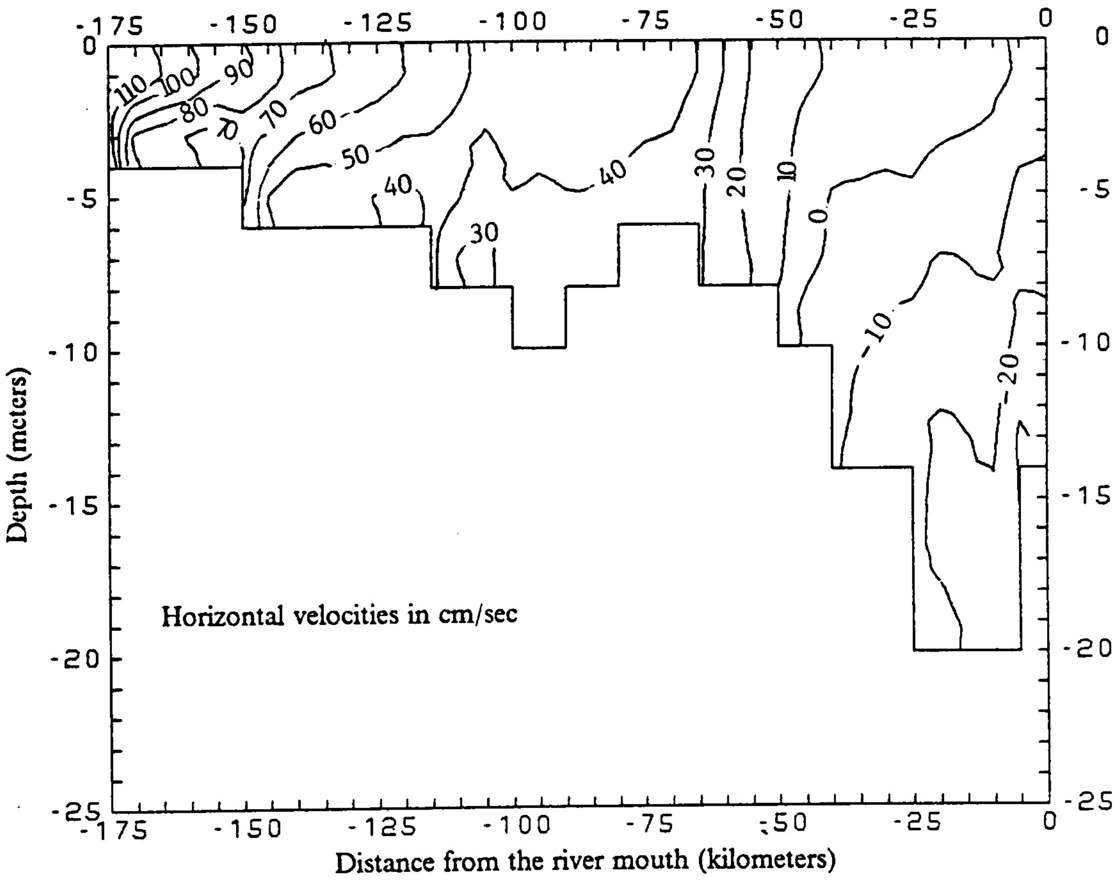

Figure 59. Horizontal velocities: 9270 cfs inflow with a 0.85 foot tidal height

simulations have the same pattern of distribution for the suspended sediment. Just as was seen for the normal case (Fig. 25), a pocket of higher suspended sediment concentrations is located about 33 miles (55 km) from the river mouth. This point lies near the null point where larger vertical velocities would be expected to occur and cause the resuspension of the sediment.

The primary interest in these three cases is the amount of change which occurs for these sets of boundary conditions with the same joint probability of exceedence. It can be plainly seen that each case affects the estuary differently. Given a lower joint probability of exceedence, a wider range of streamflows and tidal heights could be selected, and the greater would be the differences between the results. This confirms the point in Chapter 3 that a return period for a particular estuarine condition can not be assigned with the joint probabilities computed from the streamflows and tidal heights. These joint probabilities will tell one the return period of a particular streamflow-tidal height pair, but to find the changes this pair will bring to the estuarine processes, the numerical model must be run with this set of boundary conditions.

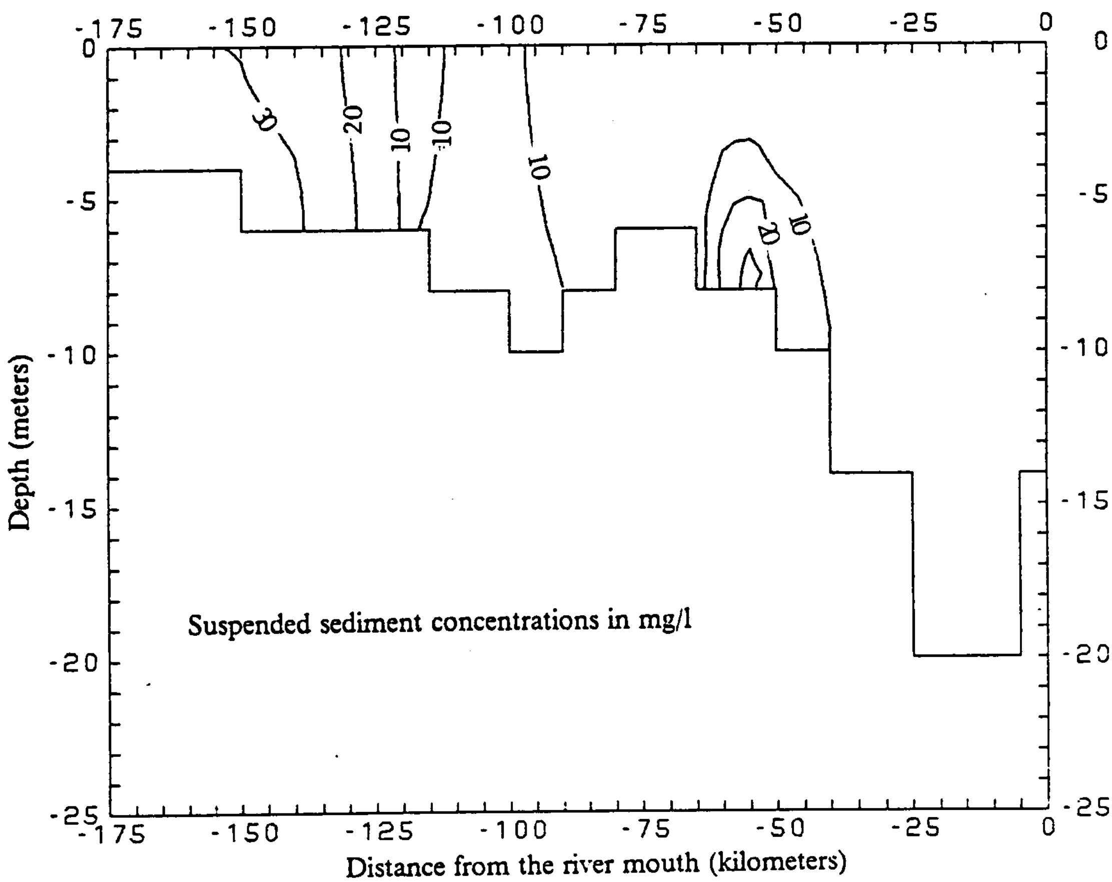

Figure 60. Sediment Concentration: 1580 cfs inflow with a 2.00 foot tidal height

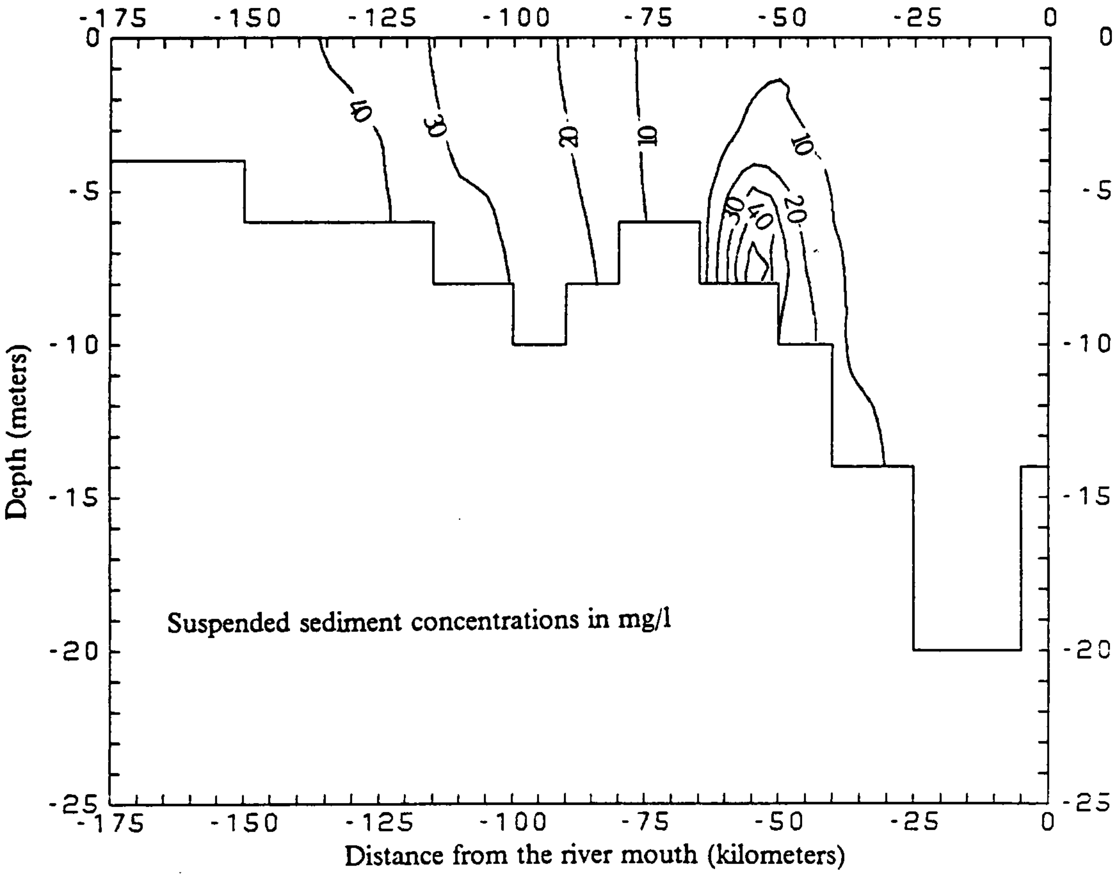

Figure 61. Sediment Concentration: 5540 cfs inflow with a 1.60 foot tidal height

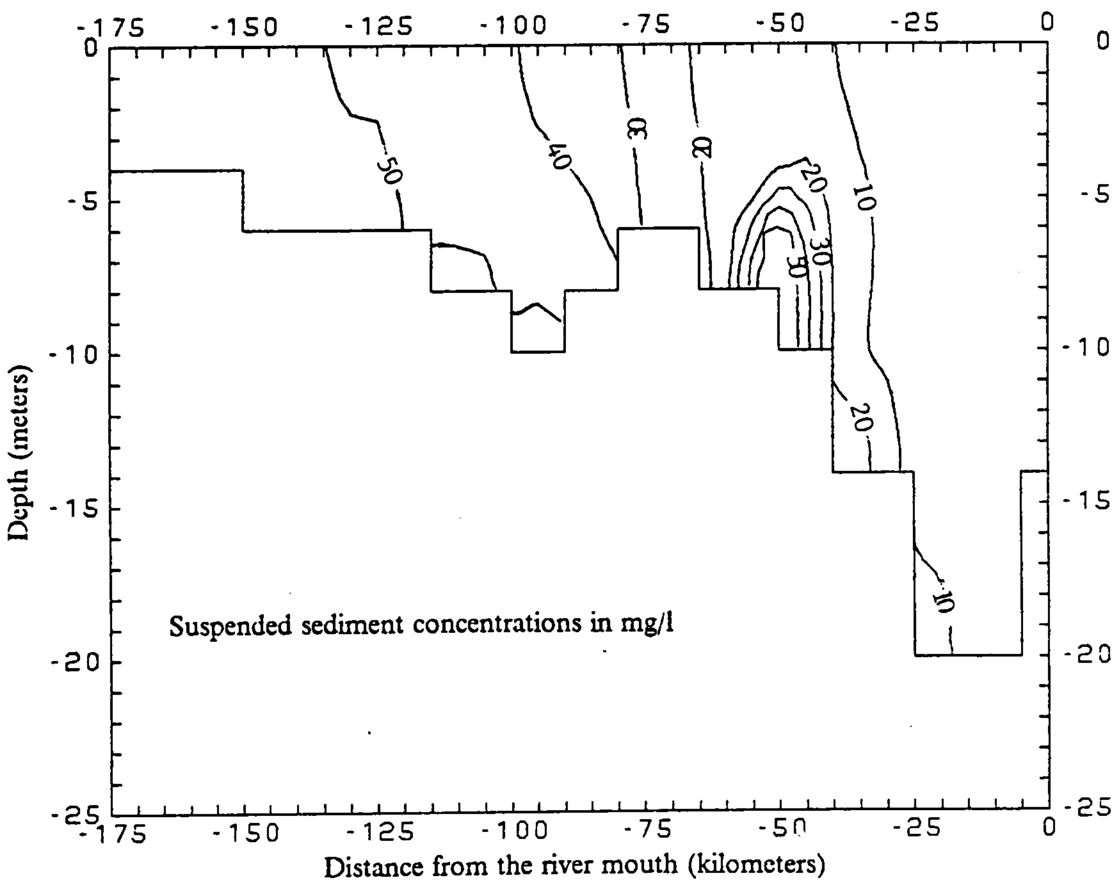

Figure 62. Sediment Concentration: 9270 cfs inflow with a 0.85 foot tidal height

CHAPTER 5

CONCLUSIONS

In order to examine the effects due to the projected rise in the sea level on the Rappahannock River estuary, a two-dimensional, time-dependent numerical model developed at the Virginia Institute of Marine Science was used to do a parametric study of the river under varying boundary conditions. At the upstream boundary of the estuary, normal, drought, and flood flows were examined. At the downstream boundary, paired against these streamflows, were the normal astronomic tide, a storm surge, and a predicted sea level rise. The numerical model, as originally written, simulated a constant streamflow at the upstream boundary and a time-varying tidal height at the downstream boundary. While this assumption of constant inflow sufficed for the normal and drought flows, it was unrealistic for flood flows. To correct for this deficiency, the model was modified to accept a hydrograph and to also vary the suspended sediment inflow with time. This is accomplished by stopping the model at selected times along the hydrograph, revising the boundary conditions, before resuming the calculations for the next time step.

At the mouth of the river, a storm surge and the heightened sea level must be added to the normal tide. This requires that a storm surge of a specified return period be selected. Subtracted from this storm surge is the highest astronomic tide computed for the duration of the model run. This difference and the projected sea level rise are simply added atop the normal tide throughout the model run to form the new downstream boundary condition.

To determine the magnitude of the 100-year flood flow on the Rappahannock River and the 100-year storm surge at the mouth of the river, flood and tide frequency analyses were performed. These frequency analyses demonstrate that small increases in the sea level will sharply reduce the return period of the storm surge required to reach the tide levels now only reached by a 100-year storm surge. Besides the separate flood and tide frequency analyses, a method for determining the joint probability of a specific streamflow and tidal height occurring simultaneously was developed.

Finding that the streamflows and tidal heights are dependent and have unknown distributions, this method transforms both data sets such that each set will have a normal distribution. The joint probability of exceedence is calculated with a bivariate normal distribution. This method is applicable to other variable pairs which are dependent and for which their distributions are unknown. While a return period for a particular streamflow-tidal height pair can be found, this is a monthly return period, but dividing this value by twelve will give a yearly return period. Application of this return period to a specific estuarine condition is not possible due to the variety of boundary conditions which exist for a single joint probability exceedence.

With the frequency analyses, the upstream and downstream boundary conditions for the numerical model are selected. By running the numerical model for ten simulations, a wide range of scenarios were studied. The most serious situation involved a drought combined with a 100-year storm surge and a 211 cm sea level rise. In this scenario, the 1 ppt isochlor shifted nearly 18 miles (30 km) upstream from its position during normal flow-normal tide conditions. While the simultaneous occurrence of a drought, storm surge, and 211 cm increase in the sea level might appear to be improbable, results nearly as serious were seen for an extended drought of two weeks matched with a 13 cm sea level rise. In this extended simulation, which is quite conceivable, the 1 ppt isochlor was observed to move 12 miles (20 km) further into the estuary as compared with the normal case.

This emphasizes the point that even small increases in the sea level can have a significant effect on the estuary's salinity during prolonged periods of low streamflow.

Three final simulations were run to illustrate the application of the joint probability method for the selection of the boundary conditions for the numerical model. Each of the three cases involved a streamflow-tidal height pair with a ten percent joint probability of exceedence. The varying effects each case had on the estuarine processes serve to reinforce the nonapplicability to estuarine conditions of the joint probabilities calculated in Chapter 3. These joint probabilities only indicate the rate of recurrence of a particular streamflow and tidal height. Prediction of the estuarine conditions for this streamflow and tidal height can only be made by running the numerical model.

All of the problems created by the rising sea level will have ecological, economic, legal, and political implications. Of ecological concern is the fate of the plant and animal life which currently lives in the estuary. While these lifeforms may gradually adapt to the increased salinity of their environment, they may not survive the intrusion of new predators who previously were unable to enter the less saline waters of the estuary. In addition to the local species of fish, marine fish species may also suffer since some of these species migrate into the estuaries to spawn. Considering the fact that the estuary is home for many commercially valuable species of fish, any detrimental change in their habitat could have an adverse effect on local economies. Although these problems may seem distantly related to the interests of most people, there are some which would affect many people directly. For example, the contamination of the freshwater stretches of the river by salt would damage surface water and groundwater sources used by nearby towns and industries. If water from the river is transferred to other locations under the terms of a flow diversion agreement, the increased salinity of the estuary may cause it to be more difficult to withdraw the amounts of freshwater mandated under the agreement. Besides these legal problems, there may be political questions involved with land use. These will arise as areas which are now relatively safe from storm surges become uninhabitable, or at the very least, may be employed for less economical uses. To properly address these problems, some understanding of the magnitude of the effect a heightened sea level would have is necessary. It has been with this goal in mind that this parametric study was made to examine the response of the Rappahannock River estuary to extreme conditions of streamflow and tidal height. This provides a framework by which to judge the extent of the changes a rising sea level would bring.

Still, the results presented must be taken as a guide not precise predictions. This is due to the lack of accurate data on the estuary's geometry, the tides at the mouth of the river, and the concentration of the suspended sediment carried into the estuary. Collection of this data and its subsequent substitution into the two-dimensional numerical model would provide more accurate results. In the meantime, the results of this paper affirm the need to bring more serious attention to the phenomenon of sea level rise.

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Appendix A

STREAM AND TIDAL GAUGING STATIONS

01668000 RAPPAHANNOCK RIVER NEAR FREDERICKSBURG, VA

(National stream-quality accounting network station)

LOCATION -- Lat 38°19'20" N, Long 77°31'05" W, Spotsylvania County, Hydrologic Unit 02080104, on right bank 1.6 mi upstream from dam of Virginia Electric and Power Co., 2.2 mi downstream from Motts Run, 3.8 mi upstream from Fredericksburg, and at mile 4.4.

DRAINAGE AREA -- 1,596 mi^2

PERIOD OF RECORD -- September 1907 to current year. Monthly discharge only for some periods, published in WSP 1302.

REVISED RECORDS -- WSP 801: 1924(M). WSP 951: 1937(M). WSP 1302: 1907-12, 1913(M), 1916(M), 1918(M), 1920-21(M). WSP 2103: Drainage area.

GAGE -- Water-stage recorder. Datum of gage is 55.18 ft National Geodetic Vertical Datum of 1929. Prior to Jan. 15, 1922, nonrecording gage, and Jan. 15 , 1922, to Aug. 2, 1966, water-stage recorder at same site at datum 1.00 ft higher.

REMARKS -- Records good except those for period of no gage-height record, Feb. 9 to Apr. 10, which are fair.

AVERAGE DISCHARGE -- 76 years, 1,658 ft^3/s, 14.11 in/yr.

EXTREMES FOR PERIOD OF RECORD -- Maximum discharge, 140,000 ft^3 /s Oct. 16, 1942, gage height, 26.9 ft, present datum, from floodmarks, from rating curve extended above 76,000 ft^3/s on basis of flow over dam and slope-area measurements at gage height 26.1 ft and 26.9 ft, present datum; minimum, 5 ft^3/s Oct. 11, 12, 1930.

EXTREMES OUTSIDE PERIOD OF RECORD -- Flood in June, 1889, was probably several feet lower than that of Oct. 16, 1942.

8638610 HAMPTON ROADS, VA JAMES RIVER

(National Ocean Survey tide gauging station)

LOCATION -- Lat 36°56.80′ N, Long 76°19.90′ W

LENGTH OF SERIES -- 365 days

SERIES BEGINS -- 71-1-1-0

AMPLITUDE RELATION -- $\frac{(K_1 + O_1)}{(M_2 + S_2)} = 0.218 \leq 0.25$ semidiurnal tide

MEAN TIDE LEVEL -- MTL = -0.008 feet

TIDAL RANGES --

Mean (MN) = 2.466 feet
Spring (SG) = 2.940 feet
Neap (NP) = 1.947 feet

CONVERSIONS FOR TIDAL HEIGHTS --

Datums apply from 1927 to 1984. Epoch: 1960-1978.

Subtract 4.13 feet to refer values to Mean Low Water (MLW).

Subtract 5.18 feet to refer values to the National Geodetic Vertical Datum (NGVD) of 1929 (formerly the Sea Level Datum of 1929).

Appendix B

INTERNATIONAL MATHEMATICAL AND STATISTICAL LANGUAGE (IMSL) SUBROUTINES

IMSL Routine Name		-	MDNRIS
Purpose		-	Inverse standard normal (Gaussian) probability distribution function.
Usage		-	CALL MDNRIS (P,Y,IER)
Arguments	P	-	Input value in the exclusive range (0.0,1.0)
	Y	-	Output value of the inverse normal (0,1) probability distribution function
	IER	-	Error parameter (output) Terminal Error IER = 129 indicates P lies outside the legal range. Plus or minus machine infinity is given as the result (sign is the sign of the function value of the nearest legal argument).
Precision/Hardware		-	Single/All
Reqd. IMSL Routines		-	MERFI,UERTST,UGETIO
Notation		-	Information on special notation and conventions is available in the manual introduction or through IMSL routine UHELP.

Algorithm: This subroutine computes Y so that

$$P = \text{Gauss}(Y) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{Y}\exp(-t^2/2)dt \quad \text{for a given value of } P.$$

For all legal arguments, computation is reduced to the computation of the inverse error function in the interval [0,1) by the application of the following identities:

$$\text{invgauss}(P) = -\sqrt{2}\cdot\text{inverfc}(2\cdot P),$$

$$\text{inverfc}(P) = \text{inverf}(1 - P),$$

$$\text{inverf}(-P) = -\text{inverf}(P).$$

The error function and complemented error function, respectively, are

$$\text{erf}(Y) = \frac{2}{\sqrt{\pi}}\int_0^Y \exp(-t^2)dt$$

$$\text{erfc}(Y) = \frac{2}{\sqrt{\pi}}\int_Y^\infty \exp(-t^2)dt$$

The interval [0,1) is divided into 4 segments. In each segment, inverf (P) is approximated by a minimax rational function. (See reference (1) for minimax approximations.) The approximation for the final 3 segments (comprising the interval (0.85,1)) are functions of the transformed variable:

$$w = \sqrt{-\ln(1 - P^2)}$$

where P is the reduced argument. This transformation of the variable improves the efficiency and stability of the approximation. (See Strecok, reference (2)).

For a complete description of the algorithm, see reference 3 below.

See references:

1. Hart, J. F. *et al*, **Computer Approximations**, New York, Wiley, 1968, 42-57.

2. Strecok, A. J., "On the Calculation of the Inverse of the Error Function", **Mathematics of Computation**, 22 (101) 1968, 144-158.

3. Kinnucan, P. and Kuki, H., "A Single Precision Inverse Error Function Subroutine", Computation Center, The University of Chicago, Chicago, Illinois.

Example: Input:

```
INTEGER IER
REAL P,Y
P = .7
CALL MDNRIS (P,Y,IER)
```

Output:

```
Y = .5244
IER = 0
```

IMSL Routine Name		- MDBNOR
Purpose		- Bivariate normal probability distribution function.
Usage		- CALL MDBNOR (X,Y,RHO,P,IER)
Arguments	X	- Input upper limit of integration for the first variable.
	Y	- Input upper limit of integration for the second variable.
	RHO	- Input correlation coefficient.
	P	- Output probability that the first variable is less than or equal to X and that the second variable is less than or equal to Y.
	IER	- Error parameter (output) Terminal Error IER = 129 indicates the absolute value of RHO is greater than or equal to one
Precision/Hardware		- Single/All
Reqd. IMSL Routines		- MDNOR,MDTNF,MERRC=ERFC,UERTST,UGETIO
Notation		- Information on special notation and conventions is available in the manual introduction or through IMSL routine UHELP.

Algorithm: MDBNOR evaluates the distribution function of the bivariate normal at the point (X,Y), where the correlation coefficient is RHO, means are zero and variances are one.

Details of the technique for computing the double integral are given in the following reference:

See reference:

Owen, D. B., **Handbook of Statistical Tables**, Addison-Wesley Publishing Company, Inc., Reading, Massachusetts, 1962, Chapter 8.

Accuracy: Comparison of results with those of the following reference indicated a maximum absolute error of less than .00001. **Tables of the Bivariate Normal Distribution Function and Related Functions**, National Bureau of Standards Applied Mathematics Series 50, June 15, 1959.

Example: The following example illustrates a case with large positive correlation (RHO = 0.9).

Input:

```
INTEGER IER
REAL X,Y,RHO,P
X = -2.0
Y =  0.0
RHO =  0.9
CALL MDBNOR (X,Y,RHO,P,IER)
END
```

Output:

```
P = 0.02275
IER = 0
```

IMSL Routine Name - MDNOR

Purpose - Normal or Gaussian probability distribution function.

Usage - CALL MDNOR (Y,P)

Arguments Y - Input at which the function is to be evaluated.

P - Output probability that a random variable having a normal (0,1) distribution will be less than or equal to Y.

Precision/Hardware - Single/All

Reqd. IMSL Routines - MERRC=ERFC

Notation - Information on special notation and conventions is available in the manual introduction or through IMSL routine UHELP.

Algorithm: MDNOR computes P = F (Y), where

$$F(Y) = \int_{-\infty}^{Y} f(t)dt = \int_{-\infty}^{Y} \frac{1}{\sqrt{2\pi}} e^{-t^2/2} dt$$

MDNOR calls IMSL routine MERRC=ERFC to perform the computation according to $P = 0.5 \times \text{ERFC}(-Y/\sqrt{2})$.

MDNOR may also be used for the general Normal (M,S^2) case for a point X by setting $Y = \frac{X-M}{S}$.

