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The model documentation is presented as a series of four programs of increasing complexity. The conservative transport model can be used to route a single conservative substance, such as dye, through a reach of a river. The simplified temperature model predicts water temperature in rivers using only equilibrium temperature and windspeed as meteorological input. The complete temperature model is highly accurate but requires rather complete meteorological data. Finally, the 10-parameter model can be used to route as many as 10 interacting constituents through a river reach. An example problem is solved for a three-parameter system involving temperature, dissolved oxygen, and biochemical oxygen demand.

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USING A LAGRANGIAN REFERENCE FRAME

By Harvey E. Jobson

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CONVERSION FACTORS

For use of those readers who may prefer to use inch-pound units rather than metric units, the conversion factors for the terms used in this report are listed below:

Multiply SI units	By	To obtain inch-pound units
meter (m)	3.281	foot (ft)
gram (g)	0.002205	pound (lb)
calorie (cal)	0.003968	British thermal unit (BTU)
meter per second (m/s)	3.281	foot per second (ft/s)
centimeter per day (cm/d)	0.03281	foot per day (ft/d)
square centimeter per hour (cm^2/h)	0.001076	square foot per hour (ft^2/h)
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)
gram per cubic centimeter (g/cm^3)	1.942	slug per cubic foot (s/ft^3)
kilopascal per degree Celsius (kPa/°C)	0.00806	pound per square inch per degree Fahrenheit [$lb/(in^2$ °F)]
centimeter per day per kilopascal [cm/(d kPa)]	2.26	foot per day per pound per square inch [$ft/(d\ lb/in^2)$]
calorie per square centimeter per hour [$cal/(cm^2h)$]	3.69	British thermal unit per square foot per hour [$BTU/(ft^2h)$]
calorie per square centimeter per degree Celsius [$cal/(cm^2$°C)]	2.05	British thermal unit per square foot per degree Fahrenheit [$BTU/(ft^2$°F)]
calorie per square centimeter per day per Kelvin [$cal/(cm^2dK)$]	2.05	British thermal unit per square foot per day per degree Rankine [$BTU/(ft^2d$°R)]
calorie per gram per degree Celsius [cal/(g°C)]	1.00	British thermal unit per pound per degree Fahrenheit [BTU/(lb°F)]
calorie per cubic centimeter per degree Celsius [$cal/(cm^3$°C)]	62.4	British thermal unit per cubic foot per degree Fahrenheit [$BTU/(ft^3$°F)]

LIST OF SYMBOLS

A = cross-sectional area of the river

ALØN = longitude

BED(I) = heat flux to the water from the bed at grid I

BOD = concentration of BOD

BW(I) = bank width at grid I

C = cross-sectional average concentration or concentration of a fluid parcel

c = concentration at a point in the cross section

C° = concentration of a parcel at time zero

cp = specific heat of water

CR(L,M) = reference concentration of constituent L in mass balance equation for constituent M

CV = heat storage capacity of the bed material

DBT(K,I) = change in water temperature which occurred at time $k\Delta t$ and grid I

DF(K) = change in concentration (or temperature) of parcel K due to dispersion in a single time step

D_f = dispersion factor; $D_f = D_x/U^2\Delta t$

DIF = thermal diffusivity of the bed material

DO = dissolved oxygen concentration

DQ(K) = apparent flow rate from parcel K to parcel K+1 due to velocity gradients in the cross section

DQQ = DQ/Q = D_f = dispersion factor

DT, Δt = time step size in hours

DTM = part of time step for which total decay reaction is small

D_x = longitudinal dispersion coefficient

DX(I) = distance between grid I and I+1

E = evaporation in depth per unit time

EA, e_a = vapor pressure of the air

e_o = saturation vapor pressure of air at a temperature equal to that of the water surface

EBH(I) = effective barrier height at grid I

FLØW(1,I)	=	velocity at grid I
FLØW(2,I)	=	cross-sectional area at grid I
FLØW(3,I)	=	river top width at grid I
FLØW(4,I)	=	tributary inflow at grid I
H	=	net addition of thermal energy to the water per unit time and surface area
H_B	=	heat flux caused by longwave radiation emitted by the water
H_C	=	heat flux conducted from the water to the air as sensible heat
H_e	=	heat utilized by evaporation
HL	=	incoming atmospheric radiation
H_N	=	net heat flux caused by incoming radiation from the sun and the sky
HS	=	incoming solar radiation
IGØ	=	interior Eulerian grid number for which output is computed
J	=	index for time step number
JDAT	=	Julian date
JTS	=	number of time steps from midnight to time zero in the model
K	=	index for fluid parcel number, or surface exchange coefficient
KØ	=	parcel number at the beginning of the time step, before renumbering
KPG(N,M)	=	parcel number of the Nth fluid parcel which passed tributary M during the current time step
L	=	latent heat of vaporization, or index for constituent number
MX	=	subreach in which the centroid of a fluid parcel is located
N	=	mass-transfer coefficient
NPT(I)	=	number of fluid parcels to pass grid point I during the time step
NS	=	total number of parcels in the system
NXSEC	=	total number of Eulerian grids

PDC(K) = total change in concentration (temperature) of fluid parcel due to a specified decay process

PDFU, PDF(K) = total change in concentration of first parcel or parcel K due to dispersion

PDT = time required for a parcel to traverse the distance to the next Eulerian grid

PDX = part of subreach remaining to be traversed

PHI = latitude

PHU, PH(K) = time first parcel or parcel K entered the system

PTU, PT(K) = concentration (or temperature) of first parcel or parcel K

PTIU, PTI(K) = initial concentration (temperature) of first parcel or parcel K

PTRU, PTR(K) = change in concentration (temperature) of first parcel or parcel K due to tributary inflow

PVU, PV(K) = volume of first parcel or parcel K

PXU, PX(K) = location of first parcel, or parcel K, in grid units

Q = discharge

RDT = part of time step Δt remaining

RFØ = response of the bed to a unit change in water temperature

RS = portion of the incoming solar radiation absorbed by the water

S_A = altitude of the sun in degrees

S_L = source term for constituent L

T = temperature of the water

t = time

T_a, TA = air temperature

TRIB(N) = concentration (temperature) of tributary N

TUP = new concentration at upstream boundary

TZM = meridian of the time zone

U = mean flow velocity

u = local flow velocity

U(I) = velocity in subreach between grids I and I+1

U_* = shear velocity

u'	= deviation from the mean velocity
$\overline{u'c'}$	= average value of the product of the velocity and concentration deficit
V	= windspeed
$\forall$	= volume of a fluid parcel
W	= width of the river
x	= longitudinal coordinate
XK	= kinematic surface exchange coefficient
XK(L,M)	= reaction rate coefficient for the rate of change of concentration of constituent L, due to the presence of constituent M
XØLD	= present location of fluid parcel
x_o	= location of a parcel at time t_o
XP	= location of a parcel in Eulerian grids
Y	= depth
α	= constant in wind function
γ	= psychrometric constant
Δa	= area of typical element of a fluid parcel
Δt, DT	= time step size in the model, in hours
Δx	= length of a fluid parcel
ε	= emissivity of water
ξ	= Lagrangian distance coordinate
ρ	= density of water
σ	= Stefan-Boltzman constant
Φ	= cross-sectional average value of the source term
ϕ	= source term evaluated at a point
ψ	= empirical function of windspeed

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ABSTRACT

A computer program for simulating one-dimensional, unsteady temperature and solute transport in a river has been developed and documented for general use. The solution approach to the convective-diffusion equation uses a moving reference frame (Lagrangian) which greatly simplifies the mathematics of the solution procedure and dramatically reduces errors caused by numerical dispersion. The solution procedure has the further advantages, relative to conventional Eulerian solution schemes, of being easy to understand in the physical sense, of being extremely stable numerically, and of providing an accounting system which is very useful for model calibration.

The model documentation is presented as a series of four programs of increasing complexity. The conservative transport model can be used to route a single conservative substance, such as dye, through a reach of a river. The simplified temperature model is used to predict water temperature in rivers, either with or without thermal loading, when few meteorological data are available. Only equilibrium temperature and windspeed are required. It is suggested that air temperature can be used to approximate equilibrium temperature. The complete temperature model is highly accurate but requires rather complete meteorological data. Finally, the 10-parameter model can be used to route as many as 10 interacting constituents through a river reach. The mathematical description of the interaction between the constituents, which does not need to be linear, is generally up to the user to supply. An example problem is solved for a three-parameter system involving temperature, dissolved oxygen, and biochemical oxygen demand.

For simplicity, all models are developed and presented assuming steady non-uniform flow. Generalization of the models to allow unsteady flow is extremely simple, involving the addition of no more than 18 cards to the program deck. The report is concluded by describing this generalization for any of the models. Before using the models with unsteady flow, a flow model must be used to calculate and store the necessary flow data at each cross section and time step. Such a flow model is available and documented.

INTRODUCTION

The simulation of the transport of heat and pollutants in rivers and estuaries has received wide attention. Historically, the problem has been approached by applying the conservation principle in the Eulerian sense. Although an enormous amount of literature exists that describes various numerical techniques for solving the resulting so called convective-diffusion equation, all practical solution schemes are mathematically very complex and contain an undesirably large amount of numerical dispersion. In general, both the mathematical complexity and numerical dispersion are the result of attempts to accurately simulate the advective term of the equation.

If the conservation principle is applied in the Lagrangian sense, the troublesome advection term does not appear so the mathematical difficulties of numerically solving the equation are much reduced. Although straightforward, transforming the Lagrangian solution back to a fixed coordinate grid is somewhat involved. The purpose of this report is to document a rather simple one-dimensional Lagrangian transport model for general use.

The model documentation is presented as a series of programs of increasing complexity. The simpler versions are, in general, a subset of the more complex program. The simplest problem therefore could be solved by the most complex program, but it is desired that the model user have the deepest understanding of the program which he is using. In order to encourage this understanding, the modeler is not troubled by options which are not necessary to his problem. By selecting the simplest possible program capable of meeting his situation, the modeler is encouraged to modify the program to more nearly fit his particular needs. Even if one is considering the most complex problem, it would be wise to work through each of the programs in the series as a learning device.

All of these models solve the convective diffusion equation in the Lagrangian reference frame. The simplest model involves the transport of a single conservative substance, such as dye. The next step is to generalize the model to predict temperatures using only equilibrium temperature and windspeed as meteorologic inputs. The third step is to develop a complete and sophisticated temperature model, and finally, a model is presented which is capable of simulating as many as 10 interacting constituents.

Many problems can be solved by use of the steady flow assumption. For example, one is often interested in predicting concentration under the assumed 10-year low flow condition. Although it is easy to generalize the transport model to handle unsteady flow, the simulation of the unsteady velocities and areas needed as input for the unsteady model is a major modeling effort in itself. It is believed, therefore, that these models will often be used under the conditions of steady flow. For this reason, all transport models are presented in the steady flow form first. After the most sophisticated transport model has been developed for steady flow conditions, the slight generalization necessary to handle unsteady flow in upland (unidirectional) rivers is presented.

The transport model discretizes a river reach into a number of subreaches separated by grid points. A maximum of 50 grid points is allowed in the code. For steady flow applications, the only hydraulic inputs needed are the discharge at the upstream end of the reach and the cross-sectional properties (area, width, and tributary inflow) at the grid points. For unsteady-flow applications a streamflow model must be used to calculate the hydraulic properties at each grid point and time step. Land (1978) has recently documented a streamflow model that is designed to supply the needed data for unsteady flow. A flow model presented by Dawdy and others (1978) is used for the example simulation of this report.

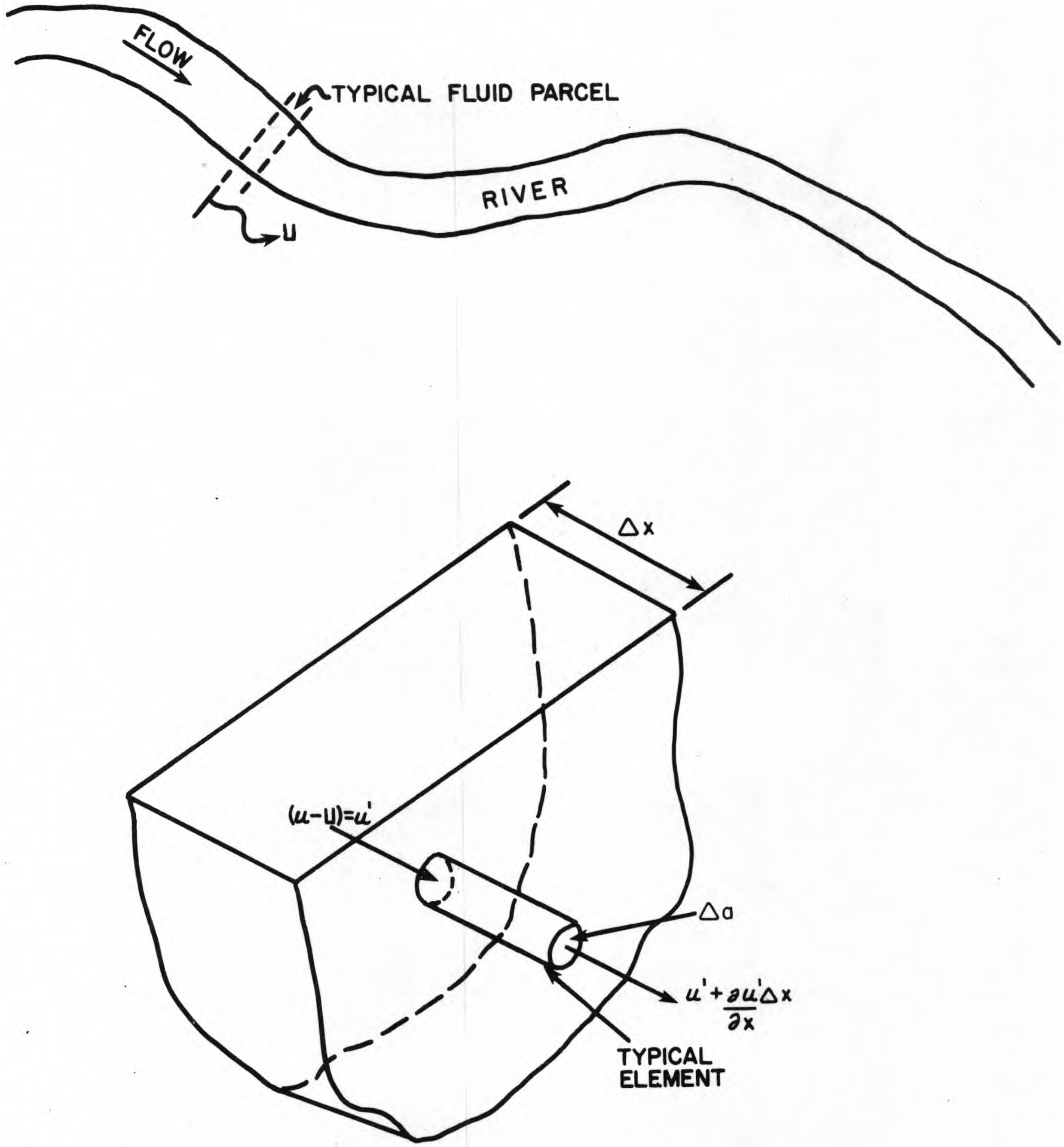
In addition to hydraulic data the transport model requires the concentration of the modeled substance at the upstream end of the reach and at each tributary for discrete time steps. Although the code is set up for equal time steps, it can be easily modified to allow unequal time steps (Barry A. Benedict, oral commun., 1980). Of course certain rate coefficients and meteorologic data are required to model specific substances.