Example: Input:

```
REAL Y,P
Y = 2.0
CALL MDNOR (Y,P)
```

Output:

```
P = .97725
```

Appendix C

THE NUMERICAL MODEL OF THE ESTUARINE PROCESSES

LIST OF THE MOST SIGNIFICANT VARIABLES IN THE COMPUTER PROGRAM

ADA(I,L)	Tidal height at the Ith transect and the Lth time step (cm)
ADAMAX(I)	Maximum tidal height at the Ith transect (cm)
ADAMIN(I)	Minimum tidal height at the Ith transect (cm)
AMPL(N)	Amplitude of the Nth tidal constituent (cm)
AVD	Average sediment particle size in microns
B(I,K)	Width of the Kth layer of the Ith transect (m)
BDSHR(I,K)	Bed shear stress for the bottom layer of the Ith transect
C(I,K,L)	Suspended sediment concentration for the Kth layer of the Ith transect at the Lth time step (mg/l)
CAVG(I,K)	Average suspended sediment concentration for the Kth layer of the Ith transect (mg/l)
CC(LL)	Suspended sediment concentration for the LLth ordinate of the sedimentgraph (mg/l)
CSTAR	Wind drag coefficient
DELTAT	Length of time step (sec)

DELTAX	Distance between transects (m)
DEPTH(I,K)	Depth at which vertical velocities exist (cm)
EPX(I,K)	Horizontal eddy viscosity coefficient
EPZ(I,K)	Vertical eddy viscosity coefficient
EROR	Resuspension constant micrograms/cm^2/sec
EX(I,K)	Horizontal turbulent diffusivity coefficient
EZ(I,K)	Vertical turbulent diffusivity coefficient
FRIK(I,K)	Friction term used to calculate BDSHR(I,K)
H(K)	Thickness of the Kth layer (m)
HEIGHT	Height of the wind wave (cm)
I	Transect number beginning at upstream boundary
K	Layer number beginning with the top layer
KB(I)	Number of layers in the Ith transect
KBU(I)	Number of layers used for the horizontal velocity calculations for the Ith transect
KMAX	Maximum number of layers in the estuary
L	Time step (Previous step: L = 1; Current step: L = 2; Next step: L = 3)

LENGTH	Length of the wind wave (cm)
LL	Time at which the horizontal velocity and suspended sediment concentration at the upstream boundary is updated (hours)
MANN(I)	Manning friction coefficient for the Ith layer
NLS	Initial salt intrusion limit in terms of the transect number
NT	Number of transects
PERIOD	Period of the wind wave (sec)
PHASE(N)	Phase angle of the Nth tidal constituent (degrees)
PRESS(I,K)	Pressure at the Kth of layer of the Ith transect
Q(I,K)	Lateral inflow at the Kth layer of the Ith transect
QQ(LL)	Horizontal velocity at the upstream boundary at time LL (cm/sec)
RHO(I,K)	Density of water for the Kth layer of the Ith transect (gm/cc)
RHOAIR	Density of air (gm/cc)
S(I,K,L)	Salinity for the Kth layer of the Ith transect (ppt)
SALDN	Initial downstream salinity (ppt)
SALUP	Initial upstream salinity (ppt)
SAVG(I,K)	Average salinity for the Kth layer of the Ith transect (ppt)

SFLDM(K)	Salinity for the Kth layer of the downstream boundary (ppt)
SIGMA(N)	Frequency of the Nth tidal constituent (1/sec)
SST(I)	Surface storage area in millions of square meters
SVC	Coefficient for the settling velocity in cgs units
T(I,K,L)	Terms used in the momentum and salt balance equations
TAUD	Critical shear stress for deposition (dynes/cm^2)
TAUE	Critical shear stress for resuspension (dynes/cm^2)
TEMP	Estuarine water temperature (degrees Celsius)
TIDE	Tidal height at downstream boundary (cm)
TIME	Time (sec)
TOFH	Time interval to reach ocean conditions after flood tide begins (hours)
U(I,K,L)	Horizontal velocity at the Kth layer of the Ith transect (cm/sec)
UAVG(I,K)	Average horizonatal velocity for the Kth layer of the Ith transect (cm/sec)
VAR	Variance of particle size distribution in microns squared
VSET	Sediment settling velocity in thousandths of a centimeter per second
W(I,K)	Vertical velocity at the Kth layer of the Ith transect (cm/sec)

WAVG(I,K)	Average vertical velocity at the Kth layer of the Ith transect (cm/sec)
WNDSPD	Wind speed (m/sec)
WDRAG	Wind stress
WAVE	Term used to calculate the exchange coefficient resulting from the mixing by wind-induced waves