BASIS FOR MODEL DEVELOPMENT

In the Lagrangian framework, one conceptually follows an individual fluid parcel while keeping track of all factors which act to change its concentration. A typical fluid parcel for a river is illustrated in figure 1. The parcel moves downstream with a velocity U. Because the flow velocity in the river, u, is not uniform in the cross section, one must consider an individual element of the fluid parcel in order to apply the conservation principle. Applying this principle to a typical element of the parcel, shown in figure 1, with cross-sectional area Δa and length Δx which moves downstream at a velocity U gives

$$\frac{\partial(c\ \Delta a\ \Delta x)}{\partial t} = \Delta a\ \Delta x\ \frac{\partial u'c}{\partial \xi} + \phi \Delta a\ \Delta x$$

in which c = concentration of the transported substance, t = time, $u' = (U - u)$ which is the local instantaneous velocity relative to the coordinate system which moves downstream with velocity U, ξ = Lagrangian distance coordinate, and ϕ = the production of the transportable substance per unit volume and time. The Lagrangian distance coordinate, ξ, is given by



TYPICAL FLUID PARCEL

Figure 1.--Typical flow element in a typical fluid parcel of a river.

$$\xi = x - x_0 - \int_{t_o}^{t} U \, d\tau \qquad (1)$$

in which x_0 is the location of the parcel at time t_o, and U is the cross-sectional average flow velocity evaluated at the location of the parcel. Note that $\xi = 0$ for the particular parcel at any time.

Dividing by $\Delta a \; \Delta x$ since they are constant for a given element of the parcel gives

$$\frac{\partial c}{\partial t} - \frac{\partial u'c}{\partial \xi} = \phi$$

Integrating the equation over the cross section, one obtains

$$\frac{\partial C}{\partial t} - \frac{\partial \overline{u'c'}}{\partial \xi} = \Phi \qquad (2)$$

in which C and Φ are the cross-sectional average value of concentration and production, respectively, and $\overline{u'c'}$ is the cross-sectional average value of the product of the velocity and concentration deficit (C - c). The term Φ can represent several processes. For example, it can represent point sources of the substance such as those that occur at tributaries, as well as a distributed source of substance such as the heat absorbed at the air-water interface. Equation 2 is applied to a series of fluid parcels along the length of the stream in order to obtain a solution for the system.

The second term in equation 2 is the so-called dispersion term. Actually, it is mainly a correction factor to account for treating a three-dimensional problem by use of a time and space averaged one-dimensional equation. For lack of a better approach, the dispersion term has invariably been represented by analogy with molecular and turbulent mixing due to diffusion. In other words, it has been assumed that

$$\overline{u'c'} = - D_x \frac{\partial c}{\partial \xi} \qquad (3)$$

in which D_x is called the longitudinal dispersion coefficient. It can be shown theoretically that $D_x = 5.9 U_* Y$ for flow in a wide open channel with a logarithmic velocity profile (Elder, 1959). Here U_* and Y are the shear velocity and depth, respectively. Fischer (1973) summarizes measurements in both the laboratory and natural channels. The reported values range from $D_x = 5.9 U_* Y$ to $D_x = 7500 \, U_* Y$.

Combining equations 2 and 3, the governing equation for Lagrangian transport is obtained as

$$\frac{\partial C}{\partial t} + \frac{\partial (D_x \partial C/\partial \xi)}{\partial \xi} = \Phi \tag{4}$$

Integrating equation 4 gives

$$C = C_o - \int_o^t \frac{\partial (D_x \partial C/\partial \xi)\, dt'}{\partial \xi} + \int_o^t \Phi dt' \tag{5}$$

in which C^o is the concentration of the parcel at time zero and C is the concentration after a time lapse of t. The time lapse (or traveltime), t, can be considered either as a single time step in the model or as the total time for a parcel to pass through the system. Equation 5 is very amenable to numerical analysis because of its integral rather than differential form.

A solution is constructed by solving equation 5 for a series of parcels. The location of each parcel is continually tracked by use of equation 1 with $\xi = 0$. Since a new parcel is added at the upstream boundary for each time step, the distance between parcels is $U\Delta t$. Knowing the distance between parcels the dispersion term can be approximated by a very simple explicit finite difference method for each time step

$$\int_o^{\Delta t} \frac{\partial (D_x \partial C/\partial \xi)}{\partial \xi} dt' \simeq \frac{D_{xi}}{U^2 \Delta t} (C^o_{i+1} - C^o_i) - \frac{D_{x\ i-1}}{U^2 \Delta t} (C^o_i - C^o_{i-1}) \tag{6}$$

in which C^o_{i-1}, C^o_i, and C^o_{i+1} are the old values of concentrations of parcel i-1, i, and i+1, respectively, and D_{xi} is the dispersion coefficient evaluated at a point halfway between parcel i and i+1. The dimensionless ratio, called the dispersion factor, D_f, is defined as

$$D_f = \frac{D_x}{U^2 \Delta t} = \left(\frac{\sqrt{D_x \Delta t}}{U\Delta t} \right)^2 \tag{7}$$

It will be seen that the accuracy of the numerical approximation is totally controlled by the value of this ratio. The distance between parcels is $U\Delta t$ and the characteristic distance scale for a diffusive process is $\sqrt{D_x \Delta t}$ (Carslaw and Jaeger, 1959). The length scale $\sqrt{D_x \Delta t}$ is a measure of the distance of travel of an advancing diffusion front. The value of the dispersion factor is seen to be the square of the ratio of the length scale of the diffusive process to the distance between parcels. It can be shown, empirically, that the accuracy of equation 6 is optimum for a value of $D_f \simeq 0.2$ but that the accuracy remains very good as long as $0.05 \leq D_f \leq 0.3$ (Jobson, 1980). The value of the dispersion factor, D_f, can be controlled by the modeler through the selection of Δt. Values outside the suggested range will generally result in the model underestimating the actual dispersion.

In order to insure that equation 6 conserves mass when applied to parcels of finite size it is well to rederive it from mass balance considerations paying special attention to the details concerning the mass balance of parcels.

Longitudinal dispersion is caused primarily by the difference in streamwise velocity between different points in the cross section (Fischer, 1972, p. B5). The boundaries between parcels are convected through the reach at the mean stream velocity while the water near the surface and center may move faster than the mean and the water near the bed and banks will move slower, as illustrated in figure 2. Because of these differential velocities, waters intermingle between Lagrangian parcels. This intermingling dominates the longitudinal dispersion process. Consider figure 2 which illustrates a wide river with parcels separated by moving planes, the dashed lines. Assuming that the concentration in each parcel is well mixed and that the flow rate from parcel K to K+1 is DQ(K), the flux of material across the boundary can easily be computed. From continuity considerations an equal apparent flow rate must exist from parcel K+1 to parcel K so the total dispersive increase in concentration of parcel K during Δt can be determined from

$$\int_0^{\Delta t} \frac{\partial \overline{u'c'}}{\partial \xi}\, dt' = \frac{DQ(K-1)\Delta t(C^o_{K-1} - C^o_K) + DQ(K)\Delta t(C^o_{K+1} - C^o_K)}{\forall} \qquad (8)$$

in which $\forall$ is the volume of parcel K.

The rate of flow of water between parcels (DQ) is determined from the distribution of velocity in the cross section and the mean velocity. The value of DQ will remain a constant percentage of the discharge, provided the velocity distribution in the cross section remains similar. For example, if there were no lateral variation in velocity and the vertical variation were logarithmic, the ratio of DQ/Q (called DQQ) would be only a function of the ratio of the mean velocity to the shear velocity. This ratio would increase from 0.092 to 0.184 as the ratio of the mean to shear velocity decreased from 10.0 to 5.0. Since the ratio of DQ/Q = DQQ is constant, equation 8 could be written as

$$\int_0^{\Delta t} \frac{\partial \overline{u'c'}}{\partial \xi}\, dt' = \frac{DQQ(K-1)AU\Delta t(C^o_{K-1} - C^o_K) + DQQ(K)AU\Delta t(C^o_{K+1} - C^o_K)}{\forall} \qquad (9)$$

in which A is the cross-sectional area of the river. For steady uniform flow the volume of the parcel is $AU\Delta t$ and equation 9 is identical to

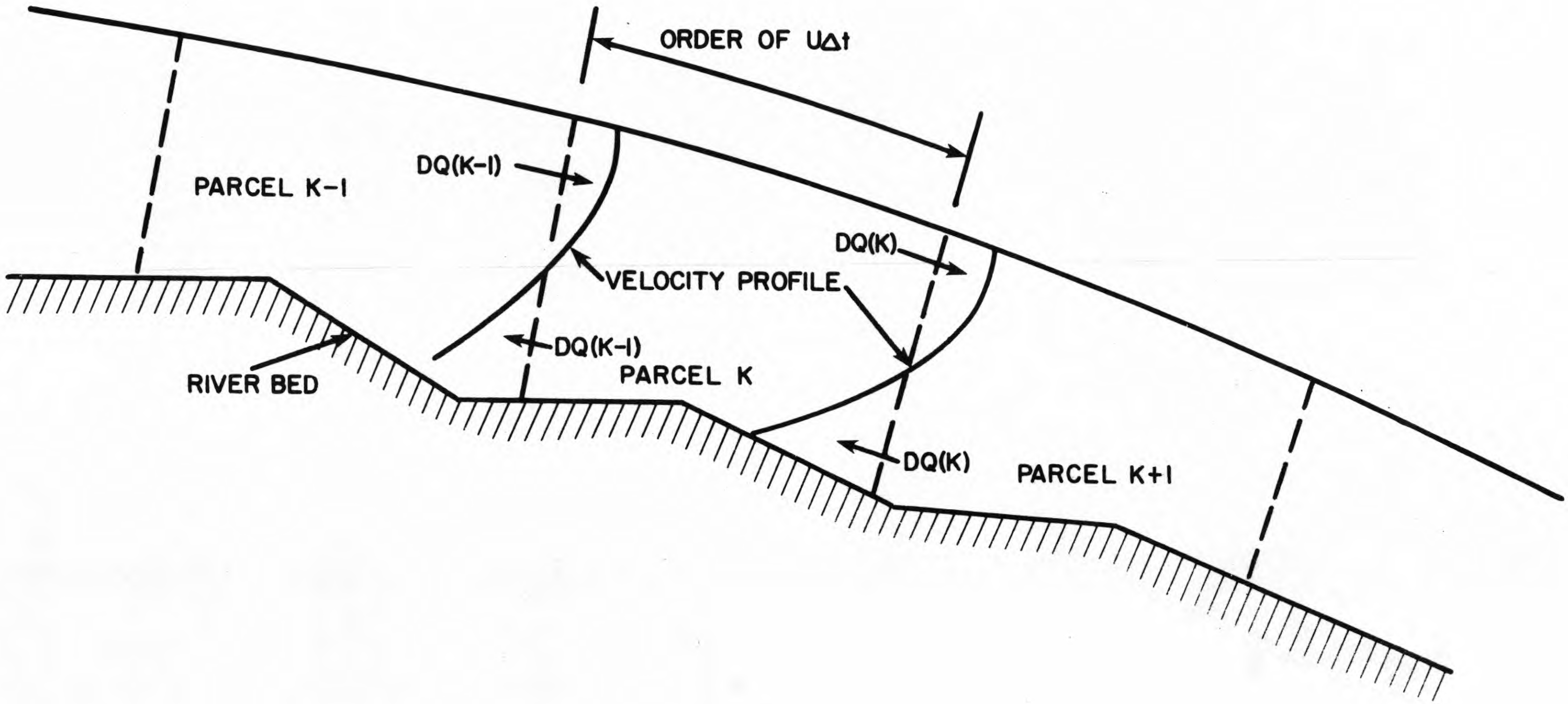


Figure 2.--Schematic of a longitudinal section of a river with fluid parcels delineated to illustrate the dispersive process.

equation 6 wherein DQQ is equivalent to D_f; however, use of equation 9 conserves mass even for nonuniform unsteady flow conditions with finite parcel sizes. For this reason equation 9 is used in the model computations.

Equation 9 can become unstable for highly unsteady flow or if adjacent parcel volumes of very unequal size exist in the river. If $DQ\Delta t > \forall$ more fluid is removed from a parcel during the time step than was there to begin with. This potential instability is overcome by forcing the value of $DQ\Delta t$ to be less than $0.35\ \forall$. This reduction in DQ is seldom executed except for extremely unsteady flow but when executed, reduces the computed dispersion below actual values.

SOLUTION ALGORITHM

The traditional Eulerian solution scheme for transport problems involves discretizing the river reach into a number of subreaches separated by grid points. The initial conditions for the solution are known concentrations of water parcels at each grid point. New concentrations of different water parcels at the same grid points are then computed for some later time, Δt. One boundary condition and a finite-difference approximation of the convective diffusion equation are used to compute the new concentrations. The new concentrations are then considered as initial or old values and the process is repeated as many times as desired.

In the Lagrangian approach, the Eulerian grid must be retained because it is the reference upon which the depth, area, and velocity of flow are defined. The solution scheme starts at time zero with a known concentration of a water parcel centered at each grid point just as in the Eulerian scheme. In the Lagrangian approach, however, new concentrations are computed by use of equation 5 for the same water parcels, which, of course, are no longer at the same location after a time lapse of Δt. The new location of each water parcel is determined by equation 1. As a result, the solution computation proceeds along advective paths (characteristic curves) defined by equation 1. The boundary condition is incorporated by adding a new parcel with its centroid at the upstream boundary for each time step. This new fluid parcel contains all the water to flow into the reach during the time $t - \Delta t/2$ to $t + \Delta t/2$. Later the volume of the parcel may change as it moves past tributaries or diversion points.

The basic bookkeeping necessary to keep track of all the information about individual fluid parcels is accomplished by setting up parcel characteristic arrays [PX(K),PV(K),PT(K)] where K is the index for the particular water parcel; PX(K) is the longitudinal location of the centroid of the parcel; PV(K) is the parcel volume; and PT(K) is the parcel concentration or temperature. The parcels are numbered in the order of their location, or time of entry to the reach, with parcel number 1 occupying the upstream boundary and parcel NS occupying the downstream boundary (fig. 3). In general, the total number of parcels in the system, NS, will be different for each time step. The maximum value of NS, which fixes the dimensions of the arrays, can be determined as the longest traveltime of a parcel through the system divided by the time-step size. The characteristics and identifying index, K, of each parcel are updated during each time step of the model.

For convenience the parcel location is measured in Eulerian grid units. For example, the parcel occupying the upstream boundary has a location of 1.0 [PX(1) = 1.0] and the parcel, K, located midway between grids 4 and 5 (in subreach 4) has a location of 4.5 [PX(K) = 4.5]. The Eulerian grids do not have to be equally spaced.