COMPUTER PROGRAM LISTING

```
C
C     ORIGINAL PROGRAM WRITTEN AT THE VIRGINIA INSTITUTE OF MARINE
C     SCIENCE, GLOUCESTER POINT, VIRGINIA.  MODEL SHOWN HERE HAS BEEN
C     MODIFIED TO HANDLE TIME-VARYING STREAMFLOW AND SUSPENDED SEDIMENT
C     CONCENTRATION AT THE UPSTREAM BOUNDARY.  MODIFICATIONS WERE MADE
C     AT VIRGINIA TECH IN THE SPRING OF 1987.  ALL FORTRAN STATEMENTS
C     BEGIN ON OR AFTER THE SEVENTH COLUMN.
C                                 200
      PARAMETER (NTRAN = 100,NLAYR=20,L=3)
      COMMON/DYN0/
     +      U(NTRAN,NLAYR,L),W(NTRAN,NLAYR),S(NTRAN,NLAYR,L),
     +      B(NTRAN,NLAYR),H(NLAYR),HMZ(NTRAN,NLAYR)
      COMMON/DYN1/
     +      RHO(NTRAN,NLAYR),ADA(NTRAN,L),DEPTH(NTRAN,NLAYR),
     +      T(NTRAN,NLAYR,L*2),EZ(NTRAN,NLAYR),EX(NTRAN,NLAYR)
      COMMON/DYN2/
     +      EPZ(NTRAN,NLAYR),EPX(NTRAN,NLAYR),PRESS(NTRAN,NLAYR),
     +      Q(NTRAN,NLAYR),KB(NTRAN),KBU(NTRAN),SST(NTRAN)
      COMMON/DYN3/
     +      BU(NTRAN,NLAYR),BW(NTRAN,NLAYR),MANN(NTRAN),
     +      FRIK(NTRAN,NLAYR)
      COMMON/SED/C(NTRAN,NLAYR,L),BDSHR(NTRAN,NLAYR),BDSED(NTRAN,NLAYR)
      COMMON/ST/STOS(NTRAN),STOC(NTRAN)
      COMMON/DYN4/
     +      SBAR(NTRAN),HRIB(NTRAN),QQ(NTRAN),CC(NTRAN),TT(NTRAN)
      DIMENSION W2(100,20),SAVG(100,20),CAVG(100,20),UAVG(100,20)
     1      ,WAVG(100,20),TAVG(100)
      DIMENSION  AMPL(5),PHASE(5),SFLDM(20),CFLDM(20)
      DIMENSION ADAMAX(100),ADAMIN(100)
      REAL LENGTH, MD(100), MANN
      DATA ADAMAX/100*-500./,ADAMIN/100*500./
      DATA TIME/0./,INCR/1/,G/980.0/
      DATA AVGN/0./,SAVG,CAVG,UAVG,WAVG,TAVG/8100*0.0/
```

```
      DATA EPZMIN,EZMIN/0.1,0.1/
C
C  READ IN NT & KMAX
C
      LOC=1
      READ(5,10) NT,KMAX
 10   FORMAT(16 I5)
      WRITE(6,20)NT,KMAX
 20   FORMAT('1','NUMBER OF TRANSECTS  =',I5,/' MAX. NUM. OF LAYERS IN AN
     1Y TRANSECT  =',I5)
C
      JJ=NT+1
C
C  READ IN NUMBER OF LAYERS PER TRANSECT
      READ(5,10) (KB(I), I=2,JJ)
       KB(1)=KB(2)
C
C  NOW READ IN LAYER THICKNESSES
C
      READ(5,30) (H(K), K=1,KMAX)
      WRITE(6,120) (K,H(K), K=1 ,  KMAX)
 120  FORMAT(/' LAYER THICKNESS (M)',/(20X,I3,3X,F5.1 ))
C
C  CONVERT TO CM
C
      DO 45 K=1,KMAX
 45       H(K)=H(K)*100
      T9=H(1)*2.
C
C  NOW THAT ALL LAYER DEPTHS & NO. OF LAYERS PER TRANSECT HAVE BEEN READ
C  IN, CALC MEAN DEPTHS & DEPTHS AT WHICH VERTICAL VELOCITIES EXIST FOR
C  THE ITH TRANSECT.
C
      DO 55 I=2,JJ
          MD(I)=0.
      N=KB(I)
```

```
      DO 65 K=1,N
         MD(I)=MD(I)+H(K)
65       DEPTH(I,K)=MD(I)
      DO 55 K=1,N
55       HMZ(I,K)=MD(I)-DEPTH(I,K)
C
C READ IN ESTURINE WIDTHS FOR EACH LAYER OF EACH TRANSECT. START WITH
C TOP LAYER TRANSECT NUMBER 1 (UPSTREAM)
C
   DO 300 I=2,JJ
   N=KB(I)
300 READ(5,444) (B(I,K),K=1,N)
444 FORMAT(15F8.0)
   WRITE(6,90) (K, K=1 , KMAX)
90 FORMAT(/' ESTUARY WIDTHS (M)',/50X,'LAYER',/' TRANSECT',5X,20 I5)
100 FORMAT(/'**********************************************************
   1****************************************************************')
   WRITE(6,100)
   DO 5 I=2,JJ
   N=KB(I)
5  WRITE(6,110) I,(B(I,K), K=1,N)
110 FORMAT(4X,I3,5X,'*',2X,20 F5.0)
C
C   READ THE SURFACE STORAGE AREA IN 10**6 SQUARE METER
   READ(5,44) (SST(I),I=2,JJ)
44 FORMAT(10F8.0)
   WRITE(6,111) (SST(I),I=2,JJ)
111 FORMAT(//,'*****STORAGE SURFACE AREA*****',/5(10X,10F10.3/))
C
C SET THE NUMBER OF LAYERS FOR U CALCULATION
   DO 112 I=3,JJ
   N=KB(I)
   KBU(I)=KB(I)
   IF(B(I-1,N).EQ.0.) KBU(I)=KB(I-1)
112 CONTINUE
```

```
      KBU(2)=KB(2)
C
C  CONVERT TO CM
C
      DO 15 I=2,JJ
      N=KB(I)
          DO 15 K=1,N
 15          B(I,K)=B(I,K)*100.
C
C  SET END 2 BOUNDARY TRANSECTS EQUAL
C
      N=KB(2)
      DO 25 K=1,N
 25      B(1,K)=B(2,K)
      N=KB(JJ)
      DO 35 K=1,N
 35      B(NT+2,K)=B(JJ,K)
C
C   CALCULATE AVERAGE WIDTH OF ADJACENT REACHES OR LAYERS
C
      JJ1=JJ+1
      KB(JJ1)=KB(JJ)
      DO 36 I=2,JJ1
      M=KB(I)
      DO 36 K=1,M
      BU(I,K)=B(I-1,K)+B(I,K)
36   BW(I,K)=B(I,K)+B(I,K+1)
C
C  READ IN THE OVERALL ESTURINE TEMP, THE LONGITUDINAL DISTANCE BETWEEN
C  TRANSECTS, & THE TIME BETWEEN ANY 2 TIME STEPS
C
      READ(5,30) TEMP,DELTAX,DELTAT
      WRITE(6,130) TEMP,DELTAX,DELTAT
 130  FORMAT(/' ESTUARINE TEMPERATURE = ',F10.4,/' DISTANCE BETWEEN TRANS
     1ECTS (M) = ',F10.4,/' TIME INTERVAL BETWEEN TIME STEPS (SECS) = ',
     2F10.4)
```

```
      DO 131 I=2,JJ
131   SST(I)=SST(I)/DELTAX*100000000.
C
C  CONVERT TO CM
C
      DELTAX=DELTAX*100
C
C  READ IN PARAMETERS TO CONTROL THE PRINTING OF VARIABLES
C
      READ(5,60) BPRINT,EPRINT,INC
 60   FORMAT(2 F10.0,I5)
      WRITE(6,70) BPRINT,EPRINT,INC
 70   FORMAT(/' PRINTING OF VARIABLES WILL COMMENCE AT THE ',F10.2,
     1      ' TIDAL CYCLE, END AT THE ',F10.2,' TIDAL CYCLE,',/'
     2      PRINTING EVERY ',I5,' TIME STEP(S)')
C  CONVERT TO SEC'S
C
      BPRINT=BPRINT*44712.
      EPRINT=EPRINT*44712.
      AVBEG=EPRINT-44712.
C
C  READ IN WIND STRESS & FRICTIONAL VARIABLES
C
      READ(5,30) CSTAR,RHOAIR,WNDSPD
 30   FORMAT(8 F10.0)
      WRITE(6,40) WNDSPD,RHOAIR,CSTAR
      WDRAG=10000.*CSTAR*WNDSPD*ABS(WNDSPD)*RHOAIR
 40   FORMAT(/' WIND SPEED  (M/S) =',F10.4,/' AIR DENSITY (GM/CC) =',
     1      F10.4,/' DRAG COEF  =',F10.4)
      READ(5,30) (MANN(I),I=2,JJ)
      WRITE(6,41) (MANN(I),I=2,JJ)
41    FORMAT(//,'*****MANNING FRICTION COEFFICIENTS*****',/5(10X,10F10.4
     1  /))
C     TO TRANSFORM MKS TO CGS  100**(2/3)=21.544
C
      DO 42 I=2,JJ
```

```
      N=KBU(I)
      DO 42 K=1,N
42    FRIK(I,K)=G*MANN(I)*MANN(I)/H(K)**0.33333/21.544
C
C  READ IN WIND WAVE CHARACTERISTICS
C
      READ(5,30) HEIGHT,PERIOD,LENGTH
      WRITE(6,50) HEIGHT,LENGTH,PERIOD
50    FORMAT(/' WIND WAVE CHARA:  HEIGHT(CM)=',F10.4,', LENGTH(CM)=',
     1      F10.4,', PERIOD(SEC)=',F10.4)
      WAVE=0.
      WAVEZ=0.
      IF (LENGTH.NE.0..AND.HEIGHT.NE.0..AND.PERIOD.NE.0.)
     1    WAVE=.00957*HEIGHT/PERIOD
C
C  CALC. SOME CONSTANTS
C
      DTX=DELTAT/DELTAX
      T10=2*DELTAX
      T2=5890+38*TEMP-.375*TEMP*TEMP
      T3=5890.72+37.774*TEMP-.33625*TEMP*TEMP
      T4=1.706+.01*TEMP
      T5=G/2/DELTAX
      T6=-G*4
      DT2=2*DELTAT
      DT8=4*DT2
      DX8=-1/T10/4
      DX16=DX8/2
      DXS4=1/(T10*T10)
      DXS8=DXS4/2
C
C   READ IN BOUNDARY INITIAL SALINITY (PARTS/THOUSANDS) & INTERPOLATE
C  FROM UPSTREAM TRANSECT ,SALUP,TO DOWNSTREAM TRANSECT,SALDN,FOR
C  STARTING MODEL
C
```

```
      READ(5,79) SALUP,SALDN,NLS
79    FORMAT(2F10.0,I10)
      WRITE(6,80) SALUP,SALDN,NLS
 80   FORMAT(/' INITIAL UPSTREAM SALINITY  =',F10.4/' INITIAL DOWNSTREAM
     1SALINTY=',F10.4/' INITIAL SALT INTRUSION LIMIT IN TERMS TRANSECT
     2NUMBER=',I3)
      READ(5,30) CUP,CDN
      WRITE(6,81) CUP,CDN
81    FORMAT(/' INITIAL UPSTREAM SED. CONCEN.=',F10.2/' INITIAL DOWNSTRE
     1AM SED. CONCEN.=',F10.2)
      DDS=(SALDN-SALUP)/(JJ-NLS)
      DO 126 I=NLS,JJ
126   S(I,1,1)=SALUP+DDS*(I-NLS)
      DO 128 I=1,NLS
128   S(I,1,1)=SALUP
      DDC=(CUP-CDN)/(JJ-2)
      DO 132 I=1,JJ
         S(I,1,2)=S(I,1,1)
         S(I,1,3)=S(I,1,1)
      STOS(I)=S(I,1,1)
      C(I,1,1)=CUP-DDC*(I-2)
      C(I,1,2)=C(I,1,1)
      C(I,1,3)=C(I,1,1)
      STOC(I)=C(I,1,1)
         K=KB(I)
         DO 133 J=2,K
      C(I,J,1)=C(I,1,1)
      C(I,J,2)=C(I,1,2)
      C(I,J,3)=C(I,1,3)
           S(I,J,1)=S(I,1,1)
           S(I,J,2)=S(I,1,2)
133         S(I,J,3)=S(I,1,3)
132   CONTINUE
C
C
C   READ OCEAN SALINITY AND SEDIMENT CONCENT. THAT COME IN AT THE DOWN-
```

```
C  STREAM TRANSECT DURING FLOOD TIDE NSFLDM AND CFLDME AND THE NUMBER
C  OF HOURS IT TAKES TO REACH SFLDM AND CFLDM AFTER FLOOD HAS STARTED
C
      K=KB(JJ)
      READ(5,140) TOFH
      READ(5,140) (SFLDM(I),I=1,K)
      READ(5,140) (CFLDM(I),I=1,K)
140   FORMAT(8F10.0)
      WRITE(6,150) TOFH
150   FORMAT(/' TIME INTERVAL FROM SBF TO REACH OCEAN CONDITIONS(HRS)=',
     1 F8.2)
      WRITE(6,151) (SFLDM(I),I=1,K)
151   FORMAT(/'*****OCEAN SALINITIES *****'/15F8.2)
      WRITE(6,152) (CFLDM(I),I=1,K)
152   FORMAT(/'*****OCEAN SEDIMENT CONCENTRATIONS*****'/15F8.2)
      MST=TOFH*3600./DELTAT
C
C   READ INPUT DATA FOR SEDIMENT RELATED PARAMETERS
C
      READ(5,30) SVC,AVD,VAR
      VSET=SVC*(AVD*AVD+VAR)/1000000.0
      WRITE(6,91)SVC,AVD,VAR,VSET
91    FORMAT(//3X,'COEFFICIENT FOR SETTLING VELOCITY IN CGS UNIT=',F10.4
     1,/3X,'AVERAGE SED. PARTICAL SIZE IN MICRON=',F6.2,/3X,'VARIANCE OF
     2PARTICAL SIZE DISTRIBUTION IN MICRON**2=',F8.2,/3X,'SED. SETTLING
     3VELOCITY IN 0.01CM/S=',F6.2)
      VSET=VSET/100.
      READ(5,30) TAUD,TAUE,EROR
      WRITE(6,92) TAUD,TAUE,EROR
92    FORMAT(//3X,'CRITICAL SHEAR STRESS FOR DEPOSITION=',F5.2,'DYNE/CM*
     1*2',/3X,'CRITICAL SHEAR STRESS FOR RESUSPENSION=',F5.2,'DYNE/CM**2
     2',/3X,'RESUSPENSION CONSTANT=',F8.4,'MICRO-GRAM/CM**2/SEC')
C
C  READ IN THE LATERAL INPUT FROM TRIBUTARIES, IF ANY.
C
      DISCH=0.
```

```
      DO 75 I = 1,NT
          READ(5,10) K
          IF (K.GT.NT) GO TO 85
      N = KB(K)
          READ(5,30) (Q(K,J), J = 1,N)
          WRITE(6,160) K,(Q(K,J), J = 1,N)
      DISCH = Q(2,1)*1000000.
      DO 75 J = 1,N
75    Q(K,J) = Q(K,J)/(0.0001*DELTAX*H(J))*100.
160       FORMAT(/' LATERAL INFLOW FOR TRANSECT',I3,'  IN CMS',/
     110X,10F10.2)
C
C  CALL THE SUBROUTINE THAT READS IN THE DOWNSTREAM TIDAL ATTRIBUTES
C  (AMPL'S & PHASES)
C
85    CALL TIDAL(AMPL,PHASE)
C
C  SET INITIAL DOWNSTREAM TIDAL HEIGHTS
C
      ADA(JJ,1) = TIDE(TIME,AMPL,PHASE)
      ADA(JJ,2) = ADA(JJ,1)
C
C  UPSTREAM BOUNDARY CONDITIONS WILL NOW BE CALC'ED OR READ IN. NOTE
C  THAT THE UPSTREAM TRANSECT'S SALINITY & VERTICAL VELOCITIES HAVE
C  ALREADY BEEN INITIALIZED (ZEROED). NOW READ IN U FOR EACH LAYER
C
      N = KB(2)
      READ(5,30) (U(2,K,2), K = 1,N)
      READ(5,30) (C(2,K,2), K = 1,N)
      DO 95 K = 1,N
          C(2,K,1) = C(2,K,2)
          C(2,K,3) = C(2,K,2)
      U(2,K,3) = U(2,K,2)
      DISCH = DISCH + U(2,K,3)*H(K)*B(2,K)
95        U(2,K,1) = U(2,K,2)
      WRITE(6,170) (K,U(2,K,2), K = 1,N)
```

```
 170 FORMAT(/' UPSTREAM TRANSECT BOUNDARY CONDITIONS:'//'     LAYER
    1 HORZ. VEL. (CM/SEC)',/(6X,I3,10X,F10.4 ))
      DO 1001 I=3,JJ
      KK=KBU(I)
      CROSS=0.
      DO 1002 K=1,KK
1002  CROSS=CROSS+H(K)*(B(I,K)+B(I-1,K))/2.
      U(I,1,1)=DISCH/CROSS
      U(I,1,2)=U(I,1,1)
      U(I,1,3)=U(I,1,1)
      DO 1003 K=2,KK
      U(I,K,1)=U(I,1,1)
      U(I,K,2)=U(I,1,2)
1003  U(I,K,3)=U(I,1,3)
1001  CONTINUE
C
C----------------------------------------------------------------
C
C   THIS SECTION IS A MODIFICATION TO THE ORIGINAL MODEL.
C
C----------------------------------------------------------------
C
C   ENTER THE NUMBER OF ORDINATES (MM) ON THE FLOOD HYDROGRAPH AND
C   THE TIME TO PEAK OF THE HYDROGRAPH (TP).  ALSO INPUT THE VALUES
C   OF THE SEA LEVEL RISE (SLR), STORM SURGE (SS) AND TIDE
C   CONVERSION FACTOR (TCF).
C
      READ(5,7) MM,TP,SLR,SS,TCF
    7 FORMAT(I5,4F6.2)
      TP=TP*3600.
C
C   ENTER THE FLOW VELOCITY (QQ) IN CM/SEC AND THE SUSPENDED
C   SEDIMENT LOAD (CC) IN MG/L FOR EACH ORDINATE ON THE HYDROGRAPH
C   AND SEDIMENTGRAPH AT THE UPSTREAM BOUNDARY.  ENTER THE TIME (TT)
C   AT WHICH THE VELOCITY AND SEDIMENT LOAD SHOULD BE UPDATED.
C
```

```
      READ(5,9) (QQ(LL),LL=1,MM)
      READ(5,9) (CC(LL),LL=1,MM)
      READ(5,9) (TT(LL),LL=1,MM)
    9 FORMAT(10F8.1)
C
C     PRINT THE INPUT VALUES.
C
      WRITE(6,77)
   77 FORMAT(/5X,'FLOOD HYDROGRAPH AND SEDIMENTGRAPH'//5X,'TIME',10X,
C    + 'VELOCITY',5X,'SUSPENDED SEDIMENT'/4X,'(HRS.)',10X,'(CM/S)',12X,
     + '(MG/L)'/)
      DO 76 LL=1,MM
      WRITE(6,89) TT(LL),QQ(LL),CC(LL)
   89 FORMAT(/3(5X,F8.1))
   76 CONTINUE
      WRITE(6,83)
   83 FORMAT(//5X,'DOWNSTREAM BOUNDARY CONDITION'/)
      WRITE(6,84) SLR,SS,TCF
   84 FORMAT(/10X,'SEA LEVEL RISE (CM) =',F6.2/10X,'STORM SURGE (CM) =',
     + F6.2/10X,'TIDE CONVERSION FACTOR =',F6.2)
C
C-------------------------------------------------------------------
C
C     END OF MODIFICATIONS FOR THIS SECTION.
C
C-------------------------------------------------------------------
C
C  DO NOT RESET VARIABLES
C
      GO TO 155
C
C     POINT WHERE ITERATION WITH TIME BEGINS
C
  105 CONTINUE
      TIME=TIME+DELTAT
```

```
      IF(TIME.GT.EPRINT) GOTO 700
C
C----------------------------------------------------------------
C
C     BEGIN MODIFICATIONS FOR THIS SECTION OF THE MAIN PROGRAM.
C
C----------------------------------------------------------------
C
C     CHECK TO SEE IF BOUNDARY CONDITIONS FOR CURRENT TIME STEP SHOULD
C     BE UPDATED AND IF THE UPDATE PRECEDES OR FOLLOWS THE TIME TO
C     PEAK OF THE HYDROGRAPH.  THE VALUE '23.' IS A TOLERANCE.
C     THIS SECTION CALLS THE APPROPRIATE SUBROUTINE TO UPDATE THE
C     BOUNDARY CONDITIONS.
C
       DIFF=TIME-TT(LOC)*3600.
       IF(ABS(DIFF).GE.23.) GOTO 164
       IF(TIME.GT.TP) THEN
        CALL UPDAT2(MD,KMAX,T9,JJ,LOC,NT)
                ELSE
        CALL UPDATE(MD,KMAX,T9,JJ,LOC,NT,SFLDM,CFLDM)
       ENDIF
       LOC=LOC+1
C
C----------------------------------------------------------------
C
C     END OF MODIFICATIONS IN THE MAIN PROGRAM.
C
C----------------------------------------------------------------
C
C  RESET VARIABLES FOR A NEW TIME STEP
C
 164  DO 165 I=1,JJ
         ADA(I,1)=ADA(I,2)
 165     ADA(I,2)=ADA(I,3)
      DO 175 I=2,JJ
        N=KB(I)
```

```
      DO 175 K=1,N
         U(I,K,1)=U(I,K,2)
         U(I,K,2)=U(I,K,3)
         S(I,K,1)=S(I,K,2)
         S(I,K,2)=S(I,K,3)
         C(I,K,1)=C(I,K,2)
174      C(I,K,2)=C(I,K,3)
175   CONTINUE
   DO 176 K=1,N
      U(JJ+1,K,1)=2.0*U(JJ,K,1)-U(JJ-1,K,1)
      U(JJ+1,K,2)=2.0*U(JJ,K,2)-U(JJ-1,K,2)
176 CONTINUE
C
C CALC THE DENSITY FOR THE CURRENT TIME STEP
C
186 DO 185 I=2,JJ
      N=KB(I)
        DO 185 K=1,N
          RHO(I,K)=(T2+3*S(I,K,2))/(T3-T4*S(I,K,2))
          IF(RHO(I,K).GE.0.0) GOTO 185
185       CONTINUE

C
C CALC THE PRESS TERM STARTING WITH THE TOP LAYER
C
   DO 205 I=3,JJ
      PRESS(I,1)=T5*((T9+ADA(I,2)+ADA(I-1,2))*
  1          (RHO(I,1)-RHO(I-1,1))/2.+(RHO(I-1,1)+RHO(I,1))*
  2          (ADA(I,2)-ADA(I-1,2)))
   K=2
        PRESS(I,K)=PRESS(I,K-1)+T5*((T9+ADA(I,2)+ADA(I-1,2))/2.*
  1              (RHO(I,K-1)-RHO(I-1,K-1))+H(K)*
  2              (RHO(I,K)-RHO(I-1,K)))
   N=KBU(I)
      DO 205 K=3,N
205      PRESS(I,K)=PRESS(I,K-1)+T5*(H(K-1)*
```

```
     1              (RHO(I,K-1)-RHO(I-1,K-1))+H(K)*
     2              (RHO(I,K)-RHO(I-1,K)))
C
C  CALC THE EDDY VISCOSITY & TURBULENT DIFFUSIVITY COEF'S USING THE
C  PREVIOUS TIME STEP'S VALUES FOR THE VARIABLES
C
      CALL EDDY(JJ,T6,LENGTH,WAVE,WAVEZ,MD)
C
C  CALC WATER SURFACE ADA(I,3) FROM CONTINUITY
C
      T7=BU(2,1)*(T9+ADA(2,2)+ADA(1,2))*U(2,1,2)
      DO 291 I=2,NT
         T8=BU(I+1,1)*(T9+ADA(I,2)+ADA(I+1,2))*U(I+1,1,2)
         ADA(I,3)=ADA(I,1)+DELTAT/(B(I,1)+SST(I))*(W(I,1)*BW(I,1)
     1          -1/T10*(T8-T7)+Q(I,1)*2*H(1))
         T7=T8
291   CONTINUE
         ADA(1,3)=ADA(2,3)-(ADA(3,3)-ADA(2,3))
         ADA(JJ,3)=TIDE(TIME,AMPL,PHASE)
C
C  CALCULATE ADVECTIVE AND DIFFUSIVE TERMS FOR BOTH MOMENTUM AND MASS
C  BALANCE EQUATIONS
C
      CALL ADIF(NT,T9)
C
C  CALCULATE HORIZONTAL VELOCITY
C
      CALL VELO(JJ,WDRAG,DT8,DX16,DXS8)
C
C  CALCULATE CONCENTRATIONS
C
      CALL MASS(NT,DT2,DX8,DXS4,VSET,TAUE,TAUD,EROR)
      CALL DONSC(MST,JJ,DTX,SFLDM,CFLDM)
C
C  NOW CALC THE VERTICAL VELOCITIES FOR THE CURRENT TIME STEP.  NOTE
```

```
C  THAT ALL W(I,KB(I))'S WERE INITIALIZED TO ZERO
C
      WMAX = -100.0
      WMIN =  100.0
      DO 225 I=2,JJ
         K=KB(I)-1
      BSUB=0.0
      GO TO 236
 235     BSUB=B(I,K+2)
 236  M=K+1
         W(I,K)=(W(I,K+1)*(B(I,K+1)+BSUB)-H(M)*(U(I+1,M,3)*
     1  BU(I+1,M)-U(I,M,3)*BU(I,M))/DELTAX
     2        +Q(I,M)*H(M)*2.)/BW(I,K)
      IF ( W(I,K) .GT. WMAX ) WMAX = W(I,K)
      IF ( W(I,K) .LT. WMIN ) WMIN = W(I,K)
         K=K-1
         IF(K.NE.0) GO TO 235
 225  CONTINUE
 155  CONTINUE
C
C  AT THIS POINT ALL U'S & S'S HAVE BEEN CALC'ED FOR THE (N+1)ST
C  TIME STEP.  TIME TO PRINT?
C
      IF  (BPRINT.GT.TIME) GO TO 105
      IF(TIME.LE.AVBEG) GO TO 501
      AVGN=AVGN+1.
      DO 650 I=2,JJ
      TAVG(I)=TAVG(I)+ADA(I,3)
      N=KB(I)
      DO 620 K=1,N
      SAVG(I,K)=SAVG(I,K)+S(I,K,3)
      CAVG(I,K)=CAVG(I,K)+C(I,K,3)
      UAVG(I,K)=UAVG(I,K)+U(I,K,3)
 620  WAVG(I,K)=WAVG(I,K)+W(I,K)
 650  CONTINUE
C-------> LOOK FOR MAXIMA AND MINIMA
```

```
      DO 651 I = 2 , JJ
      IF (ADA(I,3) .GT. ADAMAX(I) ) ADAMAX(I) = ADA(I,3)
      IF (ADA(I,3) .LT. ADAMIN(I) ) ADAMIN(I) = ADA(I,3)
  651 CONTINUE
 501  CONTINUE
C
C  YES - IS THIS THE PRINT TIME STEP?
C
      INCR = INCR-1
      IF (INCR.GT.0) GO TO 105
C
C  TIME TO PRINT.  REINITIALIZE CYCLE COUNTER & PRINT
C
      INCR = INC
      H1 = TIME/3600.
      WRITE(6,505) H1,(K, K = 2,21)
  505 FORMAT('1','SALINITY AT HOUR ',F7.2,/50X,'TRANSECT',/' LAYER',2X,
     1      20 I6)
      WRITE(6,525)
  525 FORMAT( '*********************************************************
     1*****************************************************************')
      DO 560 K = 1,KMAX
  560 WRITE(6,515) K,(S(I,K,3),I = 2,21)
  515 FORMAT(1X,I3,3X,'*',1X,20F6.1)
      WRITE(6,526) (K,K = 22,JJ)
 526  FORMAT(/,50X,'TRANSECT',/' LAYER',2X,20I6)
      WRITE(6,525)
      DO 561 K = 1,KMAX
  561 WRITE(6,515) K,(S(I,K,3),I = 22,JJ)
      WRITE(6,506) H1,(K, K = 2,21)
  506 FORMAT(//,' SED. CON. AT HOUR ',F7.2,/50X,'TRANSECT',/' LAYER',2X,
     1      20 I6)
      WRITE(6,525)
      DO 562 K = 1,KMAX
 562  WRITE(6,515) K,(C(I,K,3),I = 2,21)
      WRITE(6,526) (K,K = 22,JJ)
```

```
      WRITE(6,525)
      DO 563 K=1,KMAX
563   WRITE(6,515) K,(C(I,K,3),I=22,JJ)
      WRITE(6,516) H1,(K, K=2,21)
516   FORMAT( //,' TIDAL HEIGHT AT HOUR',F7.2,/50X,'TRANSECT',/8X,20I6)
      WRITE(6,525)
      WRITE(6,535) (ADA(I,3),I=2,21)
535   FORMAT(8X,20 F6.1)
      WRITE(6,526) (K,K=22,JJ)
      WRITE(6,525)
      WRITE(6,535) (ADA(I,3),I=22,JJ)
      WRITE(6,545) H1,(K, K=2,21)
545   FORMAT( //,' VERT. VEL. AT HOUR ',F7.2,'(IN 0.001CM)',/50X,'TRANSE
     1CT',/' LAYER',2X,20I6)
      WRITE(6,525)
      DO 570 K=1,KMAX
      DO 569 I=2,21
569   W2(I,K)=W(I,K)*1000.
570   WRITE(6,515) K,(W2(I,K),I=2,21)
      WRITE(6,526) (K,K=22,JJ)
      WRITE(6,525)
      DO 571 K=1,KMAX
      DO 572 I=22,JJ
572   W2(I,K)=W(I,K)*1000.
571   WRITE(6,515) K,(W2(I,K),I=22,JJ)
      WRITE(6,555) H1,(K, K=2,21)
555   FORMAT( //,' HORZ. VEL. AT HOUR ',F7.2,/50X,'TRANSECT',/
     1       ' LAYER',2X,20 I6)
      WRITE(6,525)
      DO 580 K=1,KMAX
580   WRITE(6,515) K,(U(I,K,3),I=2,21)
      WRITE(6,526) (K,K=22,JJ)
      WRITE(6,525)
      DO 581 K=1,KMAX
581   WRITE(6,515) K,(U(I,K,3),I=22,JJ)
      IF (TIME+DELTAT.GT.EPRINT) GO TO 700
```

```
      GO TO 105
 700  DO 702 I=2,JJ
      TAVG(I)=TAVG(I)/AVGN
      N=KB(I)
      DO 701 K=1,N
      SAVG(I,K)=SAVG(I,K)/AVGN
      CAVG(I,K)=CAVG(I,K)/AVGN
      UAVG(I,K)=UAVG(I,K)/AVGN
 701  WAVG(I,K)=WAVG(I,K)/AVGN*1000.
 702  CONTINUE
      WRITE(6,705) (K,K=2,21)
 705  FORMAT('1',' AVERAGE SALINITY',/50X,'TRANSECT',/' LAYER',2X,20I6)
      WRITE(6,525)
      DO 710 K=1,KMAX
 710  WRITE(6,515) K,(SAVG(I,K),I=2,21)
      WRITE(6,526) (K,K=22,JJ)
      WRITE(6,525)
      DO 711 K=1,KMAX
 711  WRITE(6,515) K,(SAVG(I,K),I=22,JJ)
      WRITE(6,715) (K,K=2,21)
 715  FORMAT(//,' AVERAGE SEDIMENT CONCENTRATIONS '/50X,'TRANSECT',/' LA
     1YER',2X,20I6)
      WRITE(6,525)
      DO 720 K=1,5
 720  WRITE(6,515) K,(CAVG(I,K),I=2,21)
      WRITE(6,526) (K,K=22,JJ)
      WRITE(6,525)
      DO 721 K=1,KMAX
 721  WRITE(6,515) K,(CAVG(I,K),I=22,JJ)
      WRITE(6,725) (K,K=2,21)
 725  FORMAT(//,' AVERAGE WATER SURFACE ELEVATION '/50X,'TRANSECT',/'
     1LAYER',2X,20I6)
      WRITE(6,525)
      WRITE(6,535) (TAVG(I),I=2,21)
      WRITE(6,526) (K,K=22,JJ)
      WRITE(6,525)
```

```
      WRITE(6,535) (TAVG(I),I=22,JJ)
      WRITE(6,735) (K,K=2,21)
  735 FORMAT(//,' AVERAGE HORIZONTAL VELOCITIES   '/50X,'TRANSECT',/' LA
     1YER',2X,20I6)
      WRITE(6,525)
      DO 740 K=1,KMAX
  740 WRITE(6,515) K,(UAVG(I,K),I=2,21)
      WRITE(6,526) (K,K=22,JJ)
      WRITE(6,525)
      DO 741 K=1,KMAX
  741 WRITE(6,515) K,(UAVG(I,K),I=22,JJ)
      WRITE(6,745) (K,K=2,21)
  745 FORMAT(//,' AVERAGE VERTICAL   VELOCITIES   '/50X,'TRANSECT',/' LA
     1YER',2X,20I6)
      WRITE(6,525)
      DO 750 K=1,KMAX
  750 WRITE(6,515) K,(WAVG(I,K),I=2,21)
      WRITE(6,526) (K,K=22,JJ)
      WRITE(6,525)
      DO 751 K=1,KMAX
  751 WRITE(6,515) K,(WAVG(I,K),I=22,JJ)
      WRITE(6,755) (K,K=2,21)
  755 FORMAT(//,' ACCUMULATED BOTTOM SEDMENT IN MILI  GM./CM**2'/50X,
     1'TRANSECT',/' LAYER',2X,20I6)
      WRITE(6,525)
      DO 760 K=1,KMAX
      DO 759 I=2,21
  759 BDSED(I,K)=BDSED(I,K)/1000.
  760 WRITE(6,515) K,(BDSED(I,K),I=2,21)
      WRITE(6,526) (K,K=22,JJ)
      WRITE(6,525)
      DO 761 K=1,KMAX
      DO 762 I=22,JJ
  762 BDSED(I,K)=BDSED(I,K)/1000.
  761 WRITE(6,515) K,(BDSED(I,K),I=22,JJ)
      WRITE(6,13)
```

```
 13 FORMAT('1',//10X,' MAXMUM WATER SFC ELEVATION',10X,'MINMUM WATER
   $ SFC ELEVATION',///)
    WRITE(6,525)
    DO 11 I = 2 , JJ
 11 WRITE(6,12) I ,ADAMAX(I), ADAMIN(I)
 12 FORMAT(I5,11X,F7.2,32X,F7.2)
    STOP
    END
    FUNCTION TIDE(T1,AMPL,PHASE)
C
C  CALC THE TIDAL HEIGHT FROM TIDAL AMPL'S & FROM TIDAL PHASES AT TIME
C  ZERO. 'SIGMA' IS AN ARRAY OF FREQUENCIES IN DEGREES/SEC.
C
    DIMENSION AMPL(5),PHASE(5),SIGMA(5)
    DATA SIGMA/3.87306E-3,4.17808E-3,8.05114E-3,8.33333E-3,7.89992E-3/
    TIDE=0
    DO 10 N=1,5
 10       TIDE=TIDE+AMPL(N)*COS((PHASE(N)+T1*SIGMA(N))/57.2958)
C
C   THESE MODIFICATIONS WERE MADE TO INCLUDE SEA LEVEL RISE AND
C   STORM SURGE:
C   ADD SEA LEVEL RISE TO TIDE AND MULTIPLY THIS PRODUCT BY THE
C   APPROPRIATE TIDE CONVERSION FACTOR (0.44 IN THIS EXAMPLE).
C   FINALLY, ADD THE AMOUNT OF TIDAL SURGE DUE TO A STORM.
C
    TIDE=0.44*(TIDE+0.00)+0.00
    RETURN
    END
    SUBROUTINE TIDAL(AMPL,PHASE)
C
C  THIS SUBROUTINE READS IN THE AMPL'S (CM) & PHASES (DEGREES) FOR THE
C  01, K1, M2, S2, & N2 TIDAL CONSTITUENTS FOR THE DOWNSTREAM TRANSECT
C
    DIMENSION AMPL(5),PHASE(5)
    READ(5,10) (AMPL(I), PHASE(I), I=1,5)
 10 FORMAT(5 (F5.1,1X,F6.2,3X))
```

```
      WRITE(6,20) (AMPL(I),PHASE(I), I=1,5)
20    FORMAT(/' TIDAL AMPLITUDES (CM) & PHASES (DEGREES)',/5X,'01',3X,
     1     F5.1,10X,F6.2,/5X,'K1',3X,F5.1,10X,F6.2,/5X,'M2',3X,F5.1,
     210X,F6.2,/5X,'S2',3X,F5.1,10X,F6.2,/5X,'N2',3X,F5.1,10X,F6.2)
      RETURN
      END
      SUBROUTINE EDDY(JJ,T6,LENGTH,WAVE,WAVEZ,MD)
       PARAMETER (NTRAN=100,NLAYR=20,L=3)
      COMMON/DYN0/
     +     U(NTRAN,NLAYR,L),W(NTRAN,NLAYR),S(NTRAN,NLAYR,L),
     +     B(NTRAN,NLAYR),H(NLAYR),HMZ(NTRAN,NLAYR)
      COMMON/DYN1/
     +     RHO(NTRAN,NLAYR),ADA(NTRAN,L),DEPTH(NTRAN,NLAYR),
     +     T(NTRAN,NLAYR,L*2),EZ(NTRAN,NLAYR),EX(NTRAN,NLAYR)
      COMMON/DYN2/
     +     EPZ(NTRAN,NLAYR),EPX(NTRAN,NLAYR),PRESS(NTRAN,NLAYR),
     +     Q(NTRAN,NLAYR),KB(NTRAN),KBU(NTRAN),SST(NTRAN)
      COMMON/DYN3/
     +     BU(NTRAN,NLAYR),BW(NTRAN,NLAYR),MANN(NTRAN),
     +     FRIK(NTRAN,NLAYR)
      COMMON/SED/C(NTRAN,NLAYR,L),BDSHR(NTRAN,NLAYR),BDSED(NTRAN,NLAYR)
      COMMON/ST/STOS(NTRAN),STOC(NTRAN)
      COMMON/DYN4/
     +     SBAR(NTRAN),HRIB(NTRAN),QQ(NTRAN),CC(NTRAN),TT(NTRAN)
      REAL LENGTH, MD(100), MANN
      DO 400 I=2,JJ
         N=KB(I)-1
         DO 410 K=1,N
C
C THIS ROUTINE CALC'S THE VERTICAL TURBULENT DIFFUSIVITY & EDDY
C VISCOSITY COEF'S FOR THE ITH TRANSECT, KTH LAYER.
C
C NOTE: IF U(I,K,1)-U(I,K+1,1)+U(I+1,K,1)-U(I+1,K+1,1) IS NEAR ZERO,
C      THEN EZ & EPZ ARE SET TO ZERO.
C
      TM=U(I,K,1)-U(I,K+1,1)+U(I+1,K,1)-U(I+1,K+1,1)
```

```
      IF (ABS(TM).GT..000001) GO TO 420
      EZ(I,K)=0.1
      EPZ(I,K)=0.1
      GO TO 410
420   Z=DEPTH(I,K)+ADA(I,1)
      TOTALH=MD(I)+ADA(I,1)
      RI=0.
      DELRO=RHO(I,K)-RHO(I,K+1)
      IF(DELRO.LT. -0.00001) RI=T6*(H(K)+H(K+1))*DELRO/(RHO(I,K)+RHO(I,K
     1   +1))/(TM*TM)
      IF (LENGTH.NE.0.) WAVEZ=WAVE*EXP(-6.2832*Z/LENGTH)
      FRONT=Z*HMZ(I,K)*(.0021475*Z*HMZ(I,K)*(ABS(U(I,K,1))+ABS(U(I,K+1,1
     1 ))+ABS(U(I+1,K,1))+ABS(U(I+1,K+1,1)))
     2      /TOTALH/TOTALH+WAVEZ)/TOTALH
      DIV=1+.276*RI
      IF(DIV.GE.0.) GOTO 409
409   EZ(I,K)=FRONT/(DIV**.5)
      EPZ(I,K)=FRONT/DIV
410   CONTINUE
400   CONTINUE
      N=KB(2)-1
      DO 440 K=1,N
      EZ(1,K)=EZ(2,K)
      EPZ(1,K)=EPZ(2,K)
440   CONTINUE
      DO 460 I=2,JJ
      EX(I,1)=(EZ(I,1)+EZ(I-1,1))*5000.
      EPX(I,1)=(EPZ(I,1)+EPZ(I-1,1))*5000.
      N=KBU(I)
      DO 450 K=2,N
      EPX(I,K)=(EPZ(I,K)+EPZ(I-1,K)+EPZ(I-1,K-1)+EPZ(I,K-1))*2500.
450   EX(I,K)=(EZ(I,K)+EZ(I-1,K)+EZ(I-1,K-1)+EZ(I,K-1))*2500.
460   CONTINUE
      RETURN
      END
      SUBROUTINE ADIF(NT,T9)
```

```
      PARAMETER (NTRAN = 100,NLAYR = 20,L = 3)
      COMMON/DYN0/
     +      U(NTRAN,NLAYR,L),W(NTRAN,NLAYR),S(NTRAN,NLAYR,L),
     +      B(NTRAN,NLAYR),H(NLAYR),HMZ(NTRAN,NLAYR)
      COMMON/DYN1/
     +      RHO(NTRAN,NLAYR),ADA(NTRAN,L),DEPTH(NTRAN,NLAYR),
     +      T(NTRAN,NLAYR,L*2),EZ(NTRAN,NLAYR),EX(NTRAN,NLAYR)
      COMMON/DYN2/
     +      EPZ(NTRAN,NLAYR),EPX(NTRAN,NLAYR),PRESS(NTRAN,NLAYR),
     +      Q(NTRAN,NLAYR),KB(NTRAN),KBU(NTRAN),SST(NTRAN)
      COMMON/DYN3/
     +      BU(NTRAN,NLAYR),BW(NTRAN,NLAYR),MANN(NTRAN),
     +      FRIK(NTRAN,NLAYR)
      COMMON/SED/C(NTRAN,NLAYR,L),BDSHR(NTRAN,NLAYR),BDSED(NTRAN,NLAYR)
      COMMON/ST/STOS(NTRAN),STOC(NTRAN)
      COMMON/DYN4/
     +      SBAR(NTRAN),HRIB(NTRAN),QQ(NTRAN),CC(NTRAN),TT(NTRAN)
C
C  CALC. TERMS USED IN MOMENTUM & SALT BALANCE EQN'S.  TOP LAYER FIRST
C
      DO 245 I = 2,NT
         IP1 = I + 1
         IM1 = I-1
         T(I,1,1) = U(IP1,1,2)*(S(I,1,2) + S(IP1,1,2))*BU(IP1,1)*
     1          (T9 + ADA(I,2) + ADA(IP1,2))
         T(I,1,2) = EPX(IP1,1)*BU(IP1,1)*(S(IP1,1,1)-S(I,1,1))*
     1          (T9 + ADA(I,1) + ADA(IP1,1))
         T(I,1,5) = U(IP1,1,2)*(C(I,1,2) + C(IP1,1,2))*BU(IP1,1)*
     1          (T9 + ADA(I,2) + ADA(IP1,2))
         T(I,1,6) = EPX(IP1,1)*BU(IP1,1)*(C(IP1,1,1)-C(I,1,1))*
     1          (T9 + ADA(I,1) + ADA(IP1,1))
         T(I,1,3) = (BU(IP1,1)*(T9 + ADA(I,2) + ADA(IP1,2))*U(IP1,1,2) +
     1           BU(I,1)*(T9 + ADA(I,2) + ADA(IM1,2))*U(I,1,2))*
     2           (U(I,1,2) + U(IP1,1,2))
         T(I,1,4) = (BU(IP1,1)*(T9 + ADA(I,1) + ADA(IP1,1))*EX(IP1,1) +
     1           BU(I,1)*(T9 + ADA(I,1) + ADA(IM1,1))*EX(I,1))*
```

```
     2            (U(IP1,1,1)-U(I,1,1))
C
C  NOW REMAINING LAYERS
C
      N=KB(I)
       DO 245 K=2,N
          TH  =2*H(K)
          T(I,K,1)=U(IP1,K,2)*(S(I,K,2)+S(IP1,K,2))*BU(IP1,K)*TH
          T(I,K,2)=EPX(IP1,K)*BU(IP1,K)*(S(IP1,K,1)-S(I,K,1))*TH
          T(I,K,5)=U(IP1,K,2)*(C(I,K,2)+C(IP1,K,2))*BU(IP1,K)*TH
          T(I,K,6)=EPX(IP1,K)*BU(IP1,K)*(C(IP1,K,1)-C(I,K,1))*TH
          T(I,K,3)=(BU(IP1,K)*U(IP1,K,2)+BU(I,K)*U(I,K,2))*TH *
     1             (U(I,K,2)+U(IP1,K,2))
 245      T(I,K,4)=(BU(IP1,K)*EX(IP1,K)+BU(I,K)*EX(I,K))*TH *
     1             (U(IP1,K,1)-U(I,K,1))
C
C  TERMS AT OPEN BOUNDARY
C
      I=NT+1
         IM1=I-1
         IP1=I+1
      ADA(IP1,2)=2.0*ADA(I,2)-ADA(IM1,2)
      EX(IP1,1)=2.0*EX(I,1)-EX(IM1,1)
         T(I,1,3)=(BU(IP1,1)*(T9+ADA(I,2)+ADA(IP1,2))*U(IP1,1,2)+
     1            BU(I,1)*(T9+ADA(I,2)+ADA(IM1,2))*U(I,1,2))*
     2            (U(I,1,2)+U(IP1,1,2))
         T(I,1,4)=(BU(IP1,1)*(T9+ADA(I,1)+ADA(IP1,1))*EX(IP1,1)+
     1            BU(I,1)*(T9+ADA(I,1)+ADA(IM1,1))*EX(I,1))*
     2            (U(IP1,1,1)-U(I,1,1))
      N=KB(I)
      DO 345 K=2,N
      TH=2*H(K)
      EX(IP1,K)=2.0*EX(I,K)-EX(IM1,K)
          T(I,K,3)=(BU(IP1,K)*U(IP1,K,2)+BU(I,K)*U(I,K,2))*TH *
     1             (U(I,K,2)+U(IP1,K,2))
 345      T(I,K,4)=(BU(IP1,K)*EX(IP1,K)+BU(I,K)*EX(I,K))*TH *
```

```
     1              (U(IP1,K,1)-U(I,K,1))
      RETURN
      END
      SUBROUTINE VELO(JJ,WDRAG,DT8,DX16,DXS8)
       PARAMETER (NTRAN = 100,NLAYR = 20,L = 3)
      COMMON/DYN0/
     +      U(NTRAN,NLAYR,L),W(NTRAN,NLAYR),S(NTRAN,NLAYR,L),
     +      B(NTRAN,NLAYR),H(NLAYR),HMZ(NTRAN,NLAYR)
      COMMON/DYN1/
     +      RHO(NTRAN,NLAYR),ADA(NTRAN,L),DEPTH(NTRAN,NLAYR),
     +      T(NTRAN,NLAYR,L*2),EZ(NTRAN,NLAYR),EX(NTRAN,NLAYR)
      COMMON/DYN2/
     +      EPZ(NTRAN,NLAYR),EPX(NTRAN,NLAYR),PRESS(NTRAN,NLAYR),
     +      Q(NTRAN,NLAYR),KB(NTRAN),KBU(NTRAN),SST(NTRAN)
      COMMON/DYN3/
     +      BU(NTRAN,NLAYR),BW(NTRAN,NLAYR),MANN(NTRAN),
     +      FRIK(NTRAN,NLAYR)
      COMMON/SED/C(NTRAN,NLAYR,L),BDSHR(NTRAN,NLAYR),BDSED(NTRAN,NLAYR)
      COMMON/ST/STOS(NTRAN),STOC(NTRAN)
      COMMON/DYN4/
     +      SBAR(NTRAN),HRIB(NTRAN),QQ(NTRAN),CC(NTRAN),TT(NTRAN)
      DO 500 I = 3,JJ
          IM1 = I-1
          IP1 = I + 1
C
C SET VARIABLES FOR 1ST LAYER
          K = 1
      TH = 2*H(K)
          ADA1 = ADA(I,1) + ADA(IM1,1)
          ADA2 = ADA(I,2) + ADA(IM1,2)
          ADA3 = ADA(I,3) + ADA(IM1,3)
          WUBB = 0
          TAUB = WDRAG/RHO(I,1)*BU(I,K)/2.
C
C THIS IS TO    CALC'S VARIOUS VALUES FOR THE BOTTOM OF THE KTH        57
C
```

```
      WUBA=(W(I,K)+W(IM1,K))*(U(I,K,2)+U(I,K+1,2))*
     1  (BU(I,K+1)+BU(I,K))/16.
      TAUA=.25*(BU(I,K+1)+BU(I,K))*
     1  (EZ(I,K)+EZ(IM1,K))*(U(I,K,1)-U(I,K+1,1))/(H(K+1)+H(K)+ADA1
     2  *0.5)
      SINK=0.
      DELADA=ADA3-ADA1
      IF(DELADA.LE.0.) GO TO 100
      SINK=U(I,K,2)*(SST(IM1)+SST(I))*DELADA/BU(I,K)
100   CONTINUE
      BDSHR(I,K)=FRIK(I,K)*U(I,K,1)*ABS(U(I,K,1))
C CHANGE MADE HERE
C
C
      SIDF=BDSHR(I,K)*(BU(I,K)-BU(I,K+1))/2.
      U(I,K,3)=1/(TH+ADA3)*(U(I,K,1)*(TH+ADA1)+DT8/BU(I,K)*
     1      (TAUB-TAUA-BU(I,K)*(TH+ADA2)/2/(RHO(I,K)+RHO(IM1,K))*
     2      PRESS(I,K)+DXS8*(T(I,K,4)-T(IM1,K,4))+DX16*(T(I,K,3)-T(IM
     3      1,K,3))-WUBB+WUBA-SIDF)-SINK)
      IF (KBU(I).EQ.2) GO TO 550
C
C NOW CALC U FOR ALL BUT LAST LAYER
C
      N=KBU(I)-1
        DO 540 K=2,N
      TH=2*H(K)
          WUBB=WUBA
          TAUB=TAUA
      WUBA=(W(I,K)+W(IM1,K))*(U(I,K,2)+U(I,K+1,2))*
     1  (BU(I,K+1)+BU(I,K))/16.
      TAUA=.25*(BU(I,K+1)+BU(I,K))*
     1  (EZ(I,K)+EZ(IM1,K))*(U(I,K,1)-U(I,K+1,1))/(H(K+1)+H(K))
      BDSHR(I,K)=FRIK(I,K)*U(I,K,1)*ABS(U(I,K,1))
      SIDF=BDSHR(I,K)*(BU(I,K-1)-BU(I,K+1))/4.
      U(I,K,3)=1/TH*(U(I,K,1)*TH+DT8/BU(I,K)*
     1      (TAUB-TAUA-BU(I,K)*TH/2./(RHO(I,K)+RHO(IM1,K))*
```

```
   2        PRESS(I,K)+DXS8*(T(I,K,4)-T(IM1,K,4))+DX16*(T(I,K,3)-T(IM
   3        1,K,3))-WUBB+WUBA-SIDF))
 540 CONTINUE
 550 CONTINUE
C
C NOW CALC U FOR BOTTOM LAYER
C
      K=KBU(I)
     TH=2*H(K)
      WUBB=WUBA
      WUBA=0
      TAUB=TAUA
     TAUA=0.
     BDSHR(I,K)=FRIK(I,K)*U(I,K,1)*ABS(U(I,K,1))
     SIDF=BDSHR(I,K)*(BU(I,K-1)-BU(I,K+1))/4.
     U(I,K,3)=1/TH*(U(I,K,1)*TH+DT8/BU(I,K)*
   1        (TAUB-TAUA-BU(I,K)*TH/2./(RHO(I,K)+RHO(IM1,K))*
   2        PRESS(I,K)+DXS8*(T(I,K,4)-T(IM1,K,4))+DX16*(T(I,K,3)-T(IM
   3        1,K,3))-WUBB+WUBA-SIDF))
 500 CONTINUE
     N=KBU(JJ)
     DO 600 K=1,N
 600    U(JJ+1,K,3)=2.0*U(JJ,K,3)-U(JJ-1,K,3)
     RETURN
     END
     SUBROUTINE MASS(NT,DT2,DX8,DXS4,VSET,TAUE,TAUD,EROR)
      PARAMETER (NTRAN=100,NLAYR=20,L=3)
     COMMON/DYN0/
     +      U(NTRAN,NLAYR,L),W(NTRAN,NLAYR),S(NTRAN,NLAYR,L),
     +      B(NTRAN,NLAYR),H(NLAYR),HMZ(NTRAN,NLAYR)
     COMMON/DYN1/
     +      RHO(NTRAN,NLAYR),ADA(NTRAN,L),DEPTH(NTRAN,NLAYR),
     +      T(NTRAN,NLAYR,L*2),EZ(NTRAN,NLAYR),EX(NTRAN,NLAYR)
     COMMON/DYN2/
     +      EPZ(NTRAN,NLAYR),EPX(NTRAN,NLAYR),PRESS(NTRAN,NLAYR),
     +      Q(NTRAN,NLAYR),KB(NTRAN),KBU(NTRAN),SST(NTRAN)
```

```
      COMMON/DYN3/
     +     BU(NTRAN,NLAYR),BW(NTRAN,NLAYR),MANN(NTRAN),
     +     FRIK(NTRAN,NLAYR)
      COMMON/SED/C(NTRAN,NLAYR,L),BDSHR(NTRAN,NLAYR),BDSED(NTRAN,NLAYR)
      COMMON/ST/STOS(NTRAN),STOC(NTRAN)
      COMMON/DYN4/
     +     SBAR(NTRAN),HRIB(NTRAN),QQ(NTRAN),CC(NTRAN),TT(NTRAN)
      DO 500 I=3,NT
         IM1=I-1
         IP1=I+1
C
C SET VARIABLES FOR 1ST LAYER
         K=1
      TH=2*H(K)
         FB=0
         WSBB=0
      WSBA=W(I,K)*(S(I,K,2)+S(I,K+1,2))*BW(I,K)/4.
      FA=EPZ(I,K)*BW(I,K)*(S(I,K,1)-S(I,K+1,1))
     1 /(H(K)+H(K+1)+ADA(I,1))
      DELA=ADA(I,3)-ADA(I,1)
      IF(DELA.LT.0.) GO TO 105
      SINK=S(I,K,2)*SST(I)*DELA/B(I,K)
      CINK=C(I,K,2)*SST(I)*DELA/B(I,K)
      STOS(I)=(STOS(I)*(H(K)+ADA(I,2))+S(I,K,2)*DELA*0.5)/
     1      (H(K)+ADA(I,3))
      STOC(I)=(STOC(I)*(H(K)+ADA(I,2))+C(I,K,2)*DELA*0.5-VSET*STOC(I)*
     1      DT2*0.5)/(H(K)+ADA(I,3))
      GO TO 110
105   SINK=STOS(I)*SST(I)*DELA/B(I,K)
      CINK=STOC(I)*SST(I)*DELA/B(I,K)
      STOC(I)=(STOC(I)*(H(K)+ADA(I,3))-VSET*STOC(I)*DT2*0.5)/(H(K)+ADA(I
     1      ,3))
110   CONTINUE
      S(I,K,3)=1/(H(K)+ADA(I,3))*(S(I,K,1)*(H(K)+ADA(I,1))+DT2/B(I,K)*
     1       (DX8*(T(I,K,1)-T(IM1,K,1))-WSBB+WSBA+FB-FA+DXS4*(T(I,K,2)
     2       -T(IM1,K,2)))-SINK)
```

```
      CB=0.
      WCBB=0.
      WCBA=(W(I,K)-VSET)*(C(I,K,2)+C(I,K+1,2))*BW(I,K)/4.
      CA=EPZ(I,K)*BW(I,K)*(C(I,K,1)-C(I,K+1,1))
     1 /(H(K)+H(K+1)+ADA(I,1))
      SHEAR=0.5*(ABS(BDSHR(I,K))+ABS(BDSHR(I+1,K)))*RHO(I,K)
      IF(SHEAR.LT.TAUD) GO TO 120
      IF(SHEAR.GT.TAUE) GO TO 140
      ERDEP=0.
      GO TO 150
120   ERDEP=0.0-C(I,K,2)*VSET*(1.0-SHEAR/TAUD)*(B(I,K)-B(I,K+1))
      BDSED(I,K)=BDSED(I,K)+C(I,K,2)*VSET*(1.0-SHEAR/TAUD)*DT2/2.
      GO TO 150
140   CONTINUE
      ERDEP=EROR*(SHEAR/TAUE-1.0)*DT2/2.
      IF(ERDEP.GT.BDSED(I,K)) ERDEP=BDSED(I,K)
      BDSED(I,K)=BDSED(I,K)-ERDEP
      ERDEP=ERDEP*2.0/DT2*(B(I,K)-B(I,K+1))
150   CONTINUE
      C(I,K,3)=1/(H(K)+ADA(I,3))*(C(I,K,1)*(H(K)+ADA(I,1))+DT2/B(I,K)*
     1       (DX8*(T(I,K,5)-T(IM1,K,5))-WCBB+WCBA+CB-CA+DXS4*(T(I,K,6)
     2       -T(IM1,K,6))+ERDEP)-CINK)
      IF (KB(I).EQ.2) GO TO 550
C
C NOW CALC S & C FOR ALL BUT LAST LAYER
C
        N=KB(I)-1
        DO 540 K=2,N
      TH=2*H(K)
          WSBB=WSBA
          FB=FA
      WSBA=W(I,K)*(S(I,K,2)+S(I,K+1,2))*BW(I,K)/4.
      FA=EPZ(I,K)*BW(I,K)*(S(I,K,1)-S(I,K+1,1))
     1 /(H(K)+H(K+1))
      S(I,K,3)=1/H(K)*(S(I,K,1)*H(K)+DT2/B(I,K)*
     1       (DX8*(T(I,K,1)-T(IM1,K,1))-WSBB+WSBA+FB-FA+DXS4*(T(I,K,2)
```

```
2       -T(IM1,K,2))))
     WCBB=WCBA
     CB=CA
     WCBA=(W(I,K)-VSET)*(C(I,K,2)+C(I,K+1,2))*BW(I,K)/4.
     CA=EPZ(I,K)*BW(I,K)*(C(I,K,1)-C(I,K+1,1))
1    /(H(K)+H(K+1))
     SHEAR=0.5*(ABS(BDSHR(I,K))+ABS(BDSHR(I+1,K)))*RHO(I,K)
     IF(SHEAR.LT.TAUD) GO TO 220
     IF(SHEAR.GT.TAUE) GO TO 240
     ERDEP=0.
     GO TO 250
220  ERDEP=0.0-C(I,K,2)*VSET*(1.0-SHEAR/TAUD)*(BW(I,K-1)-BW(I,K))/2.
     BDSED(I,K)=BDSED(I,K)+C(I,K,2)*VSET*(1.0-SHEAR/TAUD)*DT2/2.
     GO TO 250
240  CONTINUE
     ERDEP=EROR*(SHEAR/TAUE-1.0)*DT2/2.
     IF(ERDEP.GT.BDSED(I,K)) ERDEP=BDSED(I,K)
     BDSED(I,K)=BDSED(I,K)-ERDEP
     ERDEP=ERDEP*2.0/DT2*(BW(I,K-1)-BW(I,K))/2.
250  CONTINUE
     C(I,K,3)=1/H(K)*(C(I,K,1)*H(K)+DT2/B(I,K)*
1       (DX8*(T(I,K,5)-T(IM1,K,5))-WCBB+WCBA+CB-CA+DXS4*(T(I,K,6)
2       -T(IM1,K,6))+ERDEP))
540  CONTINUE
550  CONTINUE
C
C  NOW CALC S & C FOR K=KB(I)
C
       K=KB(I)
     TH=2*H(K)
       WSBB=WSBA
       WSBA=0
       FB=FA
       FA=0
     S(I,K,3)=1/H(K)*(S(I,K,1)*H(K)+DT2/B(I,K)*
1       (DX8*(T(I,K,1)-T(IM1,K,1))-WSBB+WSBA+FB-FA+DXS4*(T(I,K,2)
```

```
  2      -T(IM1,K,2))))
      WCBB=WCBA
      WCBA=0.
      CB=CA
      CA=0.
      SHEAR=0.5*(ABS(BDSHR(I,K))+ABS(BDSHR(I+1,K)))*RHO(I,K)
      IF(SHEAR.LT.TAUD) GO TO 320
      IF(SHEAR.GT.TAUE) GO TO 340
      ERDEP=0.
      GO TO 350
320   ERDEP=0.0-C(I,K,2)*VSET*(1.0-SHEAR/TAUD)*BW(I,K-1)/2.
      BDSED(I,K)=BDSED(I,K)+C(I,K,2)*VSET*(1.0-SHEAR/TAUD)*DT2/2.
      GO TO 350
340   CONTINUE
      ERDEP=EROR*(SHEAR/TAUE-1.0)*DT2/2.
      IF(ERDEP.GT.BDSED(I,K)) ERDEP=BDSED(I,K)
      BDSED(I,K)=BDSED(I,K)-ERDEP
      ERDEP=ERDEP*2.0/DT2*BW(I,K-1)/2.
350   CONTINUE
450   C(I,K,3)=1/H(K)*(C(I,K,1)*H(K)+DT2/B(I,K)*
  1      (DX8*(T(I,K,5)-T(IM1,K,5))-WCBB+WCBA+CB-CA+DXS4*(T(I,K,6)
  2      -T(IM1,K,6))+ERDEP))
500   CONTINUE
      RETURN
      END
      SUBROUTINE DONSC(MST,JJ,DTX,SFLDM,CFLDM)
       PARAMETER (NTRAN=100,NLAYR=20,L=3)
      COMMON/DYN0/
     +      U(NTRAN,NLAYR,L),W(NTRAN,NLAYR),S(NTRAN,NLAYR,L),
     +      B(NTRAN,NLAYR),H(NLAYR),HMZ(NTRAN,NLAYR)
      COMMON/DYN1/
     +      RHO(NTRAN,NLAYR),ADA(NTRAN,L),DEPTH(NTRAN,NLAYR),
     +      T(NTRAN,NLAYR,L*2),EZ(NTRAN,NLAYR),EX(NTRAN,NLAYR)
      COMMON/DYN2/
     +      EPZ(NTRAN,NLAYR),EPX(NTRAN,NLAYR),PRESS(NTRAN,NLAYR),
     +      Q(NTRAN,NLAYR),KB(NTRAN),KBU(NTRAN),SST(NTRAN)
```

```
      COMMON/DYN3/
     +      BU(NTRAN,NLAYR),BW(NTRAN,NLAYR),MANN(NTRAN),
     +      FRIK(NTRAN,NLAYR)
      COMMON/SED/C(NTRAN,NLAYR,L),BDSHR(NTRAN,NLAYR),BDSED(NTRAN,NLAYR)
      COMMON/ST/STOS(NTRAN),STOC(NTRAN)
      COMMON/DYN4/
     +      SBAR(NTRAN),HRIB(NTRAN),QQ(NTRAN),CC(NTRAN),TT(NTRAN)
      DIMENSION NCOUNT(20),DS(20),DC(20),SFLDM(20),CFLDM(20)
      DATA NCOUNT/20*10000/
      JM1 = JJ-1
      N = KB(JJ)
      DO 100 K = 1,N
      IF(U(JJ,K,2).LT.0.0) GO TO 10
      NCOUNT(K) = 0
      CHANGE = DTX*U(JJ,K,2)
      S(JJ,K,3) = S(JJ,K,2)-(S(JJ,K,2)-S(JM1,K,2))*CHANGE
      C(JJ,K,3) = C(JJ,K,2)-(C(JJ,K,2)-C(JM1,K,2))*CHANGE
      GO TO 100
10    IF(NCOUNT(K).EQ.0) GO TO 11
      IF(NCOUNT(K).LT.MST) GO TO 12
      S(JJ,K,3) = SFLDM(K)
      C(JJ,K,3) = CFLDM(K)
      GO TO 100
11    DS(K) = (SFLDM(K)-S(JJ,K,2))/MST
      DC(K) = (CFLDM(K)-C(JJ,K,2))/MST
12    NCOUNT(K) = NCOUNT(K) + 1
      S(JJ,K,3) = S(JJ,K,2) + DS(K)
      C(JJ,K,3) = C(JJ,K,2) + DC(K)
100   CONTINUE
      RETURN
      END
      SUBROUTINE UPDATE(MD,KMAX,T9,JJ,LOC,NT,SFLDM,CFLDM)
C
C     THIS IS A NEW SUBROUTINE USED TO UPDATE THE MODEL BOUNDARY
C     CONDITIONS TO ACCOUNT FOR THE RISING LIMB OF A FLOOD
C     HYDROGRAPH AND SEDIMENTGRAPH.  BOTH GRAPHS ARE UPDATED AT THE
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```
C    SAME TIME AND PEAK SIMULTANEOUSLY.  THIS SUBROUTINE SIMPLY
C    ADDS A NEW LAYER AND RESETS THE VARIABLES TO REFLECT THE
C    ADDITION OF THIS LAYER.
C
      PARAMETER (NTRAN = 100,NLAYR = 20,L = 3)
      COMMON/DYN0/
     +      U(NTRAN,NLAYR,L),W(NTRAN,NLAYR),S(NTRAN,NLAYR,L),
     +      B(NTRAN,NLAYR),H(NLAYR),HMZ(NTRAN,NLAYR)
      COMMON/DYN1/
     +      RHO(NTRAN,NLAYR),ADA(NTRAN,L),DEPTH(NTRAN,NLAYR),
     +      T(NTRAN,NLAYR,L*2),EZ(NTRAN,NLAYR),EX(NTRAN,NLAYR)
      COMMON/DYN2/
     +      EPZ(NTRAN,NLAYR),EPX(NTRAN,NLAYR),PRESS(NTRAN,NLAYR),
     +      Q(NTRAN,NLAYR),KB(NTRAN),KBU(NTRAN),SST(NTRAN)
      COMMON/DYN3/
     +      BU(NTRAN,NLAYR),BW(NTRAN,NLAYR),MANN(NTRAN),
     +      FRIK(NTRAN,NLAYR)
      COMMON/SED/C(NTRAN,NLAYR,L),BDSHR(NTRAN,NLAYR),BDSED(NTRAN,NLAYR)
      COMMON/ST/STOS(NTRAN),STOC(NTRAN)
      COMMON/DYN4/
     +      SBAR(NTRAN),HRIB(NTRAN),QQ(NTRAN),CC(NTRAN),TT(NTRAN)
      DIMENSION SFLDM(20),CFLDM(20)
      REAL MD(100)
      DO 1 I = 2,JJ
        KB(I) = KB(I) + 1
    1 CONTINUE
      KB(1) = KB(2)
      KMAX = KMAX + 1
      DO 2 K = KMAX,2,-1
        H(K) = H(K-1)
    2 CONTINUE
C
C    THICKNESS H(1) OF NEW TOP LAYER SET AT 200 CENTIMETERS.
C
      H(1) = 200.
      T9 = H(1)*2.
```

```
      DO 55 I=2,JJ
       MD(I)=0.
       N=KB(I)
       DO 65 K=1,N
        MD(I)=MD(I)+H(K)
        DEPTH(I,K)=MD(I)
65     CONTINUE
       DO 55 K=1,N
        HMZ(I,K)=MD(I)-DEPTH(I,K)
55    CONTINUE
      DO 3 I=2,JJ
       N=KB(I)
       DO 4 K=N,2,-1
        B(I,K)=B(I,K-1)
4      CONTINUE
C
C   WIDTH, B(I,1), OF NEW TOP LAYER SET.  ASSUME THAT RIVERBANKS SLOPE
C   UP AND AWAY FROM THE RIVER AT A 10:1 SLOPE.
C
       B(I,1)=B(I,2)+2000.
3     CONTINUE
      DO 112 I=3,JJ
       N=KB(I)
       KBU(I)=KB(I)
       IF(B(I-1,N).EQ.0.) KBU(I)=KB(I-1)
112   CONTINUE
      KBU(2)=KB(2)
      N=KB(2)
      DO 25 K=1,N
25     B(1,K)=B(2,K)
      N=KB(JJ)
      DO 35 K=1,N
35     B(NT+2,K)=B(JJ,K)
      JJ1=JJ+1
      KB(JJ1)=KB(JJ)
      DO 36 I=2,JJ1
```

```
      M = KB(I)
      DO 36 K = 1,M
        BU(I,K) = B(I-1,K) + B(I,K)
 36     BW(I,K) = B(I,K) + B(I,K + 1)
      DO 5 I = 2,JJ
      N = KB(I)
      DO 6 K = N,2,-1
        U(I,K,1) = U(I,K-1,1)
        U(I,K,2) = U(I,K-1,2)
        U(I,K,3) = U(I,K-1,3)
        W(I,K) = W(I,K-1)
        S(I,K,1) = S(I,K-1,1)
        S(I,K,2) = S(I,K-1,2)
        S(I,K,3) = S(I,K-1,3)
        C(I,K,1) = C(I,K-1,1)
        C(I,K,2) = C(I,K-1,2)
        C(I,K,3) = C(I,K-1,3)
  6   CONTINUE
C
C     SET VARIABLES IN THE NEW TOP LAYER EQUAL TO THOSE IN THE OLD TOP
C     LAYER.
C
      U(I,1,3) = U(I,2,3)
      U(I,1,2) = U(I,2,2)
      U(I,1,1) = U(I,2,1)
      W(I,1) = W(I,2)
      S(I,1,3) = S(I,2,3)
      S(I,1,2) = S(I,2,2)
      S(I,1,1) = S(I,2,1)
      C(I,1,3) = C(I,2,3)
      C(I,1,2) = C(I,2,2)
      C(I,1,1) = C(I,2,1)
  5   CONTINUE
      N = KB(2)
C
C     ADJUST UPSTREAM BOUNDARY CONDITIONS TO REFLECT THE HIGHER
```

```
C    STREAMFLOW AND SUSPENDED SEDIMENT LOAD.
C
      DO 7 K=1,N
        U(2,K,3)=QQ(LOC)
        C(2,K,3)=CC(LOC)
    7 CONTINUE
      N=KB(JJ)
      DO 16 K=N,2,-1
        SFLDM(K)=SFLDM(K-1)
        CFLDM(K)=CFLDM(K-1)
   16 CONTINUE
      SFLDM(1)=SFLDM(2)
      CFLDM(1)=CFLDM(2)
      RETURN
      END
      SUBROUTINE UPDAT2(MD,KMAX,T9,JJ,LOC,NT)
C
C    THIS IS A NEW SUBROUTINE USED TO UPDATE THE MODEL BOUNDARY
C    CONDITIONS TO ACCOUNT FOR THE FALLING LIMB OF A FLOOD
C    HYDROGRAPH AND SEDIMENTGRAPH.  BOTH GRAPHS ARE UPDATED AT THE
C    SAME TIME AND PEAK SIMULTANEOUSLY.  THIS SUBROUTINE SIMPLY
C    STRIPS OFF THE NEW LAYERS ADDED BY 'UPDATE' AND RESETS
C    THE VARIABLES TO REFLECT THE LOSS OF THIS LAYER.
C
      PARAMETER (NTRAN=100,NLAYR=20,L=3)
      COMMON/DYN0/
     +      U(NTRAN,NLAYR,L),W(NTRAN,NLAYR),S(NTRAN,NLAYR,L),
     +      B(NTRAN,NLAYR),H(NLAYR),HMZ(NTRAN,NLAYR)
      COMMON/DYN1/
     +      RHO(NTRAN,NLAYR),ADA(NTRAN,L),DEPTH(NTRAN,NLAYR),
     +      T(NTRAN,NLAYR,L*2),EZ(NTRAN,NLAYR),EX(NTRAN,NLAYR)
      COMMON/DYN2/
     +      EPZ(NTRAN,NLAYR),EPX(NTRAN,NLAYR),PRESS(NTRAN,NLAYR),
     +      Q(NTRAN,NLAYR),KB(NTRAN),KBU(NTRAN),SST(NTRAN)
      COMMON/DYN3/
     +      BU(NTRAN,NLAYR),BW(NTRAN,NLAYR),MANN(NTRAN),
```

```
     +      FRIK(NTRAN,NLAYR)
      COMMON/SED/C(NTRAN,NLAYR,L),BDSHR(NTRAN,NLAYR),BDSED(NTRAN,NLAYR)
      COMMON/ST/STOS(NTRAN),STOC(NTRAN)
      COMMON/DYN4/
     +      SBAR(NTRAN),HRIB(NTRAN),QQ(NTRAN),CC(NTRAN),TT(NTRAN)
      REAL MD(100)
      DO 1 I=2,JJ
        KB(I)=KB(I)-1
    1 CONTINUE
      KB(1)=KB(2)
      DO 2 K=2,KMAX
        H(K-1)=H(K)
    2 CONTINUE
      KMAX=KMAX-1
      T9=H(1)*2.
      DO 55 I=2,JJ
        MD(I)=0.
        N=KB(I)
        DO 65 K=1,N
          MD(I)=MD(I)+H(K)
          DEPTH(I,K)=MD(I)
   65   CONTINUE
        DO 55 K=1,N
          HMZ(I,K)=MD(I)-DEPTH(I,K)
   55 CONTINUE
      DO 3 I=2,JJ
        N=KB(I)
        DO 4 K=1,N
          B(I,K)=B(I,K+1)
    4   CONTINUE
        B(I,N+1)=0.0
    3 CONTINUE
      N=KB(2)
      DO 25 K=1,N
   25   B(1,K)=B(2,K)
      N=KB(JJ)
```

```
      DO 35 K=1,N
35    B(NT+2,K)=B(JJ,K)
      JJ1=JJ+1
      KB(JJ1)=KB(JJ)
      DO 112 I=3,JJ
       N=KB(I)
       KBU(I)=KB(I)
       IF(B(I-1,N).EQ.0.) KBU(I)=KB(I-1)
112   CONTINUE
      KBU(2)=KB(2)
      DO 36 I=2,JJ1
       M=KB(I)
       DO 36 K=1,M
        BU(I,K)=B(I-1,K)+B(I,K)
36      BW(I,K)=B(I,K)+B(I,K+1)
      DO 5 I=2,JJ
       N=KB(I)
       DO 6 K=1,N
        U(I,K,1)=U(I,K+1,1)
        U(I,K,2)=U(I,K+1,2)
        U(I,K,3)=U(I,K+1,3)
        W(I,K)=W(I,K+1)
        S(I,K,1)=S(I,K+1,1)
        S(I,K,2)=S(I,K+1,2)
        S(I,K,3)=S(I,K+1,3)
        C(I,K,1)=C(I,K+1,1)
        C(I,K,2)=C(I,K+1,2)
        C(I,K,3)=C(I,K+1,3)
  6    CONTINUE
  5   CONTINUE
C
C     AS THE NEW TOP LAYER IS STRIPPED OFF, THE OTHER LAYERS ARE
C     SHIFTED UP.  THIS PART RESETS THE VARIABLES IN THE OLD
C     BOTTOM LAYER BACK TO THEIR ORIGINAL VALUES.
C
      DO 43 I=1,JJ1
```

```
      N = KB(I) + 1
      DO 45 K = N,KMAX
        U(I,K,1) = 0.0
        U(I,K,2) = 0.0
        U(I,K,3) = 0.0
        S(I,K,1) = 30.0
        S(I,K,2) = 30.0
        S(I,K,3) = 30.0
        C(I,K,1) = 0.0
        C(I,K,2) = 0.0
        C(I,K,3) = 0.0
        W(I,K) = 0.0
45    CONTINUE
43  CONTINUE
C
C   ADJUST UPSTREAM BOUNDARY CONDITIONS TO REFLECT THE LOWER
C   STREAMFLOW AND SUSPENDED SEDIMENT LOAD.
C
      N = KB(2)
      DO 7 K = 1,N
        U(2,K,3) = QQ(LOC)
        C(2,K,3) = CC(LOC)
  7   CONTINUE
      RETURN
      END
      BLOCK DATA
      PARAMETER (NTRAN = 100,NLAYR = 20,L = 3)
      COMMON/DYN0/
     +     U(NTRAN,NLAYR,L),W(NTRAN,NLAYR),S(NTRAN,NLAYR,L),
     +     B(NTRAN,NLAYR),H(NLAYR),HMZ(NTRAN,NLAYR)
      COMMON/DYN1/
     +     RHO(NTRAN,NLAYR),ADA(NTRAN,L),DEPTH(NTRAN,NLAYR),
     +     T(NTRAN,NLAYR,L*2),EZ(NTRAN,NLAYR),EX(NTRAN,NLAYR)
      COMMON/DYN2/
     +     EPZ(NTRAN,NLAYR),EPX(NTRAN,NLAYR),PRESS(NTRAN,NLAYR),
     +     Q(NTRAN,NLAYR),KB(NTRAN),KBU(NTRAN),SST(NTRAN)
```

```
      COMMON/DYN3/
     +      BU(NTRAN,NLAYR),BW(NTRAN,NLAYR),MANN(NTRAN),
     +      FRIK(NTRAN,NLAYR)
      COMMON/SED/C(NTRAN,NLAYR,L),BDSHR(NTRAN,NLAYR),BDSED(NTRAN,NLAYR)
      COMMON/ST/STOS(NTRAN),STOC(NTRAN)
      COMMON/DYN4/
     +      SBAR(NTRAN),HRIB(NTRAN),QQ(NTRAN),CC(NTRAN),TT(NTRAN)
      DATA U,W,ADA,T,EZ,EX,EPZ,EPX,Q/30300*0./,S/6000*30./
      DATA KBU/100*0/,B,BU,BW/6000*0.0/
      DATA SBAR/100 *0./
      DATA FRIK,BDSHR/4000*0.0/,C/6000*0./,BDSED/2000*0./
      END
```