The basic solution algorithm can perhaps be best described by giving a narrative of the steps involved for one-time iteration of a conservative substance:

1. The first step is to determine the average hydraulic conditions in each subreach, river reach between two grid points. The subreach-average velocities, for example, are the average of four values, the old and new velocities at each end of the subreach. (For extremely non-uniform conditions, the average velocity can better be computed as the average inflow to the subreach divided by the average area in the subreach.) For steady flow, this step is performed outside the time loop and only involves the averaging of values at each end of the subreach.
2. The dispersion term is evaluated for each parcel. This computation involves two basic steps.
   A. The rate of flow between Lagrangian parcels [DQ(K)] is determined for each parcel in the system. The value of DQ is computed as DQQ times the flow rate in the river evaluated at a point midway between adjacent parcels. The value of DQQ is input to the program. After all values of DQ are found, values are checked and limited in size, if necessary, to force stability. The value of DQ is also set equal to zero between parcels adjacent to tributaries.
   B. The dispersion term of equation 5 is evaluated for each parcel in the system by use of equation 9, and the results are stored in an array DF(K).
3. The upstream boundary condition is satisfied. The characteristics for the parcel which will become parcel 1 are read and stored as temporary variables, the names of which end with the letter U.
   A. The new concentration at the upstream boundary (TUP) and all tributaries are read from input cards.
   B. The upstream characteristic arrays are set as:
      (1) PXU = 1.0, the parcel enters at the upstream boundary;
      (2) PVU = $Q\Delta T$ in which Q is the flow rate at the upstream boundary at the end of the time step;

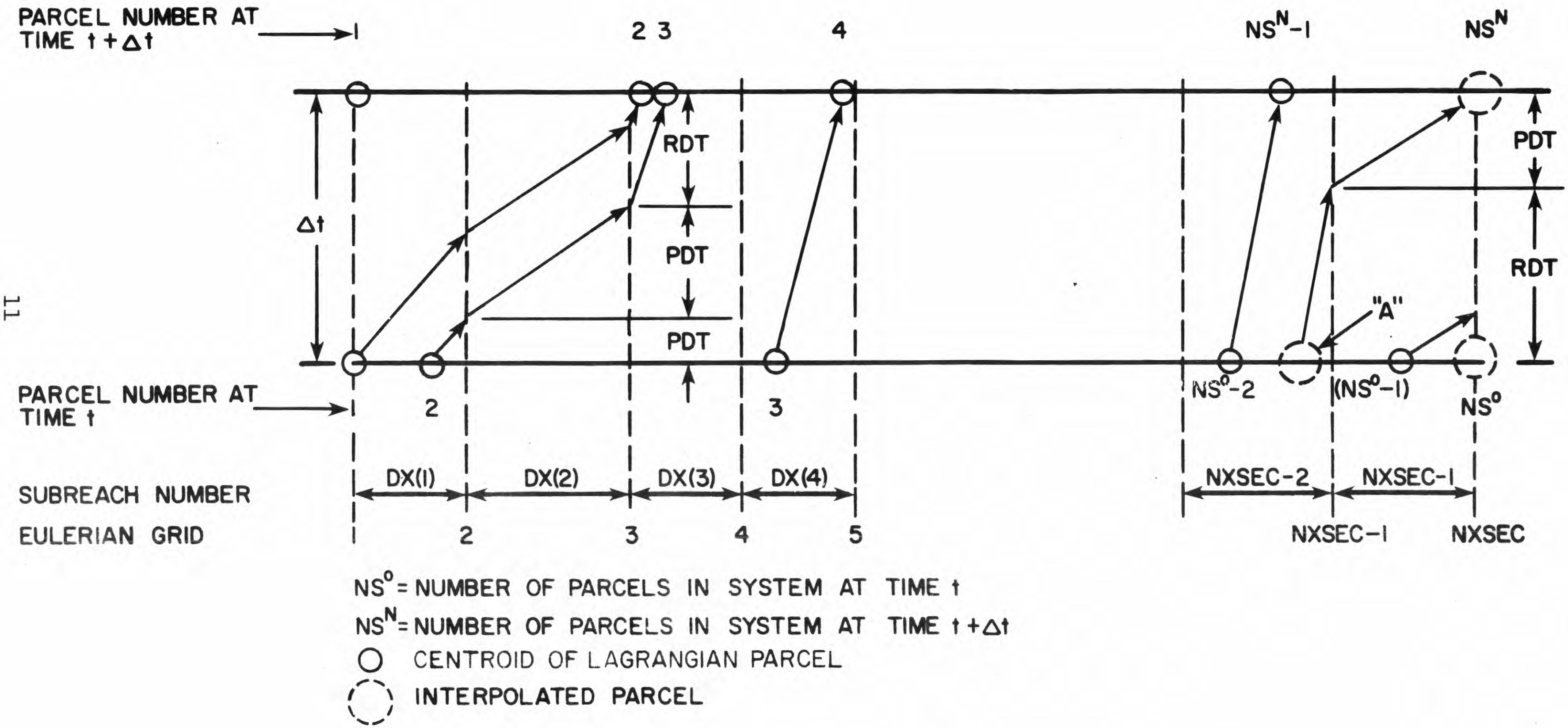


Figure 3.--Schematic of the computational scheme for the Lagrangian transport model.

(3) PTU = observed upstream concentration at the end of the time step (the boundary condition);

(4) PHU = (J + JTS)Δt is the time at which the parcel entered the system; J is the time step counter and JTS is the number of time steps from midnight to time zero of the model.

(5) PTRU = 0.0 is the effect of tributary inflow on the parcel concentration, none yet;

(6) PTIU = initial concentration of the parcel. This is also the observed upstream concentration at the end of the time step but it will be remembered throughout the parcel's travels without change.

(7) PDFU = 0.0 is the effect of dispersion on the concentration. The array PDF(K) will be obtained by integrating the dispersion term over the entire traveltime (eq. 6); of course, it starts out as zero.

4. The characteristics of the parcel which will be centered on the downstream boundary at the end of the time step (parcel NS^N in fig. 3) are determined. This parcel (parcel "A") is unique in that its characteristics are found by interpolation. The characteristics are those which should occur at the present location of parcel "A".

A. In order to determine the present location of parcel "A" (fig. 3), a term MX is defined as the subreach in which the centroid of the parcel is found.

B. It is first assumed that MX = NXSEC - 1, where NXSEC is the total number of Eulerian grids.

C. The traveltime through subreach MX is calculated as

$$PDT = DX(MX)/U(MX)$$

in which PDT is the time required for a parcel to traverse subreach MX of length DX(MX) and in which the velocity is U(MX).

D. If the traveltime for the subreach, PDT, is greater than the time remaining for movement, RDT, (RDT = Δt if MX = NXSEC - 1) the parcel is known to have originated in subreach MX. If PDT is less than RDT, the parcel originated upstream of subreach MX; so MX is reduced by 1, RDT is reduced by PDT, and steps C and D are repeated.

E. Once the subreach in which parcel "A" originated is found, the exact starting location of the centroid, XP (in Eulerian grids), is determined.

$$XP = MX + 1 - \frac{RDT}{PDT}$$

F. The index number, K, of the water parcel presently located just upstream of the added parcel "A" is found (NS^o - 2 in fig. 3) by comparing the location characteristic of each parcel (starting with NS^o - 1) to XP.

G. The total number of parcels that will be within the system at the end of the time step, NS^N, is determined as two more than the index, K, of the parcel just upstream of "A".

H. The locations of the added parcel "A" and the existing parcels just upstream and downstream of "A" are converted to real distances.

I. The old concentration of parcel "A" is obtained by linear interpolation between the adjacent parcels. The new concentration at the downstream boundary [PT(NS)] is computed by use of equation 5 wherein the old concentration of parcel "A" is used for C^o.

J. All other parcel characteristics are obtained by similar interpolation with updating where necessary. The volume of the added parcel ("A") is set equal to the volume of the parcel just downstream of parcel "A".

5. Starting with parcel NS - 1 and working upstream, the characteristics and index number of each parcel are updated.

A. The subreach where the centroid of the parcel is located (MX) is determined first as the integer part of PX(K), the old value of PX(K) is stored as XØLD, and the index number is stored as KØ.

B. The distance within the subreach remaining to be traversed, PDX, is determined

PDX = [MX + 1 - PX(K)]*DX(MX)

where DX(MX) is the length of the subreach from grid point MX to MX + 1.

C. The time for the parcel to traverse this distance, PDT, is computed from the mean velocity in the subreach.

D. If the traveltime for the remaining part of the subreach, PDT, is greater than the time remaining for movement, RDT, the program jumps to step E. Otherwise,

(1) MX is increased by 1 (the parcel has passed a Eulerian grid);

(2) XØLD is set equal to MX;

(3) The value of RDT is reduced by the time required for the parcel to reach the grid, PDT;

(4) The information that parcel K passed Eulerian grid MX during the time step is stored in the arrays NPT (number of parcels to pass grid MX) and KPG (parcel numbers of parcels to pass grid MX);

(5) The program cycles to step C with PDX = DX(MX).

E. The parcel stopped in subreach MX so all parcel characteristics are updated

(1) PX(K) = XØLD + RDT*U(MX)/DX(MX)

(2) PT(K) = PT(KØ) + DF(KØ) and PDF(K) = PDF(KØ) + DF(KØ)

(3) All other characteristics (volume, time of entry to the system, effect of tributary dilution and initial temperature, PV, PH, PTR, and PTI, respectively) simply have their index number changed from KØ to K.

6. The upstream boundary characteristics which were formerly stored in the temporary arrays (PXU, PTU, and so forth) are transferred to the characteristics arrays for index number 1. That is, PX(1) = PXU, and so forth.

7. For each tributary the program modifies the volume and concentration of each of the NPT parcels that pass the tributary location in proportion to the volume of the parcel in relation to the volume of all parcels to pass the tributary. If no parcels pass the tributary during the time step, the tributary inflow is added to the parcel which is nearest the tributary at the end of the time step.

8. For any specified interior grid (IGØ) the concentration and representative values of all parcel characteristics are determined by linear interpolation between parcels occurring just upstream and downstream of the grid.

9. Steps 2 through 8 are repeated for each time step and results are printed at specified time steps.

Flow charts and program listings will be given for each version of the program.

No model can be completely general. It is assumed that the location of all Eulerian grid points will be expressed in miles measured from some point below the downstream end of the reach. The program allows for no more than 50 grid points (49 subreaches) which are numbered starting with 1 at the upstream end. The cross-sectional area must be expressed in square meters. It is further assumed that no tributaries enter at either the first or last grid point (upstream or downstream end of the reach) and that all discharges are given in cubic meters per second. Finally, all parcel characteristic arrays are dimensioned only to 500 so no more than 500 parcels are allowable in the system at one time. One parcel is added to the system for each time step, so the maximum traveltime of a parcel through the system must be less than 500 time steps. This limitation can be removed in three ways. First, the time step size can be increased; second, the total reach length can be subdivided into two or more major sections and the program run for each section; or third, the dimensions for all arrays can be increased.

CONSERVATIVE TRANSPORT IN STEADY FLOW

The simplest possible transport problems involve the movement of a conservative type of substance, such as dye, through a river system. Although simple, the conservative transport model can be very useful for predicting concentrations which may result from spills of various pollutants which decay slowly. It is also an excellent place to start obtaining an understanding of the model itself.

Since the preceding section went into the detail of the conservative transport model, the material will not be repeated here. A generalized flow chart of the program is shown in figure 4 and a listing of the codes is shown in attachment A.

All input is by computer cards. Table 1 contains a description of the data input, sequence and arrangement used for all the models. The conservative transport model does not require all sets of data. The first card is an information card which will simply be printed back at the beginning of the output. This 80-column field will generally contain the name of the basin, period of record, date of run, and so forth.

The second card contains the number of cross sections (grid points) to be used (NXSEC), the number of time steps to be simulated (NHR), the time step size (Δt) expressed in hours, the discharge at the upstream end of the reach (Q) in cubic meters per second, the interior grid at which output is desired (IGØ), the number of time steps between output lists (IØUT), the number of tributaries to enter the stream (NTRIB), and the number of time steps between midnight and the starting time of the model (JTS). If the value of IØUT is set equal to 1, output is printed for every time step; if its value is 3, output is printed every third time step, and so forth. The format for the second card is 2I5, 2F10.2, 4I5 (line 0033, attachment A).

All other input cards have a consistent format. Each card has a free field in the first 10 columns which can be used for card identification. Following this free field are 10 seven-column data fields with a format of I7 or F7.3. Of course, a decimal punched in the field takes precedence. All integers must be right justified. All variables are real (number with a decimal) or integer according to standard notation, that is, A-H, O-Z for real and I-N for integer. The conservative transport model does not require the labeling information in set 3. These data cards are only needed for the 10-parameter model as indicated in the second column of table 1.

The next group (set 4 in table 1) of data cards needed for the conservative transport model contains the X coordinates of the grid points, expressed in miles upstream of some origin such as the river

Conservative Transport Program

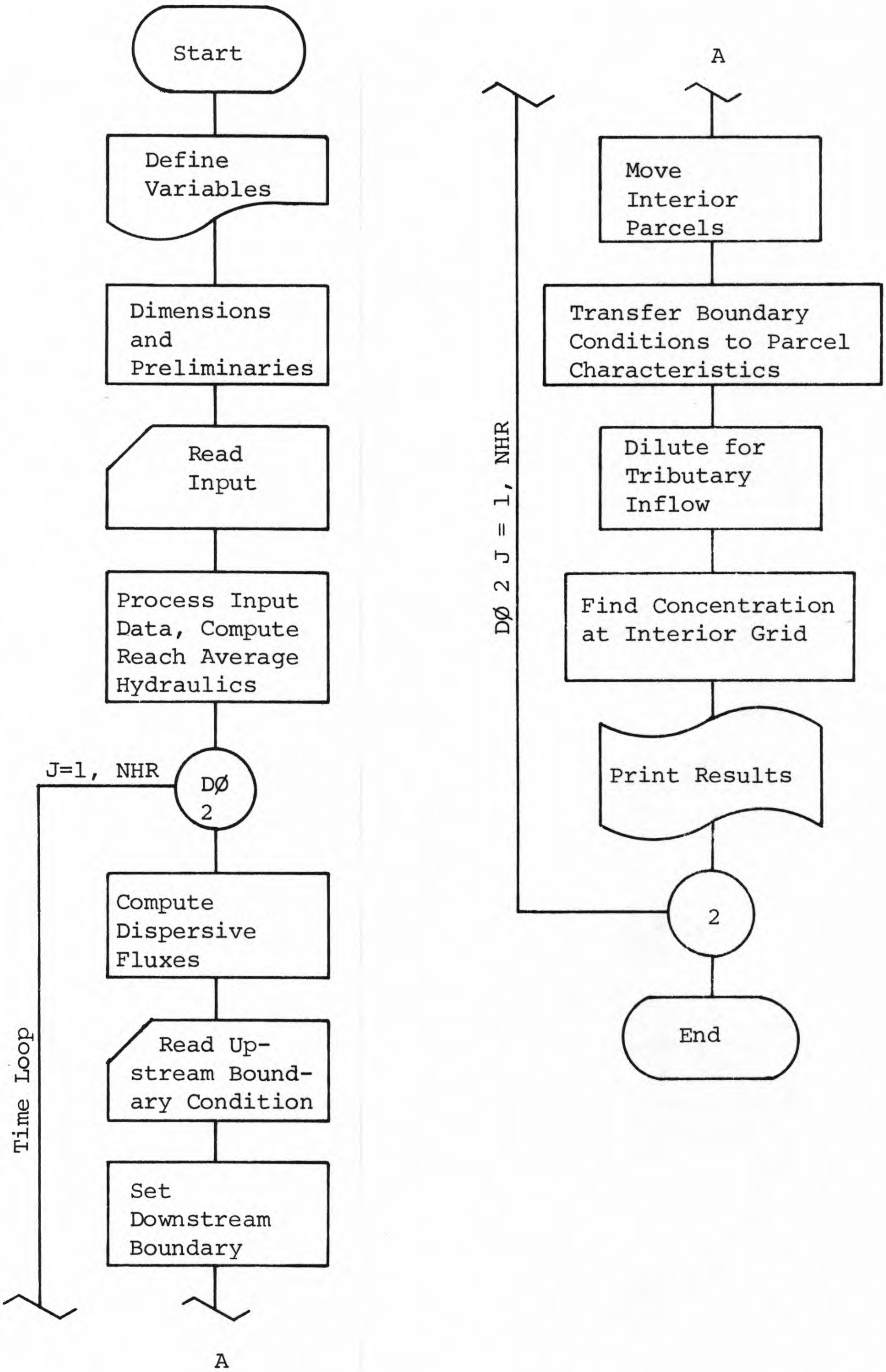


Figure 4.--Generalized flow chart for conservative transport model in steady flow.