Appendix D

COMPUTER PROGRAMS FOR THE DETERMINATION OF THE TRANSFORMATION CONSTANTS AND THE JOINT PROBABILITY OF EXCEEDENCE

LIST OF THE MOST SIGNIFICANT VARIABLES IN THE COMPUTER PROGRAMS

CHANGE	Difference between the tidal gage height and Mean Sea Level (MSL)
COV	Covariance of the transformed streamflows and tidal heights
CQT	Skew coefficient of the transformed streamflows
CST	Skew coefficient of the transformed tidal heights
DETS	Determinant of the covariance matrix
GQT	Skew of the transformed streamflows
GST	Skew of the transformed tidal heights
HIGHP	Highest joint probability of exceedence to be calculated
HIGHQ	Highest streamflow considered in the bivariate normal distribution
HIQT	Transformed value of HIGHQ
L1	Transformation constant for the tidal heights
L2	Transformation constant for the streamflows
L1(L)	Value of the likelihood function for the marginal distribution of the transformed streamflows

L2(L)	Value of the likelihood function for the marginal distribution of the transformed tidal heights
L1L2(L,K)	Value of the likelihood function for the joint distribution
LOQT	Transformed value of LOWQ
LOWP	Lowest joint probability of exceedence to be calculated
LOWQ	Lowest streamflow considered in the bivariate normal distribuiton
LQ	Transformation constant for the streamflows
LS	Transformation constant for the tidal heights
LX	Transformation constant for the marginal distributions
MEANQT	Mean of the transformed streamflows
MEANST	Mean of the transformed tidal heights
N	Number of streamflow-tidal height pairs
NN	Number of tidal heights to be used for the calculation of the joint probability of exceedence
LOQT	Transformed value of LOWQ
LOWQ	Lowest streamflow considered in the bivariate normal distribution
P	Joint probability of exceedence

P1	Joint probability that the streamflow and tidal height will fall below some specific values simultaneously
P2	Marginal probability of exceedence for the streamflows
P3	Marginal probability of exceedence for the tidal heights
PRBLVL(I)	Probability level
Q(K)	Original streamflow data
QT(K)	Transformed streamflow data
QUANT(I)	Standard normal quantile
R	Coefficient of correlation for the
RHO	Sample correlation coefficient (RHO = R)
RQ	Correlation coefficient of the transformed streamflows and standard normal quantiles
RS	Correlation coefficient of the transformed tidal heights and standard normal quantiles
S11, S22	Diagonal elements of the covariance matrix
S12	Non-diagonal elements of the covariance matrix
S(K)	Original tidal heights

SS(K)	Tidal heights used for calculation of the joint probability of exceedence
SQT	Standard deviation of the transformed streamflows
SST	Standard deviation of the transformed tidal heights
ST(K)	Transformed tidal heights
STEP	Increment step down from HIQT to LOQT (this is a negative value)
STEPP	Increment step down from HIGHP to LOWP (this is a negative value)
SUMLQ	Sum of the natural log values of the original streamflows
SUMLS	Sum of the natural log values of the original tidal heights
SUMQ	Sum of the original streamflows
SUMQT	Sum of the transformed streamflows
SUMS	Sum of the original tidal heights
SUMST	Sum of the transformed tidal heights
TOL	Tolerance for comparison in calculation of the joint probability of exceedence
TSS(K)	Transformed tidal heights used for calculation of the joint probability of exceedence
VQT	Variance of the transformed streamflows

VST Variance of the transformed tidal heights

COMPUTER PROGRAM LISTINGS

```
C
C     ALL FORTRAN STATEMENTS BEGIN ON OR AFTER THE SEVENTH COLUMN.
C     THIS PROGRAM COMPUTES THE TRANSFORMATION CONSTANTS FOR THE
C     MARGINAL DISTRIBUTIONS OF THE VARIABLES.
C
      REAL MEANQT,MEANST,LX
      REAL L1(1000),L2(1000),LQ(1000),LS(1000),LAM1(1000)
      DIMENSION Q(1000),QT(1000),S(1000),ST(1000)
C
C     INPUT THE NUMBER OF VARIABLE PAIRS AND THE DIFFERENCE BETWEEN
C     THE TIDAL GAGE HEIGHT AND THE MEAN SEA LEVEL (MSL).
C
      READ(5,10)N,CHANGE
 10   FORMAT(I5,F5.2)
C
C     ENTER THE ORIGINAL STREAMFLOWS AND TIDAL HEIGHTS.
C
      READ(5,30) (Q(K),K = 1,N)
 30   FORMAT(8F10.0)
      READ(5,31) (S(K),K = 1,N)
C
C     CONVERT THE TIDAL HEIGHTS SO THAT THEY REFER TO MSL.
C
      DO 25 K = 1,N
      S(K) = S(K)-CHANGE
 25   CONTINUE
 31   FORMAT(16F5.2)
      L = 1
C
C     SET THE RANGE OF TRANSFORMATION CONSTANTS TO BE CONSIDERED AND
C     THE INCREMENTAL STEP BETWEEN EACH VALUE.
C
```

```
      DO 40 LX = -4,4,0.01
      SUMQ = 0.
      SUMQT = 0.
      SUMLQ = 0.
      SUMS = 0.
      SUMST = 0.
      SUMLS = 0.
      DO 60 K = 1,N
      IF (LX.EQ.0.) GOTO 12
C
C     TRANSFORM THE ORIGINAL DATA.
C
      QT(K) = (Q(K)**LX-1)/LX
      ST(K) = (S(K)**LX-1)/LX
 12   LQ(K) = ALOG(Q(K))
      LS(K) = ALOG(S(K))
      IF (ABS(LX).LE.0.005) QT(K) = ALOG(Q(K))
      IF (ABS(LX).LE.0.005) ST(K) = ALOG(S(K))
      SUMQ = SUMQ + Q(K)
      SUMQT = SUMQT + QT(K)
      SUMLQ = SUMLQ + LQ(K)
      SUMS = SUMS + S(K)
      SUMST = SUMST + ST(K)
      SUMLS = SUMLS + LS(K)
 60   CONTINUE
      MEANQT = SUMQT/N
      MEANST = SUMST/N
      SUMQT2 = 0.
      SUMST2 = 0.
      DO 70 K = 1,N
      SUMQT2 = SUMQT2 + (QT(K)-MEANQT)*(QT(K)-MEANQT)
      SUMST2 = SUMST2 + (ST(K)-MEANST)*(ST(K)-MEANST)
 70   CONTINUE
      SUMQTN = SUMQT2/N
```

```
      SUMSTN=SUMST2/N
C
C     CALCULATE THE VALUES OF THE LIKELIHOOD FUNCTIONS FOR THE
C     STREAMFLOWS AND TIDAL HEIGHTS.
C
      L1(L)=-N*ALOG(SUMQTN)/2+(LX-1)*SUMLQ
      L2(L)=-N*ALOG(SUMSTN)/2+(LX-1)*SUMLS
      LAM1(L)=LX
      L=L+1
   40 CONTINUE
      DO 80 K=1,L
      WRITE(6,100) LAM1(K),L1(K),L2(K)
  100 FORMAT(3F12.3)
   80 CONTINUE
      STOP
      END
```

```
C
C    THIS PROGRAM COMPUTES THE TRANSFORMATION CONSTANTS FOR THE
C    JOINT DISTRIBUTIONS OF THE VARIABLES.
C
      REAL L1,L2,MEANST,MEANQT
      REAL LQ(700),LS(700),L1L2(85,85)
      DIMENSION S(700),Q(700),ST(700),QT(700),SAVEL1(85),SAVEL2(85)
C
C    INPUT THE NUMBER OF VARIABLE PAIRS AND THE DIFFERENCE BETWEEN
C    THE TIDAL GAGE HEIGHT AND THE MEAN SEA LEVEL (MSL).
C
      READ(5,10)N,CHANGE
 10   FORMAT(I5,F5.2)
      INITAL=0
C
C    ENTER THE ORIGINAL STREAMFLOWS AND TIDAL HEIGHTS
C
      READ(5,30) (Q(I),I=1,N)
      READ(5,35) (S(I),I=1,N)
 30   FORMAT(8F10.0)
 35   FORMAT(16F5.2)
C
C    CONVERT THE TIDAL HEIGHTS SO THAT THEY REFER TO MSL.
C
      DO 25 I=1,N
      S(I)=S(I)-CHANGE
 25   CONTINUE
C
C    SET THE RANGE OF TRANSFORMATION CONSTANTS TO BE CONSIDERED AND
C    THE INCREMENTAL STEP BETWEEN EACH VALUE.
C
      L=1
      DO 40 L1=-0.10,0.101,0.01000
      K=1
      DO 50 L2=-0.05,0.201,0.01000
```

```
      SUMS=0.
      SUMQ=0.
      SUMST=0.
      SUMQT=0.
      SUMLS=0.
      SUMLQ=0.
C
C     TRANSFORM THE ORIGINAL DATA.
C
      DO 60 I=1,N
      IF (L1.EQ.0.0) GOTO 14
      ST(I)=(S(I)**L1-1)/L1
 14   LS(I)=ALOG(S(I))
      IF(ABS(L1).LE.0.005) ST(I)=ALOG(S(I))
      SUMS=SUMS+S(I)
      SUMST=SUMST+ST(I)
      SUMLS=SUMLS+LS(I)
      IF(L2.EQ.0.0) GOTO 16
      QT(I)=(Q(I)**L2-1)/L2
 16   LQ(I)=ALOG(Q(I))
      IF(ABS(L2).LE.0.005) QT(I)=ALOG(Q(I))
      SUMQ=SUMQ+Q(I)
      SUMQT=SUMQT+QT(I)
      SUMLQ=SUMLQ+LQ(I)
 60   CONTINUE
      MEANST=SUMST/N
      MEANQT=SUMQT/N
      SUMST2=0.
      SUMQT2=0.
      SUMSQT=0.
      DO 70 I=1,N
      SUMST2=SUMST2+(ST(I)-MEANST)*(ST(I)-MEANST)
      SUMQT2=SUMQT2+(QT(I)-MEANQT)*(QT(I)-MEANQT)
      SUMSQT=SUMSQT+(ST(I)-MEANST)*(QT(I)-MEANQT)
 70   CONTINUE
```

```
      S11 = SUMST2/N
      S22 = SUMQT2/N
      S12 = SUMSQT/N
      DETS = S11*S22-S12*S12
      IF(DETS.LE.0.) L1L2(L,K) = N*ALOG(ABS(DETS))/2 + (L1-1)*SUMLS
     @     + (L2-1)*SUMLQ
      IF(DETS.LE.0.) GOTO 45
C
C  CALCULATE THE VALUE OF THE LIKELIHOOD FUNCTION FOR THE
C  JOINT DISTRIBUTION.
C
      L1L2(L,K) = -N*ALOG(DETS)/2 + (L1-1)*SUMLS + (L2-1)*SUMLQ
C
C  FIND THE HIGHEST VALUE OF THE LIKELIHOOD FUNCTION AND THE
C  CORRESPONDING TRANSFORMATION CONSTANTS.
C
      IF (INITAL.EQ.0) COMPAR = L1L2(L,K)
      INITAL = 100
      IF (L1L2(L,K).LE.COMPAR) THEN
        GOTO 45
       ELSE
        COMPAR = L1L2(L,K)
      ENDIF
      KC = K
      LC = L
 45   SAVEL2(K) = L2
      K = K + 1
 50   CONTINUE
      SAVEL1(L) = L1
      L = L + 1
 40   CONTINUE
      K = K-1
      L = L-1
      KK = K + 6
      DO 67 NN = 7,KK,7
```

```
      MM = NN-6
      WRITE(6,*) K,L
      WRITE(6,72) (SAVEL2(J),J = MM,NN)
72    FORMAT(//5X,7(10X,F6.2,2X))
      DO 80 J = 1,L
      WRITE(6,100) SAVEL1(J),(L1L2(J,M),M = MM,NN)
100   FORMAT(/F5.2,7(2X,F16.2))
80    CONTINUE
67    CONTINUE
      WRITE(6,102) COMPAR,SAVEL1(LC),SAVEL2(KC)
102   FORMAT(//5X,'The highest value is ',F16.2,' at LS = ',F5.2,' and L
     @Q = ',F5.2)
      STOP
      END
```

```
C
C   THIS PROGRAM CALCULATES THE MEAN, VARIANCE, STANDARD DEVIATION,
C   SKEW, AND SKEW COEFFICIENT FOR THE TRANSFORMED STREAMFLOWS AND
C   TIDAL HEIGHTS.  IT ALSO ORDERS THE STREAMFLOWS AND TIDAL HEIGHTS,
C   CALCULATES THE PROBABILITY LEVELS AND STANDARD NORMAL QUANTILES
C   IN ORDER TO CHECK THAT THE TRANSFORMED DATA DOES INDEED FOLLOW
C   A NORMAL DISTRIBUTION.
C
      REAL LS,LQ,MEANST,MEANQT,MEANZ
      DIMENSION Q(700),S(700),QT(700),ST(700),QHOLD(700),SHOLD(700),
     @PRBLVL(700),STHOLD(700),QTHOLD(700),QUANT(700)
C
C   INPUT THE NUMBER OF VARIABLE PAIRS, THE TRANSFORMATION CONSTANTS
C   FOR THE TIDAL HEIGHT AND STREAMFLOW, AND THE DIFFERENCE BETWEEN
C   THE TIDAL GAGE HEIGHT AND THE MEAN SEA LEVEL (MSL).
C
      READ(5,10) N,LS,LQ,CHANGE
 10   FORMAT(I5,3(F5.2))
C
C   ENTER THE ORIGINAL STREAMFLOWS AND TIDAL HEIGHTS.
C
      READ(5,20) (Q(I),I = 1,N)
      READ(5,30) (S(I),I = 1,N)
 20   FORMAT(8F10.0)
 30   FORMAT(16F5.2)
      SUMST = 0.
      SUMQT = 0.
C
C   TRANSFORM THE ORIGINAL DATA.
C
      DO 35 I = 1,N
       IF (ABS(LS).LT.0.005) THEN
          ST(I) = ALOG(S(I))
        ELSE
          ST(I) = ((S(I)-CHANGE)**LS-1.)/LS
```

```
        ENDIF
        IF (ABS(LQ).LT.0.005) THEN
           QT(I) = ALOG(Q(I))
         ELSE
           QT(I) = (Q(I)**LQ-1.)/LQ
        ENDIF
        SUMST = SUMST + ST(I)
        SUMQT = SUMQT + QT(I)
35    CONTINUE
      MEANST = SUMST/N
      MEANQT = SUMQT/N
      SUMSST = 0.
      SUMGST = 0.
      SUMSQT = 0.
      SUMGQT = 0.
      SUMCOV = 0.
      DO 40 I = 1,N
        SUMSST = SUMSST + (ST(I)-MEANST)*(ST(I)-MEANST)
        SUMGST = SUMGST + (ST(I)-MEANST)*(ST(I)-MEANST)*(ST(I)-MEANST)
        SUMSQT = SUMSQT + (QT(I)-MEANQT)*(QT(I)-MEANQT)
        SUMGQT = SUMGQT + (QT(I)-MEANQT)*(QT(I)-MEANQT)*(QT(I)-MEANQT)
        SUMCOV = SUMCOV + (ST(I)-MEANST)*(QT(I)-MEANQT)
40    CONTINUE
      VST = SUMSST/(N-1)
      SST = SQRT(VST)
        W = SUMSST/N
      VQT = SUMSQT/(N-1)
      SQT = SQRT(VQT)
        Z = SUMSQT/N
      GST = N*SUMGST/((N-1)*(N-2))
      GQT = N*SUMGQT/((N-1)*(N-2))
      CST = GST/(SST*SST*SST)
      CQT = GQT/(SQT*SQT*SQT)
      COV = SUMCOV/(N-1)
        R = SUMCOV/N
```

```
      WRITE(6,50) LS,LQ
 50  FORMAT(18X,'Tidal Height (L=',F5.2,')',10X,'Runoff (L=',F5.2,')')
      WRITE(6,60) MEANST,MEANQT
 60  FORMAT(//5X,'Mean',21X,F10.6,16X,F10.6)
      WRITE(6,70) VST,VQT
 70  FORMAT(/5X,'Variance',17X,F10.6,16X,F10.6)
      WRITE(6,80) SST,SQT
 80  FORMAT(/5X,'Standard Deviation',7X,F10.6,16X,F10.6)
      WRITE(6,90) GST,GQT
 90  FORMAT(/5X,'Skew',21X,F10.6,16X,F10.6)
      WRITE(6,100) CST,CQT
100  FORMAT(/5X,'Skew Coefficient',9X,F10.6,16X,F10.6)
      RHO=R/SQRT(W*Z)
      WRITE(6,110) RHO
110  FORMAT(/5X,'Rho = ',F10.6)
C
C    ARRANGE AND RANK THE STREAMFLOWS AND TIDAL HEIGHTS IN ASCENDING
C    ORDER.
C
      DO 55 J=1,N
        STHOLD(J)=1.0E08
        QTHOLD(J)=1.0E08
        DO 65 I=1,N
          IF (ST(I).GE.STHOLD(J)) GOTO 75
          STHOLD(J)=ST(I)
          SHOLD(J)=S(I)
          KEEPS=I
 75       IF (QT(I).GE.QTHOLD(J)) GOTO 65
          QTHOLD(J)=QT(I)
          QHOLD(J)=Q(I)
          KEEPQ=I
 65     CONTINUE
        ST(KEEPS)=1.0E10
        QT(KEEPQ)=1.0E10
```

```
 55  CONTINUE
C
C    CALCULATE THE PROBABILITY LEVEL FOR EACH RANK.
C
     DO 85 I = 1,N
      PRBLVL(I) = (I-0.5)/N
 85  CONTINUE
     DO 95 I = 1,N
      S(I) = SHOLD(I)
      ST(I) = STHOLD(I)
      Q(I) = QHOLD(I)
      QT(I) = QTHOLD(I)
 95  CONTINUE
C
C    CALCULATE THE STANDARD NORMAL QUANTILES FOR EACH RANK.
C
     DO 105 I = 1,N
      P = PRBLVL(I)
      CALL MDNRIS(P,Y,IER)
      QUANT(I) = Y
 105 CONTINUE
C
C    FIND THE CORRELATION COEFFICIENT BETWEEN THE TRANSFORMED DATA
C    AND THE STANDARD NORMAL QUANTILES.
C
     SUMZ = 0.
     DO 130 I = 1,N
      SUMZ = SUMZ + QUANT(I)
 130 CONTINUE
     MEANZ = SUMZ/N
     SUMZ2 = 0.
     SUMQ = 0.
     SUMS = 0.
     DO 140 I = 1,N
      SUMZ2 = SUMZ2 + (QUANT(I)-MEANZ)*(QUANT(I)-MEANZ)
```

```
     SUMQ=SUMQ+(QT(I)-MEANQT)*(QUANT(I)-MEANZ)
     SUMS=SUMS+(ST(I)-MEANST)*(QUANT(I)-MEANZ)
140 CONTINUE
    RQ=SUMQ/SQRT(SUMSQT*SUMZ2)
    RS=SUMS/SQRT(SUMSST*SUMZ2)
    DO 150 I=1,N
     WRITE(6,160) Q(I),QT(I),S(I),ST(I),PRBLVL(I),QUANT(I)
160   FORMAT(F10.0,5(F10.4))
150 CONTINUE
    WRITE(6,170) RQ
170 FORMAT(/5X,'The correlation coefficient for the runoff is ',F6.4)
    WRITE(6,175) LQ
175 FORMAT(5X,'Lambda for the runoff is ',F5.2)
    WRITE(6,180) RS
180 FORMAT(/5X,'The correlation coefficient for the tides is ',F6.4)
    WRITE(6,185) LS
185 FORMAT(5X,'Lambda for the tides is ',F5.2)
    STOP
    END
```

```
C
C    THIS PROGRAM COMPUTES THE STREAMFLOW-TIDAL HEIGHT PAIRS WHICH
C    GIVE A PARTICULAR JOINT PROBABILITY OF EXCEEDENCE.
C
      REAL LS,LQ,MEANST,MEANQT,LOWQ,LOQT,LOWP
      DIMENSION SS(50),TSS(50)
C
C    INPUT THE NUMBER OF DISCRETE TIDAL HEIGHTS TO BE CONSIDERED, THE
C    SAMPLE CORRELATION COEFFICIENT, THE HIGHEST AND LOWEST
C    STREAMFLOWS CONSIDERED, THE DESIRED TOLERANCE AND THE INCREMENTAL
C    STEP FOR THE STREAMFLOWS.
C
      READ(5,5) NN,RHO,HIGHQ,LOWQ,TOL,STEP
    5 FORMAT(I5,3F10.3,2F10.4)
C
C    ENTER THE TRANSFORMATION CONSTANTS FOR THE STREAMFLOW AND TIDAL
C    HEIGHT, AND THE MEAN AND STANDARD DEVIATION OF THE TRANSFORMED
C    STREAMFLOWS AND TIDAL HEIGHTS.
C
      READ(5,6) LS,MEANST,SST
      READ(5,6) LQ,MEANQT,SQT
    6 FORMAT(F5.2,2F10.4)
C
C    GIVE THE RANGE OF JOINT PROBABILITIES SPECIFIED AND THE
C    STEP BETWEEN EACH PROBABILITY.
C
      READ(5,7) HIGHP,LOWP,STEPP
    7 FORMAT(2F5.3,F5.2)
      READ(5,20) (SS(I),I = 1,NN)
   20 FORMAT(10F8.2)
C
C    TRANSFORM THE ORIGINAL TIDAL HEIGHTS.
C
      DO 25 I = 1,NN
       TSS(I) = ((SS(I)**LS-1.)/LS-MEANST)/SST
```

```
 25 CONTINUE
C
C   TRANSFORM THE VALUES FOR THE RANGE OF STREAMFLOWS.
C
    HIQT=((HIGHQ**LQ-1.)/LQ-MEANQT)/SQT
    LOQT=((LOWQ**LQ-1.)/LQ-MEANQT)/SQT
    M=1
    DO 77 PROB=HIGHP,LOWP,STEPP
    K=1
    Y=TSS(K)
C
C   COMPUTE THE MARGINAL PROBABILITIES OF THE STREAMFLOW AND TIDAL
C   HEIGHT, AND THE JOINT PROBABILITY THAT THE STREAMFLOW AND TIDAL
C   HEIGHT WILL FALL BELOW SPECIFIC VALUES SIMULTANEOUSLY.
C
    DO 30 X=HIQT,LOQT,STEP
     CALL MDBNOR(X,Y,RHO,P1,IER)
     CALL MDNOR(X,P2)
     CALL MDNOR(Y,P3)
     P=1+P1-P2-P3
     CHECK=ABS(PROB-P)
     IF (CHECK.GT.TOL) GOTO 30
     Q=((X*SQT+MEANQT)*LQ+1.)**(1/LQ)
     WRITE(6,40) M,Q,X,SS(K),TSS(K),P
 40   FORMAT(I5,F10.0,4F10.4)
     K=K+1
     IF (K.GT.NN) GOTO 77
     Y=TSS(K)
 30 CONTINUE
    M=M+1
 77 CONTINUE
    STOP
    END
```

Appendix E

COMPUTER RESULTS OF THE NUMERICAL MODEL SIMULATIONS

SIMULATION NO. 1

(End of the tenth tidal cycle)

Normal Flow, Normal Tide

1SALINITY AT HOUR 124.20

LAYER	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.1	-0.2
2 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.1	-0.2
3 *	30.0	30.0	30.0	30.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.1	-0.2
4 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	30.0	30.0
5 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	0.0	0.0	30.0	30.0	30.0	30.0	30.0

LAYER	24	25	26	27	28	29	30	31	32	33	34	35	36
1 *	0.4	0.0	0.9	2.1	4.0	5.6	6.8	8.4	8.5	10.1	11.1	11.6	13.3
2 *	0.3	0.0	0.9	2.5	4.5	6.4	7.5	8.8	9.5	10.9	11.7	12.6	14.3
3 *	0.3	0.8	1.4	3.9	5.3	7.0	8.0	9.1	10.2	11.3	12.2	13.1	14.8
4 *	0.2	0.8	3.1	4.9	6.8	8.2	8.9	9.6	10.8	11.6	12.6	13.4	15.1
5 *	30.0	30.0	30.0	5.0	9.6	9.5	9.7	10.0	11.3	12.0	12.8	13.6	15.3
6 *	30.0	30.0	30.0	30.0	30.0	9.5	11.7	11.1	11.8	12.6	13.0	13.8	15.6
7 *	30.0	30.0	30.0	30.0	30.0	13.9	12.1	13.8	12.6	13.0	13.3	13.9	15.8
8 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	12.8	13.3	13.6	14.0	30.0
9 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	15.4	13.8	14.0	14.3	30.0
10 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	15.8	13.9	14.5	14.4	30.0

SED. CON. AT HOUR 124.20

LAYER	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1 *	30.0	27.0	24.3	32.9	28.2	24.0	29.6	24.4	14.0	5.7	0.7	0.2	0.3	0.4	0.4	0.3	0.2	0.2	0.1	0.1	0.1	0.0
2 *	30.0	31.4	29.6	40.0	34.7	27.4	34.7	28.5	16.3	6.6	0.8	0.2	0.4	0.4	0.5	0.4	0.3	0.2	0.1	0.1	0.1	0.0
3 *	0.0	0.0	0.0	0.0	0.0	30.8	41.2	33.8	19.0	7.6	1.0	0.2	0.4	0.4	0.5	0.4	0.3	0.3	0.2	0.1	0.1	0.1
4 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.6	0.4	0.3	0.3	0.2	0.0	0.0	0.0
5 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.4	0.0	0.0	0.0	0.0	0.0

LAYER	24	25	26	27	28	29	30	31	32	33	34	35	36
1 *	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
2 *	0.2	0.1	0.2	0.2	0.2	0.2	0.1	0.1	0.0	0.1	0.0	0.0	0.0
3 *	0.1	1.5	0.7	0.4	0.3	0.2	0.1	0.1	0.0	0.1	0.0	0.0	0.0
4 *	-0.3	2.5	1.8	0.7	0.3	0.2	0.2	0.1	0.0	0.1	0.0	0.0	0.0
5 *	0.0	0.0	0.0	0.6	0.7	0.1	0.2	0.1	0.0	0.1	0.0	0.0	0.0
6 *	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.1	0.0	0.0	0.0
7 *	0.0	0.0	0.0	0.0	0.0	1.0	0.2	0.7	-0.1	0.1	0.0	0.0	0.0
8 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.1	0.0	0.0	0.0
9 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0
10 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.1	0.0	0.0

TIDAL HEIGHT AT HOUR 124.20

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
	52.5	51.1	49.3	47.7	45.3	41.0	37.4	33.2	27.8	22.6	19.7	15.0	10.8	8.1	5.3	2.6	0.4	-1.9	-4.3	-7.5	-11.7	-15.6

LAYER	24	25	26	27	28	29	30	31	32	33	34	35	36
	-18.0	-18.5	-18.0	-17.0	-15.7	-14.5	-13.4	-12.4	-11.0	-9.8	-8.6	-7.4	-5.8

VERT. VEL. AT HOUR 124.20(IN 0.001CM)

LAYER	TRANSECT 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	1.9	0.1	-0.5	-0.7	-1.5	-4.9	-3.0	-4.9	-3.4	-0.8	-2.8	-3.6	-7.5	2.4	-2.5	-6.7	0.2	-1.4	0.2	0.2	-0.8	-0.5
2	0.0	0.0	0.0	0.0	0.0	-5.6	-0.4	-2.5	-1.4	2.0	1.2	-6.8	-8.2	3.4	-4.9	-8.5	3.7	0.7	3.6	2.6	-0.4	-1.3
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-6.8	3.3	-7.0	-8.8	7.5	2.4	5.4	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-7.5	8.4	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LAYER	TRANSECT 24	25	26	27	28	29	30	31	32	33	34	35	36
1	-0.8	0.5	0.8	1.8	2.0	1.8	2.5	1.2	7.6	1.8	1.8	1.0	-0.5
2	-2.9	-0.3	1.2	2.7	2.9	2.9	3.3	1.5	8.1	1.8	1.9	-1.2	-3.5
3	-8.7	-0.3	1.5	2.6	3.5	5.1	4.6	2.3	7.3	2.1	2.3	-3.8	-5.6
4	0.0	0.0	0.0	3.2	1.5	6.5	4.5	2.5	6.5	2.7	3.1	-7.4	-10.0
5	0.0	0.0	0.0	0.0	0.0	6.8	2.4	2.8	8.1	3.8	3.5	-10.3	-19.3
6	0.0	0.0	0.0	0.0	0.0	4.3	1.9	2.4	10.0	5.3	3.0	-12.8	-31.9
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.4	5.3	2.2	-15.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.8	4.7	1.0	-10.3	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	2.7	-0.2	-5.4	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

HORZ. VEL. AT HOUR 124.20

LAYER	TRANSECT 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	20.4	20.1	19.1	19.0	17.7	20.2	20.8	23.1	31.4	34.3	37.3	42.7	40.2	36.0	30.9	30.5	27.6	30.8	32.3	35.0	37.3	37.9
2	20.4	14.9	14.6	15.1	14.8	18.6	20.4	22.6	29.7	33.2	34.6	37.5	36.8	34.0	28.5	29.6	28.0	30.0	31.3	32.9	33.0	32.9
3	0.0	0.0	0.0	0.0	0.0	0.0	18.1	18.7	24.2	28.8	26.6	26.4	33.2	30.9	25.7	28.6	28.1	28.4	28.6	29.0	27.3	27.6
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.6	21.5	28.0	27.8	24.4	22.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.0	0.0	0.0	0.0	0.0	0.0

LAYER	TRANSECT 24	25	26	27	28	29	30	31	32	33	34	35	36
1	32.6	23.8	15.6	11.9	8.8	6.5	5.7	6.6	4.5	4.8	2.4	0.0	-3.9
2	27.9	20.4	12.8	8.8	4.9	1.7	1.2	0.9	0.8	-1.4	-2.1	-3.0	-9.4
3	25.6	19.4	12.5	7.3	2.0	-2.7	-2.4	-3.6	-3.0	-6.8	-6.3	-6.6	-14.2
4	0.0	20.3	11.9	4.2	0.5	-5.7	-4.9	-7.6	-7.6	-11.0	-10.4	-10.1	-18.2
5	0.0	0.0	0.0	0.0	-8.3	-7.4	-6.5	-10.6	-11.9	-14.1	-13.6	-13.2	-21.4
6	0.0	0.0	0.0	0.0	0.0	0.0	-10.5	-12.6	-15.4	-17.3	-16.6	-16.0	-24.8
7	0.0	0.0	0.0	0.0	0.0	0.0	-13.4	-14.9	-16.9	-20.6	-19.7	-18.4	-29.6
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-22.1	-22.1	-20.4	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-20.9	-23.9	-22.2	0.0

SIMULATION NO. 2

(End of the tenth tidal cycle)

10-year, 7-day Drought Flow

100-year Storm Surge

13 cm Sea Level Rise

1SALINITY AT HOUR 124.20

TRANSECT

LAYER		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.3
2	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.3
3	*	30.0	30.0	30.0	30.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.3
4	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	30.0
5	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	0.1	0.1	30.0	30.0	30.0
6	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
7	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
8	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
9	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
10	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0

TRANSECT

LAYER		22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	*	0.6	0.6	1.9	2.5	4.3	5.7	7.1	8.7	9.8	11.1	11.2	12.6	13.3	14.3	15.2
2	*	0.6	0.7	2.0	2.6	4.4	5.9	7.4	9.1	10.1	11.3	11.9	13.0	13.7	14.6	15.4
3	*	0.6	0.7	1.9	3.4	4.8	7.0	8.2	9.6	10.6	11.5	12.4	13.3	14.0	14.8	15.6
4	*	30.0	30.0	1.8	4.8	7.0	8.7	9.6	10.3	11.1	11.9	13.0	13.6	14.3	14.9	15.7
5	*	30.0	30.0	30.0	30.0	30.0	9.3	14.0	12.4	11.9	12.3	13.5	14.0	14.5	15.0	15.7
6	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	12.4	14.3	13.0	13.9	14.4	14.7	15.2	15.8
7	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	16.3	14.4	15.6	14.4	14.7	14.9	15.2	15.9
8	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	14.5	14.9	15.1	15.3	30.0
9	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	16.5	15.2	15.5	15.4	30.0
10	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	16.7	15.4	15.8	15.7	30.0

SED. CON. AT HOUR 124.20

TRANSECT

LAYER		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	*	1.0	0.8	0.8	0.8	0.8	0.7	0.4	0.4	0.3	0.4	-1.0	0.2	0.4	0.4	0.3	0.2	0.2	0.1	0.1	0.0
2	*	1.0	1.1	1.1	1.0	0.9	0.8	0.5	0.4	0.3	0.4	-0.8	0.2	0.4	0.4	0.4	0.3	0.2	0.2	0.1	0.1
3	*	0.0	0.0	0.0	0.0	0.0	1.0	0.6	0.5	0.4	0.5	-0.7	0.2	0.4	0.4	0.4	0.3	0.2	0.2	0.1	0.1
4	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.4	0.4	0.3	0.2	0.2	0.1	0.0
5	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.0
6	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TRANSECT

LAYER		22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	*	0.1	0.1	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
2	*	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
3	*	0.1	0.2	0.2	0.5	0.3	0.3	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
4	*	0.0	0.0	0.2	1.1	0.5	0.4	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
5	*	0.0	0.0	0.0	0.0	0.0	0.5	0.3	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
6	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0
7	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.2	0.3	-0.1	0.0	0.0	0.0	0.0
8	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0
9	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0

TIDAL HEIGHT AT HOUR 124.20

TRANSECT

2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
139.6	139.2	138.2	136.3	133.8	130.4	127.2	123.9	120.4	118.0	114.7	110.3	106.7	104.9	102.7	100.1	97.8	95.0	92.1	88.8

TRANSECT

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
	86.2	-84.8	84.6	85.3	86.3	87.5	88.8	90.0	90.9	91.9	93.3	94.4	95.6	96.7	98.3

VERT. VEL. AT HOUR 124.20(IN 0.001CM)

LAYER	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	-2.3	-1.5	-1.4	-1.7	-2.3	-6.2	-3.6	-3.8	-3.1	-1.1	-2.6	-5.0	-11.0	3.1	-4.2	-11.3	0.7	-1.2	3.8	2.5
2	0.0	0.0	0.0	0.0	0.0	-6.8	-0.3	-1.9	-1.3	1.7	1.3	-7.9	-10.1	4.0	-7.1	-12.8	5.3	1.3	6.3	3.9
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-7.3	3.5	-9.6	-12.3	10.2	3.5	6.8	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-9.6	10.8	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	0.6	0.5	0.1	1.5	1.1	2.0	2.5	2.1	2.8	0.6	7.9	1.4	2.3	-1.8	-1.6
2	0.4	-0.4	-0.9	1.8	1.8	2.8	3.4	3.6	3.9	0.8	7.9	1.4	2.6	-4.4	-4.9
3	0.0	0.0	-3.6	1.9	2.0	3.2	3.9	6.4	5.3	1.6	6.6	1.7	2.8	-6.7	-6.6
4	0.0	0.0	0.0	0.0	0.0	5.4	1.6	8.3	5.2	2.0	5.6	2.1	3.4	-9.8	-9.5
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.9	2.7	2.9	7.4	2.7	3.5	-11.7	-16.5
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	2.1	2.8	9.7	3.6	2.7	-13.1	-26.1
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.6	3.7	1.6	-13.9	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.0	3.5	0.3	-9.2	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.1	2.1	-0.5	-4.8	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

HORZ. VEL. AT HOUR 124.20

LAYER	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	0.7	7.0	14.0	20.1	24.5	30.8	32.3	36.0	42.2	42.9	45.1	49.8	50.9	50.9	42.8	44.5	42.8	46.7	48.0	44.2
2	0.7	7.4	12.4	16.2	19.1	25.1	27.9	30.1	34.5	37.1	38.7	40.6	43.3	44.0	36.2	39.8	40.6	42.2	43.0	37.9
3	0.0	0.0	0.0	0.0	0.0	0.0	21.8	21.8	24.4	28.5	27.9	27.3	37.2	37.8	31.0	37.1	39.6	38.9	38.1	32.1
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.7	23.8	35.0	38.2	32.3	27.9	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.8	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	38.9	34.7	27.5	19.4	12.4	8.9	6.1	4.7	4.4	5.2	3.0	3.3	1.0	0.3	-6.4
2	31.5	27.3	20.6	14.2	7.5	4.3	1.2	-1.7	-1.1	-1.2	-1.4	-4.3	-4.4	-5.4	-11.4
3	24.5	21.0	16.7	11.4	4.0	0.3	-2.8	-7.0	-5.4	-6.3	-5.5	-9.5	-8.5	-9.4	-14.5
4	0.0	0.0	0.0	8.4	-0.1	-5.6	-5.5	-11.1	-8.6	-11.0	-9.9	-13.0	-11.9	-12.4	-16.7
5	0.0	0.0	0.0	0.0	0.0	0.0	-13.9	-10.5	-10.5	-14.3	-13.9	-15.4	-14.4	-14.9	-18.5
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-12.9	-15.5	-17.2	-18.1	-16.8	-16.8	-20.4
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-13.9	-15.7	-18.7	-20.9	-19.3	-18.5	-23.5
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-22.4	-21.3	-19.6	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-21.2	-22.8	-19.9	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-16.9	-20.6	-17.7	0.0