TABLE 1.--A description of the data input, sequence, and arrangement

Card no.	Models using	Variable	Description	Columns
			SET 1 - INFORMATION CARD	
1	1,2,3,4	TITLE(20)	Information card, generally the basin name, period of record, date of run, and so forth	1-80
			SET 2 - HEADER CARD	
1	1,2,3,4	NXSEC	Number of grid points	1-5
	1,2,3,4	NHR	Number of time steps the model is to be run	6-10
	1,2,3,4	DT	Length of time step in hours	11-20
	1,2,3,4	Q	Discharge at upstream boundary in cubic meters per second	21-30
	1,2,3,4	IGØ	Interior grid number where output is desired	31-35
	1,2,3,4	IØUT	Number of time steps between output listings	36-40
	1,2,3,4	NTRIB	Number of tributaries	41-45
	1,2,3,4	JTS	Number of time steps from midnight until time zero of the model	46-50
	2,3,4	A1	Constant term in wind function relation which gives the evaporation in millimeters per day when the vapor pressure difference is given in kilopascals	51-60
	2,3,4	B1	Mass-transfer coefficient in wind function relation which gives the evaporation in millimeters per day when the vapor pressure difference is given in kilopascals and the windspeed is given in meters per second	61-70
	4	NEQ	Number of parameters being modeled	71-75
			SET 3 - LABELING INFORMATION FOR PARAMETER OUTPUT	
1	4	~	Free field for card identification	1-10

TABLE 1.--A description of the data input, sequence, and arrangement--Continued

Card no.	Models using	Variable	Description	Columns
			SET 3 - LABELING INFORMATION FOR PARAMETER OUTPUT--Continued	
	4	L	Parameter number which must start with number 1 and be in sequence	11-17
	4	LABEL(M)	5 columns alpha numeric field for naming parameter L	20-24
	4	LR(M)	Parameter number for which the effect on the concentration of parameter L is tabulated	25-31
			SET 4 - RIVER MILES OF GRID POINTS	
1,2...	1,2,3,4	~	Free field for card identification	1-10
	1,2,3,4	X(I)	River miles of grid points, that is, the distance, in miles, from the river mouth to grid point I. Input data starting at upstream end, grid point I.	11-17 18-24, .., 73-80
			SET 5 - CROSS-SECTIONAL AREAS	
1,2,...	1,2,3,4	~	Free field for card identification	1-10
	1,2,3,4	FLØW(2,I)	Cross-sectional areas of river at grid points in square meters. Values are input in sequence starting at grid 1 and working downstream. For unsteady flow, the value used here is ignored; a blank card is acceptable.	11-17, 18-24, ..., 73-80
			SET 6 - TOP WIDTHS	
1,2,...	2,3,4	~	Free field for card identification	1-10

TABLE 1.--A description of the data input, sequence, and arrangement--Continued

Card no.	Models using	Variable	Description	Columns
			SET 6 - TOP WIDTHS--Continued	
	2,3,4	FLØW(3,I)	Top widths of the river at the grid points in meters. Values are input in sequence starting at grid 1 and working downstream. For unsteady flow, the values used here are ignored; a blank card is acceptable.	11-17, 18-24, ..., 73-80
			SET 7 - TRIBUTARY INFORMATION	
1,2,...	1,2,3,4	~	Free field for card identification	1-10
	1,2,3,4	IGT(N)	Grid number where the tributary enters the stream. These must be input in sequence working downstream. Use one and only one card per tributary. If no tributaries exist, no cards are necessary.	11-17
	1,2,3,4	FLOW(4,IGT(N))	Tributary inflow at grid IGT(N) in cubic meters per second. For unsteady flow, the value used here is ignored, and the tributary flow is obtained from the flow model output.	18-24
			SET 8 - DISPERSION FACTORS	
1,2,...	1,2,3,4	~	Free field for card identification	1-10,
	1,2,3,4	DQQ(I)	Dispersion factor at grid I. The dispersion factor is determined by use of equation 7. Any consistent units can be used.	11-17, 18-24,..., 73-80

TABLE 1.--A description of the data input, sequence, and arrangement--Continued

Card no.	Models using	Variable	Description	Columns
			SET 9 - INITIAL CONDITIONS	
1,2,...	1,2,3,4	~	Free field for card identification	1-10,
...M	1,2,3 or 4	PT(I) or PT(1,I)	Initial concentrations or temperatures at grid points. Data must be input in sequence starting with grid 1, the upstream end.	11-17, 18-24,..., 73-80
M+1,	4	~	Free field for card identification	1-10,
	4	PT(2,I)	Initial concentrations at grid points for parameter number 2. Data must be input in sequence starting with grid 1.	11-17, 18-24,
.	.	.	.	...,
.	.	.	.	
.	.	.	.	73-80
M(NEQ)	4	~	Free field for card identification	1-10,
M(NEQ)+1, ...	4	PT(NEQ,I)	Initial concentrations at grid points for parameter number NEQ. Data must be input in sequence starting with grid 1.	11-17, 18-24,..., 73-80
			SET 10 - RIVER LOCATION	
1	3	~	Free field for card identification	1-10,
	3	JDAT	Julian date for which shading computations are made. Fixed point variable.	11-17,
	3	PHI	Latitude of the river in degrees	18-24,
	3	ALØN	Longitude of the river in degrees	25-31,
	3	TZM	Longitude of the meridian of the time zone in degrees	32-38,

TABLE 1.--A description of the data input, sequence, and arrangement--Continued

Card no.	Models using	Variable	Description	Columns
			SET 11 - RIVER AZIMUTHS	
1,2,...	3	~	Free field for card identification	1-10,
	3	AZ(I)	Azimuth of the river at grid I in degrees clockwise from North. Use as many cards as necessary to input values for each grid starting with grid 1 on card 1.	11-17, 18-24, ..., 73-80
			SET 12 - BANK WIDTH	
1,2,...	3	~	Free field for card identification	1-10,
	3	BW(I)	Bank width at grid I in meters, see figure 10 for definition. Use as many cards as necessary starting with grid 1 on card 1	11-17, 18-24,..., 73-80
			SET 13 - EFFECTIVE BARRIER HEIGHT	
1,2,...	3	~	Free field for card identification	1-10,
	3	EBH(I)	Effective barrier height at grid I in meters, see figure 10 for definition. Use as many cards as needed starting with grid 1 on card 1.	11-17, 18-24,..., 73-80
			SET 14 - BED PROPERTIES	
1	3	~	Free field for card identification	1-10,
	3	DIF	Thermal diffusivity of the bed material, in square centimeters per hour	11-17,
	3	CV	Heat storage capacity of the bed material, in calories per cubic centimeter per degree Celsius	18-24

TABLE 1.--A description of the data input, sequence, and arrangement--Continued

Card no.	Models using	Variable	Description	Columns
			SET 15 - BOUNDARY CONDITIONS	
1Aa	1,2,3,4	~	Free field for card identification	1-10,
	1,2,3,4	TUP or TUP(1)	Concentration or temperature (Celsius) at the upstream boundary at time 0 + ΔT	11-17,
	1	TRIB(IGT(N))	Concentrations or temperatures (Celsius) of tributary inflows during the first time step. Values must be input in sequence working downstream. One value for each tributary must be entered, but no more than 9 values can be entered on the first card.	18-24, 25-31, ..., 73-80
	2,3,4	TA	Air temperature in degrees Celsius during the first time step	18-24,
	2,3,4	V	Windspeed in meters per second during the first time step	25-31,
	2,4	TRIB(IGT(N)) or TRIB(L,IGT(N))	Concentrations or temperatures (Celsius) of tributary inflows during the first time step Values must be input in sequence working down-stream. One value for each tributary must be entered, but no more than 7 values can be entered on the first card.	32-38, 39-45, ..., 73-80
	3	HS	Total incoming solar radiation during the first time step, in calories per square centimeter per day	32-38
	3	HL	Total incoming atmospheric radiation during the first time step, in calories per square centimeter per day.	39-45
	3	EA	Vapor pressure of the air during the first time period, in kilopascals	46-52
1Ab, 1Ac, •	1,2,3,4	~	Free field for card identification	1-10,
	1,2,3,4	TRIB(IGT(N)) or	Concentrations or temperatures (Celsius) of tributary inflows during the first time step	11-17, 18-24,