SIMULATION NO. 3

(End of the tenth tidal cycle)

10-year, 7-day Drought Flow

100-year Storm Surge

38 cm Sea Level Rise

ISALINITY AT HOUR 124.20

LAYER	TRANSECT 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.4	0.4
2 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.4	0.4
3 *	30.0	30.0	30.0	30.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.4	0.4
4 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	0.0	0.0	0.0	0.1	0.1	0.3	0.4	30.0
5 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	0.1	0.1	30.0	30.0	30.0
6 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
7 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
8 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
9 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
10 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0

LAYER	TRANSECT 22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1 *	0.7	0.8	2.2	2.8	4.6	5.9	7.3	8.9	10.0	11.3	11.5	12.8	13.5	14.5	15.3
2 *	0.7	0.8	2.2	2.9	4.7	6.2	7.6	9.3	10.4	11.5	12.1	13.2	13.9	14.7	15.5
3 *	0.7	0.9	2.2	3.7	5.1	7.3	8.4	9.8	10.8	11.7	12.6	13.5	14.2	14.9	15.6
4 *	30.0	30.0	2.0	5.2	7.3	9.1	9.8	10.5	11.3	12.1	13.2	13.8	14.5	15.1	15.7
5 *	30.0	30.0	30.0	30.0	30.0	9.7	14.3	12.6	12.1	12.4	13.7	14.1	14.7	15.2	15.8
6 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	12.6	14.4	13.1	14.1	14.5	14.8	15.3	15.8
7 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	16.4	14.6	15.7	14.5	14.8	15.0	15.3	15.9
8 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	14.7	15.0	15.3	15.4	30.0
9 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	16.6	15.3	15.6	15.6	30.0
10 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	16.7	15.4	15.9	15.8	30.0

SED. CON. AT HOUR 124.20

LAYER	TRANSECT 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1 *	1.0	0.7	0.8	0.8	0.8	0.7	0.4	0.4	0.4	0.4	0.0	0.3	0.4	0.4	0.3	0.2	0.2	0.2	0.1	0.1
2 *	1.0	1.1	1.1	1.1	0.9	0.8	0.5	0.4	0.4	0.4	0.0	0.3	0.4	0.4	0.4	0.3	0.2	0.2	0.1	0.1
3 *	0.0	0.0	0.0	0.0	0.0	1.0	0.6	0.5	0.5	0.5	0.1	0.3	0.4	0.4	0.4	0.3	0.2	0.2	0.1	0.1
4 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.4	0.4	0.3	0.2	0.2	0.2	0.0
5 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.0
6 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LAYER	TRANSECT 22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1 *	0.1	0.1	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
2 *	0.1	0.1	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
3 *	0.1	0.1	0.2	0.5	0.2	0.3	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
4 *	0.0	0.0	0.2	1.0	0.5	0.4	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
5 *	0.0	0.0	0.0	0.0	0.0	0.5	0.3	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
6 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0
7 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.3	0.0	0.0	0.0	0.0	0.0
8 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TIDAL HEIGHT AT HOUR 124.20

TRANSECT 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
147.9	147.6	146.7	145.0	142.6	139.5	136.6	133.6	130.4	128.0	124.8	120.4	116.9	115.2	113.0	110.4	108.1	105.3	102.6	99.4

LAYER	TRANSECT 22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
	96.9	95.7	95.6	96.4	97.4	98.6	99.9	101.0	102.0	102.9	104.3	105.4	106.6	107.7	109.3

VERT. VEL. AT HOUR 124.20(IN 0.001CM)

LAYER		TRANSECT 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	*	-2.3	-1.4	-1.4	-1.7	-2.4	-6.3	-3.6	-3.9	-3.2	-1.2	-2.7	-5.1	-11.2	3.2	-4.3	-11.7	0.8	-1.2	3.9	2.7
2	*	0.0	0.0	0.0	0.0	0.0	-6.8	-0.2	-1.9	-1.3	1.7	1.3	-7.9	-10.2	4.1	-7.3	-13.1	5.5	1.4	6.4	4.0
3	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-7.3	3.5	-9.7	-12.6	10.4	3.5	6.8	0.0
4	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-9.7	10.9	0.0	0.0	0.0
5	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LAYER		TRANSECT 22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	*	0.7	0.6	0.1	1.6	1.1	2.0	2.5	2.1	2.8	0.5	7.9	1.3	2.4	-2.1	-1.7
2	*	0.5	-0.3	-0.7	2.0	1.8	2.8	3.4	3.6	3.9	0.7	7.8	1.4	2.7	-4.8	-5.0
3	*	0.0	0.0	-3.2	2.1	2.1	3.2	3.9	6.5	5.4	1.5	6.5	1.7	2.9	-7.1	-6.6
4	*	0.0	0.0	0.0	0.0	0.0	5.5	1.6	8.4	5.2	1.9	5.5	2.1	3.4	-10.2	-9.4
5	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.9	2.8	2.8	7.4	2.7	3.5	-11.9	-16.2
6	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	2.1	2.8	9.7	3.7	2.7	-13.2	-25.5
7	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.6	3.7	1.6	-13.9	0.0
8	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.0	3.5	0.3	-9.2	0.0
9	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.1	2.0	-0.6	-4.8	0.0
10	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

HORZ. VEL. AT HOUR 124.20

LAYER		TRANSECT 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	*	0.7	7.1	14.2	20.4	24.9	31.4	33.2	36.8	43.1	43.7	45.8	50.6	51.8	52.2	43.7	45.5	44.1	47.9	49.3	45.2
2	*	0.7	7.2	12.1	16.0	19.0	25.2	28.2	30.3	34.7	37.4	39.1	41.0	43.8	44.8	36.7	40.5	41.5	43.1	43.8	38.5
3	*	0.0	0.0	0.0	0.0	0.0	0.0	21.6	21.6	24.2	28.5	28.1	27.5	37.5	38.4	31.4	37.6	40.5	39.5	38.6	32.4
4	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.8	23.9	35.4	38.9	32.7	28.1	0.0
5	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.2	0.0	0.0	0.0
6	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LAYER		TRANSECT 22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	*	39.3	34.5	27.1	19.0	12.1	8.7	5.9	4.7	4.4	5.2	2.9	3.2	0.9	0.2	-6.7
2	*	31.5	26.9	20.0	13.7	7.1	4.0	1.0	-1.9	-1.3	-1.3	-1.6	-4.5	-4.5	-5.6	-11.5
3	*	24.3	20.5	16.0	10.8	3.3	-0.3	-3.2	-7.4	-5.6	-6.5	-5.6	-9.7	-8.6	-9.6	-14.4
4	*	0.0	0.0	0.0	7.5	-1.1	-6.4	-5.9	-11.5	-8.8	-11.2	-10.1	-13.1	-11.9	-12.5	-16.5
5	*	0.0	0.0	0.0	0.0	0.0	0.0	-14.1	-10.6	-10.8	-14.6	-14.0	-15.4	-14.4	-15.0	-18.1
6	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-13.1	-15.7	-17.3	-18.1	-16.9	-16.9	-19.9
7	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-13.9	-15.8	-18.8	-20.9	-19.4	-18.6	-22.8
8	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-22.3	-21.4	-19.6	0.0
9	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-21.3	-22.9	-19.9	0.0
10	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-17.0	-20.6	-17.7	0.0

SIMULATION NO. 4

(End of the tenth tidal cycle)

10-year, 7-day Drought Flow

100-year Storm Surge

55 cm Sea Level Rise

1SALINITY AT HOUR 124.20

TRANSECT

LAYER	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.3	0.4	0.4
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.3	0.4	0.5
3	30.0	30.0	30.0	30.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.3	0.5	0.5
4	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	0.0	0.0	0.0	0.1	0.1	0.3	0.5	30.0
5	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	0.1	0.2	30.0	30.0	30.0
6	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
7	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
8	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
9	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
10	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0

TRANSECT

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	0.8	0.9	2.3	3.0	4.8	6.1	7.4	9.1	10.2	11.4	11.6	12.9	13.6	14.6	15.4
2	0.8	0.9	2.3	3.1	4.9	6.3	7.8	9.5	10.5	11.6	12.2	13.3	14.0	14.9	15.6
3	0.8	1.0	2.3	3.9	5.3	7.4	8.6	9.9	10.9	11.9	12.8	13.6	14.3	15.0	15.7
4	30.0	30.0	2.2	5.4	7.6	9.3	10.0	10.6	11.5	12.2	13.3	13.9	14.6	15.1	15.7
5	30.0	30.0	30.0	30.0	30.0	10.0	14.6	12.8	12.2	12.6	13.8	14.2	14.8	15.3	15.8
6	30.0	30.0	30.0	30.0	30.0	30.0	30.0	12.7	14.5	13.2	14.2	14.6	14.9	15.4	15.9
7	30.0	30.0	30.0	30.0	30.0	30.0	30.0	16.5	14.7	15.8	14.6	14.9	15.1	15.4	15.9
8	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	14.7	15.1	15.3	15.5	30.0
9	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	16.6	15.4	15.7	15.6	30.0
10	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	16.7	15.5	15.9	15.8	30.0

SED. CON. AT HOUR 124.20

TRANSECT

LAYER	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	1.0	0.8	0.8	0.8	0.8	0.7	0.4	0.4	0.4	0.4	-0.1	0.3	0.4	0.4	0.3	0.2	0.2	0.2	0.1	0.1
2	1.0	1.2	1.1	1.0	0.9	0.8	0.5	0.4	0.4	0.4	0.0	0.3	0.4	0.4	0.4	0.3	0.2	0.2	0.1	0.1
3	0.0	0.0	0.0	0.0	0.0	1.0	0.6	0.5	0.4	0.5	0.0	0.3	0.4	0.4	0.4	0.3	0.2	0.2	0.1	0.1
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.4	0.4	0.3	0.2	0.2	0.2	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TRANSECT

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	0.1	0.1	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
2	0.1	0.1	0.2	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
3	0.1	0.2	0.2	0.5	0.3	0.2	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.2	1.0	0.5	0.4	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.4	0.3	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.2	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TIDAL HEIGHT AT HOUR 124.20

TRANSECT

2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
153.6	153.4	152.5	150.8	148.6	145.7	143.0	140.2	137.1	134.8	131.7	127.3	123.8	122.1	120.0	117.4	115.1	112.4	109.8	106.7

TRANSECT

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
	104.3	103.2	103.2	104.0	105.0	106.2	107.4	108.5	109.5	110.4	111.8	112.9	114.1	115.2	116.7

VERT. VEL. AT HOUR 124.20(IN 0.001CM)

TRANSECT

LAYER	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	-2.2	-1.4	-1.4	-1.7	-2.4	-6.3	-3.6	-3.9	-3.2	-1.3	-2.7	-5.1	-11.4	3.3	-4.4	-12.0	0.9	-1.2	4.0	2.8
2	0.0	0.0	0.0	0.0	0.0	-6.7	-0.2	-1.9	-1.4	1.6	1.3	-8.0	-10.3	4.1	-7.3	-13.3	5.6	1.4	6.4	4.1
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-7.3	3.5	-9.8	-12.7	10.5	3.6	6.8	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-9.8	11.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TRANSECT

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	0.8	0.7	0.2	1.6	1.1	2.0	2.5	2.2	2.9	0.5	7.9	1.4	2.4	-2.4	-1.7
2	0.5	-0.2	-0.6	2.1	1.8	2.8	3.4	3.7	3.9	0.6	7.8	1.4	2.7	-5.0	-5.1
3	0.0	0.0	-2.9	2.2	2.1	3.2	3.9	6.6	5.4	1.5	6.5	1.7	2.9	-7.4	-6.7
4	0.0	0.0	0.0	0.0	0.0	5.6	1.6	8.5	5.2	1.9	5.5	2.2	3.5	-10.4	-9.4
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0	2.8	2.8	7.3	2.8	3.5	-12.1	-16.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	2.1	2.8	9.6	3.8	2.7	-13.4	-25.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.6	3.8	1.6	-14.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.0	3.5	0.3	-9.2	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.2	2.0	-0.6	-4.8	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

HORZ. VEL. AT HOUR 124.20

TRANSECT

LAYER	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	0.7	7.1	14.2	20.5	25.1	31.7	33.6	37.1	43.5	44.1	46.3	51.1	52.4	52.9	44.2	46.2	44.9	48.6	50.0	45.8
2	0.7	7.1	11.9	15.8	18.8	25.1	28.2	30.3	34.7	37.6	39.3	41.3	44.1	45.3	37.0	40.9	42.1	43.6	44.2	38.8
3	0.0	0.0	0.0	0.0	0.0	0.0	21.4	21.3	24.0	28.4	28.1	27.5	37.7	38.7	31.5	37.9	41.0	39.9	38.9	32.6
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.8	23.9	35.6	39.3	32.9	28.1	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.4	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TRANSECT

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	39.5	34.4	26.9	18.8	11.9	8.5	5.8	4.6	4.3	5.2	2.8	3.1	0.9	0.2	-6.9
2	31.5	26.6	19.7	13.4	6.8	3.8	0.8	-2.1	-1.4	-1.4	-1.7	-4.6	-4.6	-5.7	-11.5
3	24.2	20.2	15.6	10.4	2.9	-0.6	-3.5	-7.6	-5.8	-6.6	-5.7	-9.7	-8.7	-9.7	-14.3
4	0.0	0.0	0.0	6.8	-1.7	-6.8	-6.2	-11.7	-9.0	-11.3	-10.1	-13.1	-12.0	-12.6	-16.3
5	0.0	0.0	0.0	0.0	0.0	0.0	-14.3	-10.7	-11.0	-14.7	-14.1	-15.5	-14.5	-15.1	-17.8
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-13.2	-15.9	-17.4	-18.1	-16.9	-17.0	-19.5
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-13.9	-15.8	-18.8	-20.8	-19.4	-18.6	-22.4
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-22.3	-21.4	-19.7	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-21.3	-22.9	-19.9	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-17.0	-20.6	-17.7	0.0

SIMULATION NO. 5

(End of the tenth tidal cycle)

10-year, 7-day Drought Flow

100-year Storm Surge

211 cm Sea Level Rise

1SALINITY AT HOUR 124.20

LAYER	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.4	0.5	0.9	1.1	1.1
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.4	0.5	0.9	1.1	1.1
3	30.0	30.0	30.0	30.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.4	0.6	0.9	1.1	1.2
4	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	0.1	0.1	0.3	0.4	0.6	0.9	1.2	30.0
5	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	0.5	0.6	30.0	30.0	30.0
6	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
7	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
8	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
9	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
10	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0

TRANSECT

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	1.6	1.8	3.7	4.5	6.3	7.5	8.8	10.4	11.5	12.7	12.8	13.9	14.6	15.4	15.8
2	1.6	1.9	3.8	4.7	6.4	7.8	9.1	10.8	11.8	12.8	13.3	14.2	14.8	15.6	15.9
3	1.6	2.1	3.8	5.6	6.9	8.9	9.9	11.2	12.2	13.0	13.8	14.4	15.1	15.7	15.9
4	30.0	30.0	3.8	7.6	9.6	10.9	11.2	11.7	12.6	13.3	14.2	14.6	15.2	15.7	15.9
5	30.0	30.0	30.0	30.0	30.0	12.2	16.1	13.7	13.1	13.6	14.6	14.9	15.4	15.8	16.0
6	30.0	30.0	30.0	30.0	30.0	30.0	30.0	13.7	15.1	13.9	15.0	15.3	15.5	15.8	16.0
7	30.0	30.0	30.0	30.0	30.0	30.0	30.0	17.0	15.2	16.3	15.3	15.5	15.6	15.9	16.0
8	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	15.4	15.6	15.8	15.9	30.0
9	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	16.7	15.8	15.9	16.0	30.0
10	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	16.9	15.8	16.0	16.0	30.0

SED. CON. AT HOUR 124.20

TRANSECT

LAYER	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	1.0	0.8	0.8	0.8	0.8	0.8	0.5	0.4	0.3	0.3	-0.6	0.3	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.1
2	1.0	1.3	1.1	1.0	1.0	0.8	0.5	0.4	0.4	0.4	-0.5	0.3	0.4	0.4	0.3	0.2	0.2	0.2	0.2	0.1
3	0.0	0.0	0.0	0.0	0.0	1.0	0.6	0.5	0.4	0.4	-0.4	0.3	0.4	0.4	0.3	0.2	0.2	0.2	0.2	0.1
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.4	0.3	0.2	0.2	0.2	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TRANSECT

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
3	0.1	0.2	0.2	0.4	0.2	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.2	0.8	0.3	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.3	0.2	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0

TIDAL HEIGHT AT HOUR 124.20

TRANSECT

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	207.2	207.0	206.4	205.3	204.0	202.2	200.6	198.9	196.9	195.6	193.3	189.7	186.7	185.3	183.5	181.3	179.5	177.3	175.5	173.7

TRANSECT

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
	172.6	172.4	172.7	173.6	174.3	175.3	176.5	177.4	178.3	179.2	180.6	181.7	182.8	183.8	185.4

VERT. VEL. AT HOUR 124.20(IN 0.001CM)

TRANSECT

LAYER	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	-2.1	-1.3	-1.3	-1.5	-2.2	-5.8	-3.4	-3.9	-3.5	-1.6	-3.0	-5.4	-12.3	3.8	-4.8	-13.2	1.5	-0.9	4.8	3.3
2	0.0	0.0	0.0	0.0	0.0	-5.9	-0.3	-1.8	-1.4	1.4	1.2	-8.1	-10.7	4.4	-7.7	-14.2	6.3	1.7	6.8	4.2
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-7.2	3.6	-10.1	-13.2	11.1	3.8	6.6	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-9.8	11.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TRANSECT

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	1.0	0.9	0.3	1.8	1.0	2.0	2.8	2.2	3.0	-0.4	8.1	1.6	2.1	-3.9	-2.2
2	0.7	0.1	-0.1	2.6	1.8	2.8	3.7	3.8	4.1	-0.5	7.7	1.8	2.4	-6.5	-5.3
3	0.0	0.0	-1.1	2.8	1.9	3.4	4.3	7.0	5.6	0.2	6.0	2.1	2.8	-8.7	-6.7
4	0.0	0.0	0.0	0.0	0.0	5.9	1.9	9.2	5.3	0.9	4.7	2.6	3.5	-11.5	-8.6
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.4	3.0	2.2	6.1	3.5	3.7	-12.9	-13.9
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4	2.5	2.5	8.3	4.8	3.0	-13.7	-21.1
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.3	4.4	2.1	-13.7	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.1	3.6	0.8	-9.1	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.8	1.9	-0.2	-4.8	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

HORZ. VEL. AT HOUR 124.20

TRANSECT

LAYER	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	0.7	7.3	14.5	20.5	24.8	30.9	33.3	36.8	43.7	44.9	47.5	53.3	55.3	57.5	47.1	49.9	49.7	52.9	53.9	48.0
2	0.7	6.7	11.0	14.4	16.9	22.8	26.4	28.4	33.2	36.7	39.0	41.6	45.3	47.9	38.3	43.0	45.3	45.8	46.1	38.9
3	0.0	0.0	0.0	0.0	0.0	0.0	18.7	18.9	21.7	26.4	27.0	27.1	38.0	40.2	32.0	39.1	43.4	41.2	39.7	31.7
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.4	23.2	36.0	41.0	33.1	27.3	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.5	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0:0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TRANSECT

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	40.1	33.8	25.8	18.0	11.5	8.2	5.7	4.7	4.3	5.0	1.8	2.0	0.5	-0.4	-7.9
2	30.3	24.7	17.5	11.9	5.7	3.0	0.1	-3.0	-1.9	-2.0	-2.3	-5.8	-5.5	-6.3	-11.3
3	22.2	17.5	12.3	8.2	0.7	-2.3	-4.8	-8.9	-6.5	-7.4	-5.9	-10.3	-9.4	-9.9	-13.1
4	0.0	0.0	0.0	2.6	-5.5	-9.2	-7.9	-13.4	-9.8	-12.2	-9.7	-13.2	-12.3	-12.6	-14.3
5	0.0	0.0	0.0	0.0	0.0	0.0	-15.0	-11.8	-12.6	-15.6	-13.4	-15.1	-14.5	-14.8	-15.2
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-14.3	-16.8	-16.7	-17.1	-16.6	-16.5	-16.3
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-13.7	-16.6	-18.5	-19.0	-18.7	-18.1	-18.3
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-20.0	-20.3	-19.2	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-18.9	-21.3	-19.5	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-15.8	-19.1	-17.6	0.0

SIMULATION NO. 6

(End of the twentieth tidal cycle)

100-year Flood Flow

100-year Storm Surge

13 cm Sea Level Rise

1SALINITY AT HOUR 248.40

TRANSECT

LAYER	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	0.0
2	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	0.0
3	0.0	-0.1	0.0	-0.1	0.0	-0.2	-0.1	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.1	-0.1	0.1	0.0
4	30.0	30.0	30.0	30.0	30.0	-0.3	-0.1	-0.2	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.1	-0.1	0.2	0.0
5	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	0.0	-0.1	0.0	-0.2	0.1	-0.1	0.2	30.0
6	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	-0.2	0.1	30.0	30.0	30.0
7	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
8	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
9	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
10	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
11	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0

TRANSECT

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	0.0	0.1	-0.1	0.1	-0.2	0.3	0.9	2.6	3.7	4.9	6.2	7.8	8.9	10.3	11.0
2	0.0	0.1	-0.1	0.1	-0.1	0.4	1.1	2.9	4.1	5.3	6.8	8.2	9.5	10.8	12.9
3	0.0	0.1	-0.1	0.1	-0.1	0.5	1.4	3.1	4.3	5.6	7.1	8.6	10.0	11.5	14.1
4	0.0	0.1	-0.1	0.0	0.1	0.9	2.0	3.1	4.7	6.1	7.4	9.1	11.0	12.5	15.4
5	30.0	30.0	-0.1	-0.1	0.2	2.7	3.2	2.8	5.5	6.8	7.6	9.7	12.1	13.2	16.0
6	30.0	30.0	30.0	30.0	30.0	5.8	3.5	2.5	6.5	7.5	7.5	10.2	12.7	13.7	16.0
7	30.0	30.0	30.0	30.0	30.0	30.0	30.0	2.1	8.8	9.7	7.4	10.9	13.1	13.9	16.0
8	30.0	30.0	30.0	30.0	30.0	30.0	30.0	2.8	13.8	10.0	7.3	11.9	13.4	14.1	16.0
9	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	7.1	13.0	13.7	14.2	30.0
10	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	10.3	14.4	14.1	14.3	30.0
11	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	14.7	15.1	14.2	14.2	30.0

SED. CON. AT HOUR 248.40

TRANSECT

LAYER	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	70.0	157.3	50.3	143.2	80.9	150.9	166.4	138.8	167.8	196.1	261.6	176.8	234.0	294.3	236.2	249.9	269.6	227.9	220.4	210.2
2	70.0	158.1	49.4	146.6	74.8	182.0	180.6	142.4	172.5	199.9	274.0	176.8	253.7	306.9	239.5	269.0	286.5	235.6	230.0	220.8
3	70.0	157.5	49.1	148.6	66.2	224.9	196.3	145.3	175.8	202.0	278.4	174.9	272.1	314.6	240.7	282.2	296.9	238.8	233.6	227.6
4	0.0	0.0	0.0	0.0	0.0	558.2	240.8	150.8	179.5	202.2	278.8	160.8	304.2	326.8	240.2	298.7	310.1	241.3	273.2	236.4
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	492.8	362.9	229.2	327.1	334.2	247.1	266.8	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	496.5	385.1	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TRANSECT

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	251.7	214.1	195.3	256.3	202.4	117.3	50.7	18.3	7.8	3.3	1.5	0.6	0.3	0.1	0.1
2	260.6	218.9	206.3	272.4	212.3	117.6	49.1	15.2	6.9	2.9	1.1	0.5	0.2	0.1	0.1
3	266.1	221.8	214.9	284.1	218.5	115.3	46.5	12.4	6.2	2.5	0.9	0.4	0.2	0.1	0.0
4	268.5	219.7	230.6	299.9	220.8	103.9	38.6	7.9	5.3	2.0	0.5	0.3	0.1	0.1	0.0
5	0.0	0.0	398.0	330.7	214.6	56.8	21.4	2.9	4.3	1.2	0.3	0.3	0.1	0.1	0.0
6	0.0	0.0	0.0	0.0	0.0	30.2	13.9	1.4	3.8	0.6	0.2	0.3	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	3.3	-0.5	0.2	0.2	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	3.1	-0.6	0.1	0.2	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.0

TIDAL HEIGHT AT HOUR 248.40

TRANSECT

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	287.0	262.4	239.7	219.6	202.9	186.8	166.3	150.5	136.1	128.4	119.9	112.7	107.0	102.6	99.2	95.2	91.4	87.8	85.1	84.4

TRANSECT

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
	84.8	85.5	86.7	88.2	89.7	90.7	91.9	92.6	93.7	94.4	95.1	95.9	96.9	97.8	99.1

VERT. VEL. AT HOUR 248.40(IN 0.001CM)

LAYER		TRANSECT 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	*	-2.2	0.0	-3.6	-5.3	-8.6	-8.6	-7.9	-9.1	-7.1	-2.9	-7.4	-8.8	-17.3	5.5	-6.8	-17.9	-1.0	-4.0	0.4	1.8
2	*	-4.9	4.9	-0.6	-2.9	-7.1	-16.1	-4.0	-7.3	-2.7	2.5	4.2	-10.7	-23.7	12.4	-8.0	-22.3	4.7	-0.7	7.2	6.3
3	*	0.0	0.0	0.0	0.0	0.0	-45.3	2.5	-6.4	1.0	7.9	7.9	-18.4	-21.6	13.0	-14.0	-25.0	12.8	2.9	9.1	8.2
4	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-23.2	12.7	-20.2	-25.9	22.6	4.2	18.8	0.0
5	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-28.2	31.6	0.0	0.0	0.0
6	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LAYER		TRANSECT 22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	*	0.5	0.2	0.7	-0.1	1.1	1.2	2.8	3.8	-1.6	0.5	12.7	0.9	1.8	1.9	-1.5
2	*	1.6	0.2	0.4	-0.7	1.1	1.0	3.1	6.6	-3.6	-0.1	17.3	0.1	1.9	1.6	-2.5
3	*	1.5	-0.7	-0.4	-2.4	2.4	2.5	5.4	13.8	-6.2	-0.6	23.7	-1.3	2.3	-0.2	-6.8
4	*	0.0	0.0	-8.4	-4.0	3.5	3.3	7.5	28.1	-10.1	-1.1	29.9	-3.8	2.8	-3.4	-11.1
5	*	0.0	0.0	0.0	0.0	0.0	1.9	5.0	34.7	-13.6	-1.3	34.5	-8.4	4.4	-7.2	-18.3
6	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.4	-16.2	-0.4	39.9	-20.9	5.2	-10.2	-36.4
7	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.4	-16.4	0.9	41.9	-39.9	4.9	-13.7	-69.1
8	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	42.9	-42.3	4.8	-21.9	0.0
9	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40.0	-39.7	5.8	-16.5	0.0
10	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.9	-31.9	8.2	-12.4	0.0
11	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

HORZ. VEL. AT HOUR 248.40

LAYER		TRANSECT 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	*	180.0	173.9	166.5	159.8	147.1	144.9	148.7	135.3	130.5	121.8	116.7	107.8	104.7	106.5	89.2	90.6	88.1	90.4	90.2	77.0
2	*	180.0	155.2	142.7	135.4	125.2	131.7	123.8	114.3	111.5	108.2	103.8	91.3	90.2	94.8	73.9	77.2	77.4	78.2	78.3	64.6
3	*	180.0	194.0	179.7	169.8	152.2	161.9	110.7	99.4	97.8	98.3	91.8	76.3	81.1	84.9	63.0	68.8	70.9	70.3	69.6	56.3
4	*	0.0	0.0	0.0	0.0	0.0	0.0	144.9	128.1	126.5	115.6	108.0	84.7	95.3	75.5	54.1	65.5	67.8	65.8	59.3	67.2
5	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	87.7	66.8	82.9	67.8	70.0	77.4	0.0
6	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	90.4	0.0	0.0	0.0
7	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LAYER		TRANSECT 22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	*	64.8	57.4	46.4	36.5	24.3	22.0	20.0	19.7	23.8	18.9	21.7	28.9	22.7	21.7	21.0
2	*	51.4	43.7	34.4	25.4	17.2	14.3	12.5	10.2	14.6	11.0	12.0	16.9	11.9	11.5	10.1
3	*	41.6	33.9	27.0	18.7	12.9	9.8	7.8	4.0	8.5	5.6	5.6	9.3	4.5	4.4	-1.0
4	*	51.4	40.9	32.6	14.9	11.1	5.7	2.8	-3.7	-0.4	-0.7	-1.5	-0.6	-5.7	-5.8	-15.6
5	*	0.0	0.0	0.0	19.7	20.5	4.8	-2.7	-11.6	-15.3	-9.0	-8.7	-12.8	-15.5	-14.0	-24.3
6	*	0.0	0.0	0.0	0.0	0.0	0.0	-4.7	-13.6	-26.4	-14.6	-11.2	-20.6	-20.5	-19.3	-30.9
7	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-38.6	-17.0	-11.1	-29.8	-24.9	-22.9	-40.8
8	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-78.6	-10.5	-10.1	-41.3	-30.0	-25.6	-67.2
9	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-52.1	-33.6	-26.4	0.0
10	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-66.7	-32.4	-28.0	0.0
11	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-118.8	-18.6	-45.6	0.0

SIMULATION NO. 7

(End of the twentieth tidal cycle)

100-year Flood Flow

100-year Storm Surge

38 cm Sea Level Rise

1SALINITY AT HOUR 248.40

TRANSECT

LAYER	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1 *	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.1	-0.1	0.1	0.0
2 *	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.1	-0.1	0.1	0.0
3 *	0.0	-0.1	0.0	-0.1	0.0	-0.2	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.1	-0.1	0.1	0.0
4 *	30.0	30.0	30.0	30.0	30.0	-0.2	-0.1	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.1	-0.1	0.2	0.0
5 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	0.0	-0.1	0.0	-0.1	0.1	-0.1	0.2	30.0
6 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	-0.2	0.1	30.0	30.0	30.0
7 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
8 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
9 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
10 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
11 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0

TRANSECT

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1 *	0.0	0.1	-0.1	0.1	-0.2	0.3	1.0	2.7	3.9	5.1	6.4	7.9	9.1	10.5	11.2
2 *	0.0	0.1	-0.1	0.1	-0.1	0.5	1.2	3.0	4.2	5.5	7.0	8.4	9.7	11.0	13.0
3 *	0.0	0.1	-0.1	0.1	-0.1	0.6	1.5	3.2	4.4	5.8	7.3	8.7	10.2	11.6	14.2
4 *	0.0	0.1	-0.1	0.0	0.1	1.0	2.1	3.2	4.8	6.2	7.6	9.2	11.1	12.6	15.4
5 *	30.0	30.0	-0.1	-0.1	0.4	2.8	3.4	2.9	5.6	7.0	7.7	9.8	12.2	13.3	16.0
6 *	30.0	30.0	30.0	30.0	30.0	5.9	3.6	2.6	6.6	7.6	7.6	10.3	12.8	13.7	16.0
7 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	2.2	9.0	9.8	7.5	11.0	13.2	14.0	16.0
8 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	3.0	14.1	10.2	7.4	12.0	13.5	14.1	16.0
9 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	7.2	13.1	13.7	14.2	30.0
10 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	10.5	14.4	14.1	14.4	30.0
11 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	14.8	15.1	14.3	14.2	30.0

SED. CON. AT HOUR 248.40

TRANSECT

LAYER	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1 *	70.0	156.5	51.9	140.5	85.1	149.2	160.8	134.1	168.2	196.6	260.7	176.7	229.3	291.2	235.5	249.1	268.6	229.2	221.6	211.9
2 *	70.0	157.2	51.1	143.8	79.1	180.0	174.7	137.7	173.0	200.5	272.9	176.7	248.3	303.5	238.8	267.5	284.9	236.6	230.8	222.4
3 *	70.0	156.6	50.8	145.8	70.6	222.4	190.2	140.6	176.5	202.6	277.2	174.9	266.1	311.1	240.0	280.2	295.0	239.6	234.2	229.2
4 *	0.0	0.0	0.0	0.0	0.0	553.9	234.6	145.8	180.3	202.8	277.6	161.6	297.5	323.0	239.5	296.3	307.9	241.9	277.6	238.5
5 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	483.3	358.5	228.9	324.1	331.6	247.4	270.3	0.0
6 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	491.1	381.8	0.0	0.0	0.0
7 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TRANSECT

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1 *	253.8	212.6	196.2	257.3	200.5	115.1	51.8	20.2	10.6	6.3	3.7	2.7	2.1	1.5	1.3
2 *	262.7	217.4	207.1	273.0	209.8	115.0	50.4	17.2	10.0	6.0	3.3	2.7	2.1	1.5	0.9
3 *	268.1	220.2	215.6	284.5	215.5	112.6	48.1	14.5	9.5	5.7	2.9	2.6	1.9	1.4	0.6
4 *	270.6	218.1	231.1	300.2	215.3	100.2	40.9	9.7	8.8	5.1	2.4	2.5	1.6	1.1	0.2
5 *	0.0	0.0	396.9	331.5	202.1	54.4	25.6	4.2	8.3	4.2	1.9	2.5	1.2	1.0	0.0
6 *	0.0	0.0	0.0	0.0	0.0	1.1	20.3	2.4	8.2	3.4	1.6	2.6	0.9	0.8	0.0
7 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	8.5	0.5	1.5	2.4	0.7	0.8	0.0
8 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	10.4	-0.1	1.4	2.3	0.5	0.8	0.0
9 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	2.2	0.2	0.8	0.0
10 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	2.1	0.0	1.0	0.0
11 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	2.1	0.5	1.2	0.0

TIDAL HEIGHT AT HOUR 248.40

TRANSECT

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	293.9	269.7	247.4	227.5	211.1	195.2	174.9	159.3	145.2	137.5	129.1	122.1	116.7	112.3	109.1	105.2	101.5	98.0	95.6	95.1

TRANSECT

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
	95.6	96.3	97.5	99.2	100.6	101.7	102.9	103.6	104.7	105.2	106.1	106.9	107.9	108.7	110.2

VERT. VEL. AT HOUR 248.40(IN 0.001CM)

TRANSECT

LAYER	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	-2.0	0.1	-3.6	-5.2	-8.7	-8.6	-7.9	-9.1	-7.2	-3.0	-7.3	-8.8	-17.5	5.9	-6.8	-18.1	-0.8	-3.6	0.7	2.0
2	-4.7	4.9	-0.6	-2.9	-7.1	-16.0	-4.1	-7.3	-2.8	2.5	4.2	-10.7	-23.8	12.6	-8.1	-22.4	4.8	-0.5	7.3	6.4
3	0.0	0.0	0.0	0.0	0.0	-45.1	2.5	-6.4	1.0	7.9	7.9	-18.4	-21.7	13.2	-14.0	-25.0	12.8	3.2	8.9	8.2
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-23.2	12.8	-20.2	-25.9	22.6	4.3	18.6	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-28.2	31.6	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TRANSECT

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	0.3	0.1	0.7	-0.1	1.1	1.2	2.8	4.2	-2.2	0.5	13.2	0.9	1.6	2.1	-1.3
2	1.5	0.1	0.4	-0.7	1.1	1.1	3.1	7.0	-4.2	-0.2	17.9	0.0	1.7	1.8	-2.4
3	1.4	-0.8	-0.3	-2.3	2.6	2.6	5.3	14.4	-6.8	-0.8	24.4	-1.5	2.1	0.0	-6.7
4	0.0	0.0	-8.3	-3.8	3.9	3.5	7.3	28.8	-10.8	-1.4	30.5	-4.0	2.6	-3.2	-11.0
5	0.0	0.0	0.0	0.0	0.0	2.5	4.8	35.4	-14.3	-1.5	35.1	-8.6	4.2	-7.1	-18.2
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.9	-16.8	-0.5	40.3	-21.3	5.1	-10.0	-36.3
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.8	-17.0	1.0	42.1	-40.5	4.8	-13.5	-68.9
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	43.0	-42.8	4.8	-21.7	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40.1	-40.2	5.8	-16.4	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.0	-32.3	8.2	-12.3	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

HORZ. VEL. AT HOUR 248.40

TRANSECT

LAYER	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	180.0	174.1	166.6	159.9	147.2	145.1	148.9	135.6	131.0	122.2	117.1	108.0	105.0	107.1	89.2	90.8	88.5	90.6	90.2	76.4
2	180.0	154.9	142.4	135.0	124.8	131.5	123.7	114.3	111.5	108.3	103.9	91.4	90.3	95.1	73.8	77.3	77.6	78.2	78.1	63.8
3	180.0	193.6	179.2	169.1	151.6	161.5	110.4	99.2	97.7	98.3	91.9	76.3	81.1	85.1	62.9	68.8	71.1	70.3	69.3	55.6
4	0.0	0.0	0.0	0.0	0.0	0.0	144.3	127.7	126.1	115.4	108.0	84.6	95.3	75.6	53.9	65.4	67.8	65.7	58.7	66.7
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	87.8	66.5	82.8	67.8	69.8	76.6	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	90.3	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TRANSECT

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	63.9	56.9	46.1	36.1	24.2	22.1	20.0	19.7	23.6	19.0	21.7	28.8	22.4	21.4	20.7
2	50.5	43.3	34.2	25.2	17.1	14.4	12.5	10.2	14.4	11.1	11.9	16.8	11.6	11.4	9.8
3	40.9	33.5	26.8	18.5	12.8	9.7	7.7	3.9	8.2	5.8	5.6	9.3	4.4	4.3	-1.2
4	50.4	40.3	32.3	14.7	10.9	5.4	2.6	-4.0	-1.1	-0.7	-1.4	-0.8	-5.9	-5.7	-15.7
5	0.0	0.0	0.0	19.4	20.0	3.6	-3.3	-11.9	-16.1	-9.0	-8.4	-13.0	-15.6	-13.9	-24.3
6	0.0	0.0	0.0	0.0	0.0	0.0	-6.3	-13.8	-27.1	-14.5	-10.9	-20.8	-20.5	-19.1	-30.8
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-39.2	-16.8	-10.7	-29.9	-24.9	-22.8	-40.7
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-79.9	-9.7	-9.5	-41.5	-29.9	-25.4	-67.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-52.3	-33.5	-26.2	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-66.8	-32.3	-27.7	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-119.1	-17.8	-45.0	0.0

SIMULATION NO. 8

(End of the twentieth tidal cycle)

10-year, 7-day Drought Flow

100-year Storm Surge

55 cm Sea Level Rise

1SALINITY AT HOUR 248.40

LAYER (TRANSECT →)	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1 *	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.1	-0.1	0.1	0.0
2 *	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.1	-0.1	0.1	0.0
3 *	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.1	-0.1	0.1	0.0
4 *	30.0	30.0	30.0	30.0	30.0	-0.2	-0.1	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.1	-0.1	0.2	0.0
5 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	0.0	-0.1	0.1	-0.1	0.1	-0.1	0.2	30.0
6 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	-0.2	0.1	30.0	30.0	30.0
7 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
8 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
9 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
10 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
11 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0

LAYER (TRANSECT →)	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1 *	0.0	0.1	-0.1	0.1	-0.1	0.4	1.0	2.8	4.0	5.2	6.5	8.0	9.2	10.5	11.3
2 *	0.0	0.1	-0.1	0.1	-0.1	0.5	1.3	3.1	4.3	5.6	7.1	8.5	9.8	11.0	13.0
3 *	0.0	0.1	-0.1	0.1	-0.1	0.6	1.5	3.3	4.5	5.9	7.4	8.8	10.3	11.7	14.2
4 *	0.0	0.1	-0.1	0.0	0.2	1.1	2.2	3.3	4.9	6.3	7.6	9.3	11.2	12.6	15.4
5 *	30.0	30.0	-0.1	-0.1	0.5	2.9	3.4	3.0	5.7	7.1	7.8	9.9	12.2	13.3	16.0
6 *	30.0	30.0	30.0	30.0	30.0	5.8	3.7	2.7	6.7	7.7	7.7	10.4	12.9	13.8	16.0
7 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	2.3	9.1	9.9	7.6	11.1	13.3	14.0	16.0
8 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	3.1	14.2	10.3	7.5	12.0	13.5	14.2	16.0
9 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	7.2	13.1	13.8	14.2	30.0
10 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	10.6	14.5	14.1	14.4	30.0
11 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	14.9	15.2	14.3	14.2	30.0

SED. CON. AT HOUR 248.40

LAYER (TRANSECT →)	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1 *	70.0	156.5	53.0	139.1	87.3	148.4	156.7	130.9	168.4	196.9	260.1	177.3	226.0	289.7	235.6	248.3	267.7	228.8	221.3	211.4
2 *	70.0	157.2	52.2	142.4	81.4	179.0	170.5	134.4	173.3	200.7	272.1	177.3	244.6	301.7	238.8	266.2	283.7	236.0	230.2	221.9
3 *	70.0	156.5	51.9	144.3	73.0	221.0	185.8	137.3	176.8	202.9	276.4	175.6	262.0	309.1	240.1	278.6	293.5	239.0	233.6	228.7
4 *	0.0	0.0	0.0	0.0	0.0	550.9	230.2	142.4	180.7	203.1	276.8	162.6	293.0	321.0	239.7	294.3	306.2	241.0	279.8	238.2
5 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	477.2	356.2	229.3	321.6	329.6	246.4	271.9	0.0
6 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	486.6	379.3	0.0	0.0	0.0
7 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LAYER (TRANSECT →)	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1 *	254.2	212.6	196.5	258.3	199.2	113.6	51.1	19.9	10.4	6.2	3.7	2.7	2.1	1.5	1.3
2 *	263.1	217.3	207.4	273.8	208.1	113.1	49.7	17.0	9.9	6.0	3.2	2.7	2.0	1.5	0.9
3 *	268.5	220.1	215.8	285.2	213.6	110.4	47.4	14.3	9.4	5.6	2.9	2.6	1.9	1.4	0.6
4 *	271.0	217.8	231.2	300.8	212.0	96.9	40.3	9.5	8.7	5.1	2.4	2.5	1.6	1.1	0.2
5 *	0.0	0.0	395.0	332.2	192.5	50.9	25.9	4.1	8.2	4.2	1.8	2.5	1.2	1.0	0.0
6 *	0.0	0.0	0.0	0.0	0.0	-19.9	22.4	2.4	8.1	3.4	1.6	2.6	0.9	0.8	0.0
7 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	8.5	0.5	1.5	2.4	0.7	0.8	0.0
8 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9	10.4	0.0	1.4	2.3	0.5	0.8	0.0
9 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	2.1	0.2	0.8	0.0
10 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	2.1	0.0	1.0	0.0
11 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	2.1	0.5	1.1	0.0

TIDAL HEIGHT AT HOUR 248.40

TRANSECT	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	298.6	274.6	252.5	232.9	216.6	200.8	180.7	165.3	151.3	143.6	135.4	128.5	123.2	118.8	115.7	112.0	108.3	104.9	102.7	102.4

LAYER (TRANSECT →)	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
	102.8	103.6	104.9	106.6	108.0	109.1	110.4	111.1	112.0	112.6	113.5	114.3	115.3	116.2	117.6

VERT. VEL. AT HOUR 248.40(IN 0.001CM)

LAYER		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	*	-1.8	0.2	-3.6	-5.2	-8.7	-8.6	-7.9	-9.1	-7.3	-3.0	-7.2	-8.8	-17.8	6.2	-6.9	-18.2	-0.7	-3.4	1.0	2.1
2	*	-4.6	4.9	-0.5	-2.9	-7.1	-16.0	-4.1	-7.3	-2.8	2.4	4.3	-10.7	-24.0	12.8	-8.1	-22.5	4.8	-0.3	7.4	6.4
3	*	0.0	0.0	0.0	0.0	0.0	-45.0	2.5	-6.4	0.9	7.9	8.0	-18.4	-21.8	13.3	-14.0	-25.1	12.9	3.3	8.8	8.2
4	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-23.2	12.8	-20.2	-25.9	22.7	4.4	18.4	0.0
5	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-28.1	31.5	0.0	0.0	0.0
6	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TRANSECT

LAYER		22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	*	0.1	0.0	0.8	-0.2	1.1	1.3	2.7	4.4	-2.6	0.6	13.6	0.8	1.5	2.2	-1.3
2	*	1.4	0.1	0.4	-0.7	1.2	1.1	3.1	7.2	-4.5	-0.2	18.3	-0.1	1.6	1.9	-2.4
3	*	1.4	-0.8	-0.3	-2.3	2.8	2.7	5.2	14.6	-7.2	-0.9	24.8	-1.6	2.0	0.1	-6.6
4	*	0.0	0.0	-8.2	-3.8	4.1	3.6	7.0	29.2	-11.2	-1.5	31.0	-4.2	2.6	-3.1	-11.0
5	*	0.0	0.0	0.0	0.0	0.0	3.0	4.5	35.8	-14.7	-1.6	35.5	-8.8	4.2	-7.0	-18.1
6	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.2	-17.2	-0.6	40.7	-21.5	5.0	-9.9	-36.2
7	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.1	-17.4	1.0	42.4	-41.0	4.7	-13.4	-68.7
8	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	43.1	-43.2	4.8	-21.5	0.0
9	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40.1	-40.5	5.8	-16.2	0.0
10	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.1	-32.6	8.3	-12.2	0.0
11	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

HORZ. VEL. AT HOUR 248.40

TRANSECT

LAYER		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	*	180.0	174.2	166.7	159.9	147.2	145.2	149.1	135.7	131.2	122.4	117.3	108.1	105.1	107.5	89.2	90.8	88.7	90.6	90.1	75.9
2	*	180.0	154.7	142.1	134.8	124.6	131.3	123.6	114.2	111.5	108.3	104.0	91.3	90.3	95.3	73.7	77.2	77.7	78.1	77.8	63.3
3	*	180.0	193.3	178.8	168.7	151.2	161.2	110.2	99.1	97.6	98.2	91.9	76.2	81.1	85.3	62.8	68.8	71.1	70.2	69.0	55.0
4	*	0.0	0.0	0.0	0.0	0.0	0.0	144.0	127.5	125.9	115.3	107.9	84.4	95.2	75.7	53.7	65.3	67.8	65.6	58.2	66.2
5	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	87.8	66.2	82.6	67.7	69.6	76.0	0.0
6	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	90.2	0.0	0.0	0.0
7	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TRANSECT

LAYER		22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	*	63.4	56.6	45.9	35.8	24.1	22.1	20.1	19.7	23.5	19.2	21.5	28.7	22.3	21.2	20.4
2	*	50.0	43.0	34.1	24.9	17.1	14.4	12.5	10.1	14.2	11.3	11.8	16.7	11.5	11.2	9.6
3	*	40.4	33.3	26.7	18.3	12.7	9.7	7.6	3.8	8.0	5.9	5.6	9.2	4.3	4.2	-1.4
4	*	49.8	40.0	32.1	14.4	10.7	5.1	2.4	-4.2	-1.4	-0.6	-1.4	-0.9	-5.9	-5.7	-15.7
5	*	0.0	0.0	0.0	19.2	19.7	2.6	-3.7	-12.1	-16.5	-9.0	-8.3	-13.2	-15.6	-13.9	-24.3
6	*	0.0	0.0	0.0	0.0	0.0	0.0	-7.7	-14.0	-27.5	-14.5	-10.6	-20.9	-20.5	-19.1	-30.8
7	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-39.6	-16.7	-10.4	-30.0	-24.8	-22.7	-40.6
8	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-80.6	-9.2	-9.2	-41.7	-29.8	-25.3	-66.8
9	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-52.4	-33.5	-26.1	0.0
10	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-67.0	-32.2	-27.6	0.0
11	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-119.3	-17.2	-44.6	0.0

SIMULATION NO. 9

(End of the twentieth tidal cycle)

100-year Flood Flow

100-year Storm Surge

211 cm Sea Level Rise

1SALINITY AT HOUR 248.40

TRANSECT

LAYER		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	*	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.1	-0.1	0.1	0.0
2	*	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.1	-0.1	0.1	0.0
3	*	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.1	-0.1	0.1	0.0
4	*	30.0	30.0	30.0	30.0	30.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.1	-0.1	0.2	0.0
5	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	0.0	-0.1	0.1	-0.1	0.1	-0.1	0.3	30.0
6	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	-0.2	0.1	30.0	30.0	30.0
7	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
8	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
9	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
10	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
11	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0

TRANSECT

LAYER		22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	*	0.1	0.1	0.0	0.1	0.0	0.7	1.6	3.5	4.9	6.1	7.4	9.0	10.2	11.3	12.2
2	*	0.1	0.1	0.0	0.1	0.0	0.9	1.9	3.8	5.2	6.5	7.9	9.3	10.6	11.8	13.6
3	*	0.1	0.1	0.0	0.1	0.1	1.1	2.2	4.0	5.4	6.8	8.1	9.6	11.0	12.3	14.6
4	*	0.1	0.1	0.0	0.1	0.3	1.8	2.9	3.9	5.8	7.2	8.3	10.0	11.9	13.1	15.5
5	*	30.0	30.0	0.0	-0.1	1.7	3.1	4.3	3.6	6.6	7.9	8.3	10.6	12.7	13.7	16.0
6	*	30.0	30.0	30.0	30.0	30.0	2.7	4.9	3.3	7.5	8.6	8.2	11.0	13.3	14.1	16.0
7	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	2.9	9.8	10.7	8.1	11.7	13.7	14.3	16.0
8	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	4.2	15.8	11.3	8.0	12.5	13.9	14.4	16.0
9	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	7.7	13.6	14.2	14.5	30.0
10	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	11.7	14.7	14.5	14.6	30.0
11	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	15.3	15.4	14.7	14.4	30.0

SED. CON. AT HOUR 248.40

TRANSECT

LAYER		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	*	70.0	158.8	64.2	127.8	100.4	141.9	129.4	107.0	172.0	189.8	253.3	179.4	198.2	270.8	237.4	239.4	263.6	230.7	224.0	214.7
2	*	70.0	159.4	63.4	130.9	95.2	170.5	141.7	110.6	177.6	193.6	264.4	179.5	213.8	282.0	240.8	254.0	277.0	236.5	231.4	225.8
3	*	70.0	158.4	63.3	132.7	87.5	209.3	155.7	113.4	181.6	195.9	268.5	178.5	228.2	289.0	242.3	263.9	285.2	238.7	234.8	233.1
4	*	0.0	0.0	0.0	0.0	0.0	527.5	199.6	117.2	185.9	196.8	268.9	169.6	255.7	300.2	243.0	277.0	296.7	239.6	297.7	245.2
5	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	430.3	333.7	235.9	300.9	318.2	243.8	287.0	0.0
6	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	453.0	363.5	0.0	0.0	0.0
7	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TRANSECT

LAYER		22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	*	260.0	208.4	200.4	263.9	187.7	101.8	46.7	17.7	9.4	5.7	3.3	2.4	1.8	1.3	1.0
2	*	269.0	212.6	211.1	277.5	193.6	98.4	44.7	14.7	8.9	5.4	2.9	2.3	1.7	1.2	0.7
3	*	274.7	215.3	219.1	287.3	197.2	93.1	42.5	12.2	8.4	5.1	2.5	2.3	1.6	1.1	0.4
4	*	277.7	212.8	232.5	299.9	193.2	69.3	36.8	7.5	7.9	4.6	2.1	2.2	1.3	0.9	0.2
5	*	0.0	0.0	373.8	324.4	122.1	12.8	29.4	3.2	7.6	3.7	1.6	2.1	1.0	0.8	0.0
6	*	0.0	0.0	0.0	0.0	0.0	-79.5	46.9	1.7	7.5	2.9	1.5	2.2	0.7	0.7	0.0
7	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	8.0	0.2	1.3	2.1	0.5	0.6	0.0
8	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.7	10.3	0.1	1.3	1.9	0.4	0.6	0.0
9	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	1.8	0.1	0.6	0.0
10	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	1.7	0.0	0.8	0.0
11	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	1.8	0.4	0.9	0.0

TIDAL HEIGHT AT HOUR 248.40

TRANSECT

2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
340.9	318.5	298.2	280.3	265.5	251.0	232.6	218.5	205.5	198.7	191.6	186.4	182.1	178.9	176.7	173.6	170.9	168.9	168.1	168.0

TRANSECT

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
	168.5	170.4	172.3	174.2	175.7	176.9	178.1	178.8	179.9	180.8	181.8	182.9	183.9	185.0	186.3

VERT. VEL. AT HOUR 248.40(IN 0.001CM)

LAYER	TRANSECT 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	-0.3	0.6	-3.3	-5.2	-9.0	-8.4	-7.9	-9.3	-7.7	-2.6	-5.9	-8.7	-17.8	6.8	-6.8	-18.3	0.5	-1.8	1.6	1.0
2	-3.6	5.2	-0.4	-2.8	-7.2	-15.6	-4.1	-7.3	-3.1	2.6	4.8	-10.5	-23.6	12.8	-7.9	-22.1	5.6	0.9	7.0	5.6
3	0.0	0.0	0.0	0.0	0.0	-44.0	2.4	-6.4	0.8	7.8	8.0	-17.9	-21.1	13.1	-13.7	-24.4	13.2	4.0	8.0	7.4
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-22.4	12.5	-19.6	-25.1	22.4	4.6	16.8	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-27.2	30.5	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LAYER	TRANSECT 22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	0.8	0.4	0.4	0.2	1.6	1.3	1.9	5.2	-3.1	-0.3	15.9	0.2	1.5	2.1	-1.1
2	1.7	0.3	0.2	-0.2	2.0	1.7	1.8	8.4	-5.3	-1.4	21.1	-1.0	1.5	1.6	-2.4
3	1.5	-0.5	-0.5	-1.2	4.5	4.2	2.6	16.7	-8.4	-2.6	28.2	-2.8	1.8	-0.3	-6.6
4	0.0	0.0	-7.7	-2.2	6.7	6.5	2.1	32.3	-12.7	-3.5	34.4	-5.4	2.5	-3.3	-10.7
5	0.0	0.0	0.0	0.0	0.0	9.7	0.4	38.8	-16.5	-3.1	38.5	-10.2	4.1	-7.1	-17.6
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	34.1	-19.1	-1.5	43.0	-23.9	5.1	-9.9	-35.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.8	-19.7	0.8	44.0	-44.5	4.9	-13.2	-66.4
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	43.8	-46.2	5.0	-20.9	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40.6	-43.0	6.1	-15.6	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.5	-34.5	8.4	-11.3	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

HORZ. VEL. AT HOUR 248.40

LAYER	TRANSECT 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	180.0	174.6	166.8	160.1	147.6	146.0	150.4	136.9	132.8	123.8	118.0	107.0	103.8	107.4	87.8	89.4	88.4	88.5	87.4	71.4
2	180.0	152.8	139.7	132.3	122.5	129.9	122.5	113.3	111.0	108.2	103.3	89.1	88.3	94.0	71.8	75.4	76.5	75.4	74.1	58.8
3	180.0	190.5	175.2	164.8	147.7	158.3	108.3	97.4	96.3	97.5	90.7	73.9	79.0	83.7	61.0	67.1	69.9	67.5	65.1	51.2
4	0.0	0.0	0.0	0.0	0.0	0.0	140.7	124.7	123.6	113.9	106.2	81.5	92.2	73.6	51.6	63.1	66.1	62.5	53.7	61.2
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	84.7	63.0	79.5	65.4	65.8	69.3	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	87.3	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LAYER	TRANSECT 22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	60.9	53.6	43.0	33.9	22.9	21.6	20.6	19.6	24.1	18.9	19.9	28.3	20.8	19.3	18.4
2	47.8	40.1	31.2	23.3	15.8	13.4	12.4	9.7	14.3	10.7	10.4	15.9	10.3	9.8	7.8
3	38.5	30.7	24.1	17.0	11.5	8.3	7.1	3.3	7.8	5.3	4.7	8.3	3.3	3.1	-2.5
4	46.9	36.5	28.4	13.0	8.5	2.0	0.3	-5.1	-3.4	-1.5	-1.6	-2.4	-6.7	-6.2	-15.6
5	0.0	0.0	0.0	18.0	15.3	-7.5	-9.8	-12.2	-18.9	-9.9	-7.2	-14.4	-15.7	-13.7	-23.7
6	0.0	0.0	0.0	0.0	0.0	0.0	-24.7	-13.1	-29.8	-15.3	-8.8	-21.9	-20.3	-18.8	-29.9
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-41.8	-17.3	-8.1	-31.0	-24.5	-22.3	-39.2
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-85.9	-6.4	-6.7	-42.8	-29.4	-24.9	-64.4
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-53.5	-32.9	-25.7	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-67.7	-31.0	-27.1	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-120.8	-13.4	-41.5	0.0

SIMULATION NO. 10

(End of the thirty-fifth tidal cycle)

10-year, 7-day Drought Flow

13 cm Sea Level Rise

1SALINITY AT HOUR 434.70

LAYER	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	0.0	0.0	0.0	-0.2	-0.1	-0.4	0.2	0.4
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.3	0.1	0.4
3	30.0	30.0	30.0	30.0	30.0	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.3	0.1	0.4
4	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	0.0	0.0	0.0	-0.1	-0.1	-0.3	0.0	30.0
5	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	-0.1	-0.1	30.0	30.0	30.0
6	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
7	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
8	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
9	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
10	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	1.3	-0.6	2.0	1.7	3.2	4.6	6.6	8.3	9.0	10.4	9.8	10.8	11.9	12.1	14.1
2	1.3	-0.5	2.0	1.7	3.3	4.9	6.9	8.7	9.5	10.5	11.3	11.9	12.4	13.2	14.8
3	1.3	-0.5	1.9	6.7	4.1	6.2	7.4	9.0	9.9	10.7	11.5	12.1	12.8	13.5	15.1
4	30.0	30.0	1.8	7.3	14.7	10.6	8.5	9.7	10.4	10.9	11.8	12.3	13.0	13.7	15.3
5	30.0	30.0	30.0	30.0	30.0	10.2	13.6	11.1	11.0	11.1	12.1	12.5	13.2	13.9	15.5
6	30.0	30.0	30.0	30.0	30.0	30.0	30.0	11.1	11.8	11.4	12.4	12.9	13.3	14.0	15.6
7	30.0	30.0	30.0	30.0	30.0	30.0	30.0	13.9	12.5	13.9	13.0	13.1	13.4	14.1	15.8
8	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	13.1	13.4	13.6	14.1	30.0
9	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	13.8	13.6	13.9	14.4	30.0
10	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	13.8	13.7	14.1	14.5	30.0

SED. CON. AT HOUR 434.70

LAYER	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	1.0	11.9	-0.8	0.1	-4.7	-2.2	-256.3	-57.1	******	2923.9	******	******	2340.3	88.1	-13.5	7.3	4.3	-1.5	-23.0	-17.7
2	1.0	11.5	-0.8	0.3	-3.8	-6.0	-210.9	-119.6	******	2936.9	******	******	1604.8	104.9	-14.7	6.0	3.5	-0.5	-19.3	-15.0
3	0.0	0.0	0.0	0.0	0.0	-11.6	-192.6	-204.6	******	3344.1	******	******	1140.3	113.6	-15.3	5.5	3.2	0.1	-17.6	-12.8
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	519.0	122.2	-16.7	5.1	3.1	0.9	-15.3	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.1	2.7	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	-17.4	11.3	3.6	-4.3	3.1	1.6	-0.3	0.0	0.4	1.1	5.2	-1.8	0.6	-0.2	0.0
2	-16.1	10.1	3.4	-4.0	3.1	1.4	-0.7	-0.1	0.2	0.4	-0.3	-0.2	0.1	-0.1	0.0
3	-14.5	8.5	3.2	-10.3	39.4	0.4	-1.3	-0.2	0.1	0.3	-0.3	-0.2	0.1	-0.1	0.0
4	0.0	0.0	0.8	-3.6	-142.2	0.0	0.6	0.0	0.1	0.2	-0.2	-0.2	0.2	-0.1	0.0
5	0.0	0.0	0.0	0.0	0.0	8.3	5.5	0.0	0.0	0.2	-0.1	-0.3	0.2	-0.1	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	0.2	0.0	-0.3	0.2	-0.1	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.9	-0.7	2.3	0.1	-0.3	0.2	-0.1	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	-0.4	0.3	-0.1	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	-0.7	0.5	-0.2	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	-1.0	1.0	-1.0	0.0

TIDAL HEIGHT AT HOUR 434.70

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	46.2	44.9	42.5	39.0	35.0	30.5	26.7	23.3	20.0	17.7	14.9	10.6	7.4	5.9	4.1	2.1	0.4	-2.0	-4.7	-8.0

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
	-10.9	-11.8	-10.9	-8.6	-6.4	-4.4	-2.6	-1.0	0.3	1.4	2.9	4.1	5.1	6.1	7.5

VERT. VEL. AT HOUR 434.70(IN 0.001CM)

LAYER		TRANSECT 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	*	-2.2	-1.6	-1.5	-1.7	-2.1	-5.4	-3.2	-3.3	-2.6	-0.9	-2.2	-3.8	-7.6	1.5	-3.4	-7.9	-0.5	-1.1	1.4	1.7
2	*	0.0	0.0	0.0	0.0	0.0	-6.7	-0.1	-1.7	-1.1	1.7	1.2	-6.5	-7.8	2.8	-5.9	-9.5	3.3	1.2	4.3	3.5
3	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-6.1	2.8	-8.0	-9.5	7.6	3.0	5.8	0.0
4	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-7.8	8.7	0.0	0.0	0.0
5	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LAYER		TRANSECT 22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	*	0.5	1.5	1.4	2.7	2.6	4.7	4.0	3.7	4.1	2.1	8.8	2.6	2.6	-0.3	-2.3
2	*	0.2	0.3	0.9	2.0	3.5	5.5	5.0	5.8	5.1	3.0	8.3	2.8	3.7	-3.7	-6.9
3	*	0.0	0.0	-0.7	1.5	1.7	6.2	6.8	9.3	6.3	4.0	6.5	2.9	4.7	-7.0	-9.0
4	*	0.0	0.0	0.0	0.0	0.0	6.3	4.0	11.7	5.5	3.6	6.0	3.1	5.8	-11.4	-14.2
5	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.6	2.9	3.9	9.4	3.3	5.9	-14.3	-25.2
6	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.6	2.7	3.3	12.7	3.4	4.7	-16.4	-39.6
7	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.1	2.8	3.2	-18.1	0.0
8	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.9	1.9	1.4	-11.8	0.0
9	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	1.0	-0.1	-5.9	0.0
10	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

HORZ. VEL. AT HOUR 434.70

LAYER		TRANSECT 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	*	0.7	6.2	12.2	17.5	21.4	27.1	26.8	30.1	35.1	35.8	37.9	40.9	40.0	37.9	33.3	34.0	31.8	35.4	37.6	36.6
2	*	0.7	7.0	12.4	16.5	19.4	24.7	25.3	27.3	30.8	32.8	34.0	35.4	36.0	34.2	29.7	32.3	31.6	34.3	35.4	34.5
3	*	0.0	0.0	0.0	0.0	0.0	0.0	21.4	20.9	22.9	26.3	25.3	24.7	31.8	30.0	26.0	30.8	31.3	32.5	31.7	30.7
4	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.0	20.7	29.7	30.4	27.7	23.8	0.0
5	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.9	0.0	0.0	0.0
6	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LAYER		TRANSECT 22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	*	35.6	31.1	22.1	11.7	2.5	-2.9	-6.3	-7.1	-6.6	-5.7	-10.9	-11.1	-10.3	-12.0	-19.1
2	*	30.6	26.5	17.3	9.0	-0.7	-6.5	-11.2	-12.8	-10.8	-11.8	-13.4	-16.2	-15.1	-15.0	-24.4
3	*	24.5	21.8	14.3	6.4	-0.3	-9.2	-14.1	-15.8	-13.1	-15.0	-16.3	-18.8	-18.0	-18.0	-27.9
4	*	0.0	0.0	0.0	1.5	-2.9	-6.8	-13.1	-19.8	-15.5	-17.9	-19.5	-20.1	-19.7	-20.3	-29.9
5	*	0.0	0.0	0.0	0.0	0.0	0.0	-16.0	-17.0	-17.4	-19.5	-21.6	-21.0	-20.9	-22.3	-31.0
6	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-18.1	-19.3	-23.0	-23.2	-22.7	-24.0	-32.6
7	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-17.4	-20.0	-22.9	-26.4	-25.2	-25.4	-36.2
8	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-27.8	-27.1	-26.0	0.0
9	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-27.7	-27.2	-25.7	0.0
10	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-23.1	-23.2	-21.7	0.0

SIMULATION NO. 11

(End of the tenth tidal cycle)

Ten Percent Joint Probability of Exceedence

1580 cfs (44.7 m^3/s) Inflow

61 cm Tidal Height

1SALINITY AT HOUR 124.20

TRANSECT

LAYER	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
3	30.0	30.0	30.0	30.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
4	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0
5	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	0.0	0.0	30.0	30.0	30.0
6	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
7	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
8	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
9	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
10	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0

TRANSECT

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	0.2	-0.1	0.5	0.5	1.8	3.3	5.1	6.7	7.9	9.3	9.5	11.0	11.9	12.7	14.1
2	0.2	-0.1	0.5	0.5	1.9	3.6	5.4	7.3	8.4	9.6	10.3	11.6	12.4	13.2	14.7
3	0.2	-0.1	0.5	1.4	2.4	4.9	6.2	7.8	8.9	9.9	10.9	12.0	12.8	13.7	15.1
4	30.0	30.0	0.2	2.0	4.4	6.2	7.8	8.9	9.7	10.4	11.6	12.3	13.2	13.9	15.3
5	30.0	30.0	30.0	30.0	30.0	6.5	11.2	10.6	10.5	10.8	12.1	12.7	13.4	14.1	15.5
6	30.0	30.0	30.0	30.0	30.0	30.0	30.0	10.6	12.8	11.8	12.5	13.2	13.6	14.2	15.6
7	30.0	30.0	30.0	30.0	30.0	30.0	30.0	15.0	13.1	14.6	13.4	13.6	13.8	14.4	15.8
8	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	13.5	13.9	14.1	14.4	30.0
9	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	15.9	14.4	14.5	14.6	30.0
10	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	16.3	14.5	15.0	15.0	30.0

SED. CON. AT HOUR 124.20

TRANSECT

LAYER	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	30.0	29.8	28.3	29.4	27.9	29.1	25.4	25.9	17.4	19.6	8.5	7.6	9.9	11.2	13.2	9.5	7.8	6.8	4.7	2.9
2	30.0	35.0	34.9	36.3	33.8	32.3	28.8	29.1	19.2	21.3	9.4	8.1	10.6	12.2	14.3	10.6	8.8	7.6	5.2	3.1
3	0.0	0.0	0.0	0.0	0.0	38.0	33.4	33.3	21.4	23.3	10.4	8.5	11.1	12.8	15.2	11.2	9.4	8.0	5.5	3.4
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.8	14.3	17.3	11.9	10.0	8.9	6.3	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.5	12.3	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TRANSECT

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	3.4	2.4	6.5	6.9	6.5	5.0	4.6	3.1	2.8	2.3	1.2	1.0	0.8	0.6	0.3
2	3.5	2.7	6.6	7.6	7.1	6.3	6.0	4.1	3.7	2.6	1.5	1.5	1.0	0.6	0.3
3	3.8	3.2	5.7	24.6	12.2	10.9	8.0	4.7	4.2	2.7	1.5	1.7	1.1	0.6	0.2
4	0.0	0.0	-0.8	54.0	24.4	16.0	8.1	5.2	4.6	2.5	1.4	1.8	1.0	0.6	0.2
5	0.0	0.0	0.0	0.0	0.0	16.0	20.1	2.9	4.5	2.3	1.2	2.0	0.9	0.5	0.1
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	5.7	1.1	1.0	1.9	0.8	0.5	0.1
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.9	7.4	7.8	-0.3	1.7	0.8	0.5	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	1.4	0.7	0.4	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.7	1.6	0.8	0.5	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.9	2.3	1.6	-0.5	0.0

TIDAL HEIGHT AT HOUR 124.20

TRANSECT

2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
89.7	88.5	85.2	81.2	77.6	72.9	68.9	64.9	61.1	58.1	53.8	49.0	45.2	43.1	40.2	36.8	34.2	31.2	28.2	24.8

TRANSECT

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
	21.2	18.3	16.9	16.9	17.6	18.6	19.9	21.1	22.2	23.2	24.7	25.8	27.0	28.2	29.8

VERT. VEL. AT HOUR 124.20(IN 0.001CM)

LAYER	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1 *	1.3	-0.4	-1.0	-1.2	-1.9	-6.2	-3.7	-3.8	-2.4	-2.0	-1.8	-4.8	-10.0	2.5	-3.2	-7.7	1.1	-1.1	1.6	1.0
2 *	0.0	0.0	0.0	0.0	0.0	-6.9	-0.3	-1.9	-1.1	1.4	1.6	-7.7	-9.8	3.7	-6.2	-9.9	5.0	1.0	4.7	3.1
3 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-7.4	3.5	-8.7	-10.4	9.2	2.9	6.0	0.0
4 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-8.7	9.8	0.0	0.0	0.0
5 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TRANSECT

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1 *	-0.3	-0.2	-0.5	0.9	1.0	1.9	2.1	1.9	2.6	1.0	7.9	1.6	2.0	0.3	-0.9
2 *	-0.1	-1.0	-2.2	0.6	1.5	2.8	3.0	3.1	3.5	1.3	8.1	1.6	2.1	-2.0	-3.9
3 *	0.0	0.0	-7.0	0.6	1.8	3.0	3.5	5.5	4.8	2.1	7.2	1.9	2.4	-4.4	-5.9
4 *	0.0	0.0	0.0	0.0	0.0	4.3	1.5	7.1	4.7	2.3	6.2	2.4	3.1	-7.8	-9.9
5 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.2	2.4	2.8	7.9	3.2	3.4	-10.4	-18.6
6 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4	1.9	2.5	9.9	4.4	2.8	-12.5	-30.5
7 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.3	4.5	2.0	-14.4	0.0
8 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.7	4.2	0.8	-9.8	0.0
9 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	2.4	-0.3	-5.1	0.0
10 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

HORZ. VEL. AT HOUR 124.20

TRANSECT

LAYER	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1 *	19.5	21.6	22.7	24.6	25.1	28.8	30.2	33.7	39.6	39.2	43.5	46.3	47.1	45.4	39.0	38.9	34.7	37.1	38.1	38.4
2 *	19.5	15.8	17.3	19.4	20.1	24.5	27.2	29.7	33.9	35.3	38.9	39.1	41.5	40.9	34.6	36.3	34.1	35.0	35.8	34.9
3 *	0.0	0.0	0.0	0.0	0.0	0.0	22.2	22.4	25.0	28.1	29.2	26.9	36.4	36.1	30.5	34.6	33.9	32.9	32.4	30.3
4 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.1	24.7	33.5	33.2	28.0	24.7	0.0
5 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.0	0.0	0.0	0.0
6 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TRANSECT

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1 *	38.3	37.3	31.2	22.6	14.8	11.2	8.1	6.1	5.4	6.2	4.1	4.4	1.9	0.2	-4.4
2 *	32.8	31.2	25.5	18.4	11.1	7.3	3.7	0.7	0.5	0.2	0.0	-2.5	-3.0	-4.0	-10.2
3 *	26.5	25.5	22.8	16.7	9.3	4.5	0.3	-4.2	-3.4	-4.5	-3.9	-7.9	-7.2	-7.8	-14.6
4 *	0.0	0.0	0.0	16.3	7.5	0.3	-2.0	-7.7	-6.3	-8.8	-8.4	-11.9	-11.0	-11.0	-18.1
5 *	0.0	0.0	0.0	0.0	0.0	0.0	-11.0	-8.7	-7.9	-12.0	-12.6	-14.7	-13.9	-13.8	-20.9
6 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-11.4	-13.5	-16.0	-17.7	-16.7	-16.2	-23.8
7 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-13.7	-15.0	-17.4	-20.8	-19.4	-18.3	-28.1
8 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-22.2	-21.6	-19.8	0.0
9 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-20.7	-23.2	-21.1	0.0
10 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-16.2	-20.9	-18.9	0.0

SIMULATION NO. 12

(End of the tenth tidal cycle)

Ten Percent Joint Probability of Exceedence

5540 cfs (157 m^3/s) Inflow

49 cm Tidal Height

1SALINITY AT HOUR 124.20

LAYER	TRANSECT 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	-0.1	0.1	-0.1
2 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	-0.1	0.1	-0.1
3 *	30.0	30.0	30.0	30.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.1	-0.1
4 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.1	30.0
5 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	0.0	0.0	30.0	30.0	30.0
6 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
7 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
8 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
9 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
10 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0

LAYER	TRANSECT 22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1 *	0.2	-0.2	0.2	-0.1	0.4	1.6	3.5	5.4	6.8	8.3	8.7	10.2	11.2	11.8	13.4
2 *	0.2	-0.2	0.2	-0.1	0.4	1.9	3.9	6.0	7.3	8.7	9.4	10.9	11.7	12.6	14.3
3 *	0.2	-0.2	0.2	0.2	1.0	3.4	4.8	6.6	7.9	9.0	10.1	11.3	12.2	13.1	14.8
4 *	30.0	30.0	0.1	0.3	2.7	4.9	6.7	7.9	8.7	9.5	10.8	11.6	12.6	13.4	15.1
5 *	30.0	30.0	30.0	30.0	30.0	5.1	10.4	9.8	9.7	10.0	11.3	12.0	12.9	13.6	15.4
6 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	9.9	12.3	11.2	11.8	12.6	13.1	13.8	15.6
7 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	14.8	12.6	14.2	12.8	13.1	13.3	14.0	15.8
8 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	13.0	13.5	13.6	14.1	30.0
9 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	15.7	14.0	14.1	14.3	30.0
10 *	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	16.2	14.2	14.6	14.7	30.0

SED. CON. AT HOUR 124.20

LAYER	TRANSECT 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1 *	40.0	43.3	40.1	43.8	40.0	43.3	38.1	41.9	35.3	40.3	31.6	30.0	28.1	26.0	26.8	22.3	19.7	17.5	14.2	9.1
2 *	40.0	45.2	42.1	46.3	42.3	45.4	40.6	45.3	38.4	43.7	35.3	31.7	29.7	27.8	28.5	24.3	21.7	18.9	15.6	9.8
3 *	0.0	0.0	0.0	0.0	0.0	50.8	44.6	50.7	43.1	48.5	39.3	33.7	30.9	29.1	29.9	25.3	22.9	19.8	16.5	10.7
4 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.9	32.4	33.1	26.5	24.4	21.5	20.7	0.0
5 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.3	29.6	0.0	0.0	0.0
6 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LAYER	TRANSECT 22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1 *	7.8	4.9	5.7	6.0	9.8	7.5	6.8	4.9	4.2	3.6	2.0	1.7	1.3	0.9	0.6
2 *	8.2	5.2	5.3	6.5	10.5	9.5	8.9	6.5	5.5	4.2	2.5	2.3	1.7	1.1	0.5
3 *	8.8	5.7	3.4	29.2	24.8	16.6	11.9	7.4	6.3	4.3	2.6	2.6	1.8	1.0	0.4
4 *	0.0	0.0	-9.8	71.5	65.3	24.0	12.5	8.2	6.9	4.1	2.5	2.8	1.8	1.0	0.3
5 *	0.0	0.0	0.0	0.0	0.0	21.5	28.5	4.9	6.8	3.8	2.3	3.0	1.7	0.9	0.2
6 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	8.6	2.2	2.0	2.8	1.6	0.8	0.1
7 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.1	11.0	10.2	0.6	2.5	1.5	0.8	0.1
8 *	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.9	1.5	0.7	0.0

TIDAL HEIGHT AT HOUR 124.20

TRANSECT 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
123.6	113.9	103.3	92.9	83.9	75.2	68.7	62.8	56.9	52.7	48.1	42.6	38.2	36.1	33.5	30.6	28.2	25.2	21.9	17.5

LAYER	TRANSECT 22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
	12.6	8.4	5.9	5.4	5.9	6.8	8.0	9.1	10.1	11.1	12.4	13.6	14.8	16.0	17.6

VERT. VEL. AT HOUR 124.20(IN 0.001CM)

TRANSECT

LAYER	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	6.7	1.3	-0.2	-1.1	-2.3	-7.3	-2.7	-3.7	-2.9	-0.8	-1.9	-4.8	-9.7	2.6	-3.9	-10.0	0.4	-1.4	2.1	1.4
2	0.0	0.0	0.0	0.0	0.0	-9.6	0.4	-2.0	-1.3	2.2	1.8	-8.2	-9.7	3.8	-6.9	-11.8	4.8	1.2	5.5	3.6
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-7.4	3.4	-9.5	-11.8	9.7	3.4	6.9	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-9.4	10.6	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TRANSECT

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	-0.3	-0.3	-0.8	0.5	0.9	1.9	2.0	1.9	2.4	1.1	7.9	1.7	1.7	0.9	-0.6
2	-0.1	-1.2	-3.0	-0.3	1.3	2.9	3.0	3.2	3.1	1.3	8.4	1.6	1.7	-1.1	-3.5
3	0.0	0.0	-8.8	-0.3	1.7	3.0	3.6	5.7	4.4	2.1	7.6	1.9	2.1	-3.7	-5.6
4	0.0	0.0	0.0	0.0	0.0	3.8	1.4	7.2	4.3	2.3	6.8	2.4	2.9	-7.2	-10.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.2	2.1	2.8	8.4	3.3	3.4	-10.1	-19.4
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4	1.7	2.5	10.3	4.6	2.9	-12.6	-32.1
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.5	4.7	2.2	-14.9	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.8	4.5	1.0	-10.3	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	2.6	-0.2	-5.4	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

HORZ. VEL. AT HOUR 124.20

TRANSECT

LAYER	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	68.2	70.3	64.4	60.2	54.5	54.8	50.6	48.7	51.5	50.3	51.1	52.4	51.4	49.5	42.1	42.5	39.7	43.6	45.3	44.6
2	68.2	48.9	45.1	42.7	39.4	43.5	42.2	39.8	42.3	43.8	44.4	43.9	45.1	43.5	36.6	39.3	38.8	40.9	42.1	40.4
3	0.0	0.0	0.0	0.0	0.0	0.0	30.8	28.0	29.9	33.8	32.3	30.0	39.2	37.6	31.7	37.1	38.3	38.2	37.7	35.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.0	24.8	35.5	37.1	32.2	28.3	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.2	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TRANSECT

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	43.2	41.5	34.7	25.2	16.4	12.7	9.8	7.5	7.0	7.4	5.6	5.8	3.1	0.7	-2.9
2	37.2	35.1	28.9	21.1	13.4	9.3	5.4	2.1	1.8	1.4	1.3	-1.0	-1.9	-2.9	-8.9
3	30.2	29.0	26.2	19.7	12.7	7.3	2.0	-2.8	-2.5	-3.3	-2.8	-6.7	-6.3	-6.5	-14.0
4	0.0	0.0	0.0	20.7	11.9	3.7	-0.1	-6.5	-5.8	-7.9	-7.6	-11.3	-10.5	-10.0	-18.2
5	0.0	0.0	0.0	0.0	0.0	0.0	-9.6	-7.9	-7.6	-11.3	-12.1	-14.4	-13.8	-13.1	-21.5
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-11.3	-13.0	-15.6	-17.7	-16.8	-15.9	-25.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-13.7	-14.6	-16.9	-21.3	-19.8	-18.3	-29.8
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-22.8	-22.1	-20.3	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-21.0	-23.8	-22.1	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-16.1	-21.3	-19.6	0.0

SIMULATION NO. 13

(End of the tenth tidal cycle)

Ten Percent Joint Probability of Exceedence

9270 cfs (262 m^3/s) Inflow

26 cm Tidal Height

1SALINITY AT HOUR 124.20

LAYER		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	*	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.1	-0.1	0.1	-0.1	0.1	-0.1	0.1	-0.1
2	*	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.1	-0.1	0.1	-0.1	0.1	-0.1	0.1	-0.1
3	*	30.0	30.0	30.0	30.0	30.0	-0.1	0.0	-0.1	0.0	-0.1	0.0	-0.1	0.1	-0.1	0.1	-0.1	0.1	-0.1	0.1	-0.1
4	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	0.1	-0.1	0.1	-0.1	0.1	-0.1	0.1	30.0
5	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	-0.2	0.1	30.0	30.0	30.0
6	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
7	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
8	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
9	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
10	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0

LAYER		22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	*	0.0	0.0	-0.1	0.2	-0.2	-0.2	1.2	3.0	4.7	6.5	7.1	8.8	10.1	10.4	12.0
2	*	0.0	0.0	-0.1	0.2	-0.2	0.0	1.7	3.8	5.5	7.0	7.9	9.6	10.7	11.6	13.5
3	*	0.0	0.0	-0.1	0.1	-0.3	1.5	2.6	4.5	6.1	7.4	8.7	10.1	11.2	12.2	14.3
4	*	30.0	30.0	-0.1	0.1	0.0	2.4	5.0	6.2	7.1	8.0	9.5	10.5	11.6	12.6	14.7
5	*	30.0	30.0	30.0	30.0	30.0	2.5	8.2	8.5	8.4	8.6	10.1	10.9	11.9	12.9	15.2
6	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	8.5	11.3	10.1	10.7	11.6	12.2	13.2	15.5
7	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	14.0	11.7	13.5	11.8	12.2	12.5	13.3	15.8
8	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	12.1	12.8	12.8	13.5	30.0
9	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	15.3	13.4	13.5	13.8	30.0
10	*	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	16.0	13.6	14.1	14.0	30.0

SED. CON. AT HOUR 124.20

LAYER		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	*	50.0	53.0	50.1	52.2	50.8	51.9	49.9	51.8	47.3	49.8	45.7	44.5	42.9	40.7	42.8	36.9	37.3	35.3	33.3	26.5
2	*	50.0	54.5	51.6	54.0	52.5	53.0	51.4	53.5	49.1	51.6	49.2	46.5	45.1	43.5	45.7	40.4	41.0	38.2	36.5	28.7
3	*	0.0	0.0	0.0	0.0	0.0	55.2	53.5	55.9	51.4	54.0	52.7	48.8	46.9	45.7	47.8	42.1	43.2	39.9	38.6	31.0
4	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	55.1	51.1	53.2	44.1	46.0	43.3	46.5	0.0
5	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.5	56.6	0.0	0.0	0.0
6	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LAYER		22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	*	24.8	18.2	19.1	8.6	12.0	10.9	10.5	7.8	6.3	5.6	3.2	2.6	2.0	1.5	1.1
2	*	26.4	19.2	20.5	8.2	13.2	14.4	14.7	11.0	8.5	6.7	4.3	3.9	3.0	2.1	1.1
3	*	28.2	20.3	21.7	6.1	12.4	34.1	20.8	12.6	9.6	6.9	4.4	4.4	3.2	2.0	0.8
4	*	0.0	0.0	28.1	-5.4	112.7	61.1	23.9	14.0	10.4	6.7	4.3	4.6	3.2	1.9	0.6
5	*	0.0	0.0	0.0	0.0	0.0	56.7	34.8	10.2	10.3	6.4	4.1	4.7	3.1	1.7	0.4
6	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	13.3	4.5	3.8	4.4	2.9	1.6	0.2
7	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	44.6	16.8	13.7	2.4	3.7	2.8	1.4	0.1
8	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	2.9	2.9	1.3	0.0
9	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.2	4.1	3.1	1.2	0.0
10	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.9	6.6	5.0	-1.6	0.0

TIDAL HEIGHT AT HOUR 124.20

TRANSECT	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	199.7	177.4	152.5	127.5	105.8	84.8	70.4	59.7	50.1	44.0	37.3	30.2	24.8	22.4	19.1	15.8	13.5	10.2	6.7	1.7

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
	-4.6	-10.8	-14.8	-16.4	-16.3	-15.5	-14.4	-13.4	-12.5	-11.6	-10.4	-9.3	-8.1	-6.9	-5.3

VERT. VEL. AT HOUR 124.20(IN 0.001CM)

LAYER	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	12.7	1.8	-0.7	-2.0	-3.9	-11.6	-1.7	-2.9	-2.5	0.1	-0.6	-4.8	-9.9	2.8	-4.0	-9.4	0.3	-1.8	1.8	1.0
2	0.0	0.0	0.0	0.0	0.0	-15.4	1.5	-1.9	-1.2	3.1	2.4	-8.8	-10.2	4.0	-7.4	-11.6	4.9	1.1	5.5	3.6
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-7.9	3.7	-10.3	-11.8	9.9	3.5	7.2	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-9.6	10.7	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TRANSECT

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	-0.6	-0.8	-1.1	-0.3	0.3	1.7	2.1	2.1	2.1	1.3	7.6	1.8	1.3	1.5	-0.2
2	-0.3	-1.8	-3.7	-1.8	0.3	2.7	3.1	3.5	2.7	1.4	8.4	1.7	1.3	-0.3	-2.8
3	0.0	0.0	-10.6	-2.3	0.9	2.1	3.6	6.4	3.9	2.3	8.1	1.9	1.7	-3.0	-5.2
4	0.0	0.0	0.0	0.0	0.0	1.8	1.3	7.4	3.9	2.5	7.5	2.5	2.7	-6.8	-10.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	1.9	2.9	9.1	3.4	3.4	-10.1	-20.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4	1.5	2.4	11.0	4.7	3.1	-13.0	-33.7
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.0	4.9	2.5	-15.7	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.1	4.7	1.3	-10.9	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	2.8	-0.1	-5.7	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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TRANSECT

LAYER	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	114.1	118.8	109.8	103.6	93.7	92.9	84.6	75.5	72.3	66.8	64.7	60.2	56.8	53.8	45.5	45.2	41.3	45.0	47.4	47.2
2	114.1	77.5	72.2	69.7	65.0	72.0	69.3	60.1	58.1	57.2	55.1	50.4	49.9	47.1	39.6	42.1	40.4	42.6	44.2	43.2
3	0.0	0.0	0.0	0.0	0.0	0.0	49.2	40.9	39.9	42.9	39.4	34.5	43.3	40.5	34.1	39.8	39.8	39.8	39.6	37.6
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.8	26.5	38.1	38.4	33.5	29.6	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.7	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TRANSECT

LAYER	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	47.0	46.4	39.8	29.7	19.3	14.8	11.6	9.1	9.0	9.0	7.9	8.0	5.2	1.8	-0.8
2	41.1	39.9	34.2	25.3	16.9	12.7	8.3	4.2	3.6	3.1	3.2	1.4	0.1	-0.7	-6.5
3	33.8	33.3	31.6	24.2	17.5	13.1	5.8	-0.3	-0.9	-1.7	-1.0	-4.7	-4.6	-4.4	-12.3
4	0.0	0.0	0.0	24.9	19.3	11.1	5.1	-2.9	-4.7	-6.5	-6.3	-10.0	-9.4	-8.3	-17.4
5	0.0	0.0	0.0	0.0	0.0	0.0	-4.6	-5.1	-6.5	-10.2	-11.3	-13.8	-13.3	-12.1	-21.6
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-10.8	-12.0	-15.1	-17.7	-16.8	-15.5	-25.8
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-13.6	-14.0	-16.4	-21.8	-20.2	-18.5	-31.5
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-23.8	-22.8	-21.1	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-22.0	-24.8	-23.6	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-16.3	-22.1	-20.7	0.0

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