TABLE 1.--A description of the data input, sequence, and arrangement--Continued

Card no.	Models using	Variable	Description	Columns
			SET 15 - BOUNDARY CONDITIONS--Continued	
•		TRIB(L,IGT(N))	Values must be input in sequence working downstream. No more than 10 values can be entered by use of this card. The first value will be for tributary 10 in model 1, tributary 8 in models 2 and 4, and tributary 1 in model 3. Use as many cards as necessary to enter all tributary values.	..., 73-80
1Ba	4	~	Free field for card identification	1-10
	4	TUP(2)	Concentration of constituent 2 at upstream boundary at time 0 + ΔT	11-17
	4	TRIB(L,IGT(N))	Concentrations of constituent 2 in tributary inflow during the first time step. Values must be input in sequence working downstream. One value for each tributary but only 9 values on this card.	18-24, 25-31, ..., 73-80
1Bb,	4	~	Free field for card identification	1-10,
1Bc	4	TRIB(L,IGT(N))	Additional tributary concentrations as needed	11-17, 18-24, ..., 73-80
• • •			• • •	
1C, 1D,...			Follow by identical card sequences for the other constituents • • •	
2Aa			Same as card 1Aa, except for time 0 + 2ΔT.	
2Ab			Same as card 1Ab, except for time 0 + 2ΔT.	

TABLE 1.--A description of the data input, sequence, and arrangement--Continued

Card no.	Models using	Variable	Description	Columns
		SET 15 - BOUNDARY CONDITIONS--Continued		
2Ac			Same as card 1Ac, except for time 0 + 2ΔT.	
2Ba			Same as card 1Ba, except for time 0 + 2ΔT.	
2Bb			Same as card 1Bb, except for time 0 + 2ΔT.	
			•	
			•	
			•	
			Follow by identical sequences of cards for each time step.	

mouth. The format for these cards is (10X, 10F7.3) where the first 10 spaces on each card is a free field (line 0035, attachment A). The grid point locations as well as all other grid information must be input in sequence starting at the upstream end and working downstream. Of course, only cards as needed are used.

The next group of data (set 5 in table 1) contains the cross-sectional area at each grid point expressed in square meters. The format for these data is the same as for the X-coordinates. The conservative transport model does not need the river top widths contained in the sixth set of cards.

The next group of data (set 7 in table 1) contains information concerning the location and flow for each tributary. One card is used for each tributary and on each card the location (grid number, IGT) and discharge [FLØW(4,I)] in cubic meters per second are given. The format is 10X, I7, F7.2 (line 0040, attachment A). If no tributaries are present, no cards are needed.

The next group of data (set 8 in table 1) contains the dispersion factor values (DQQ) representative of each grid point. The DQQ values (NXSEC values) are input with the standard format (10X, 10F7.3).

The next group of data (set 9 in table 1) contains the initial concentration at each grid point, PT(K), input with the standard format. Data sets 10, 11, 12, 13, and 14 are needed only for the complete temperature model.

Finally, the boundary conditions are read with at least one card for each time step (set 15 in table 1). The first card should contain information relative to the time 0 + Δt hours. The first piece of information on this card is the upstream concentration followed by the concentration at each tributary. The tributary concentrations must be in sequence with the upstream-most tributary being given first. The standard format is used. If 9 or less tributaries exist, all information for each time step will be on one card. If 10 or more tributaries exist, more than one card will be required. The concentrations for tributary number 10 will be the first number on card 2, the concentration of tributary 20 will be the first number on card 3, and so forth.

At the end of the program listed in attachment A is a listing of the data cards used to generate an example problem. This problem has eight grid points and runs for forty 1-hour time steps. The upstream discharge is 12.00 m^3/s and the output is computed at grid 6 as well as at the downstream end. The print interval is every time step and one tributary exists. The third card contains the river mile of each of the eight grid points and the fourth card contains the cross-sectional areas in square meters. The fifth card indicates that a tributary enters at grid 5 with a discharge of 0.65 m^3/s. The mean velocity through the reach is expected to be about 0.5 m/s and the mean depth is about 0.4 m. Assuming a dispersion coefficient of 45 m^2/s, equation 7 gives the value of the dispersion factor to be 0.05. A dispersion coefficient of 45 m^2/s is 1,125 times the product of the depth and the shear velocity if the shear velocity is one-fifth of the mean velocity. All values of DQQ are equal to 0.05 as seen on the sixth card and all initial concentrations are zero, card 7. The rest of the cards are the boundary conditions with the time step number shown in columns 3 and 4.

The output of the example problem is shown in attachment A. The first part of the output is self explanatory. The output labeled "Initial Conditions" represents the steady-state flow conditions in the steady flow model. The computed data are contained in the third part of the output. The first column is time in days and hours with day 1 being the first day of the model simulation and the hour being clock time. The next 5 columns refer to the interior grid IGØ (in this case grid 6). The second column is the concentration at grid 6 for the time in column 1. The traveltime is the time required for the parcel centroid to traverse the distance from grid 1 to grid IGØ (grid 6 in the example). However, if the traveltime is more than the time lapsed since the start of the simulation, this lapsed time is given. The model simulation started at 4 hours past midnight (JTS = 4 since Δt = 1 hour), and the first output occurs at hour 5.00. Therefore, the traveltime for this entry is 1.00 hours. The traveltimes increase systematically for 8 hours, at grid 6, because it takes 8.56 hours for a parcel to traverse the reach. During the initial period when the traveltime equals the lapsed time, the computed concentration is highly dependent on the initial conditions.

The fourth column is the concentration the parcel had when it was at grid 1. Columns 5 and 6 are the changes in the parcel concentration which occurred during its transit from grid 1 due to dispersion and tributary dilution. The values in these columns were determined by evaluating the integrals on the righthand side of equation 5. To illustrate, consider the output on day 1 at 15.00 hours. The parcel at grid 6 on day 1, hour 15, entered the system 8.45 hours earlier (1 day, 6.55 hours) with an initial concentration of 30.0. During its 8.45-hour transit from grid 1, dispersion decreased its concentration by 0.87, while tributary dilution increased its concentration by 0.28. The parcel, therefore, arrived at grid 6 with a concentration of 30.00 - 0.87 + 0.28 = 29.41 as shown in column 2.

The last 5 columns contain the same information except that this information pertains to the downstream most grid (grid 8 in the example). For example, the parcel which occupies grid 8 on day 2, hour 4.00, entered the system at grid 1 on day 1, hour 14.56, with a concentration of 0.00. During its 13.44-hour transit, dispersion increased its concentration by 5.36, and tributary dilution increased its concentration by 1.66. The parcel arrived at grid 8 with a concentration of 0 + 5.36 + 1.66 = 7.02 as shown in column 8.

Figure 5 contains a plot of input concentration as well as the computed concentrations at grids 6 and 8 for the entire time period. The peak concentration due to the center input pulse appears truncated at grids 6 and 8. This occurs because the concentration at these grids is obtained by linear interpolation between parcels on either side of the grid. By chance, the parcel with the peak concentration did not stop near grid 6 so the linear interpolation was poor. This apparent error could be corrected by using a shorter time step.

SIMPLIFIED TEMPERATURE MODEL

It is often necessary to be able to predict either natural or elevated river temperatures, but rarely are complete meteorological data available. The simplified temperature model allows one to simulate approximate river temperatures with a minimum of meteorologic data. Only equilibrium temperature and windspeed are required. And of these two the equilibrium temperature is by far the most important. It is believed that air temperature can be substituted for equilibrium temperature for most practical applications to predict water temperatures to within ± 1 or 2°C.

Rewriting equation 1 where the transportable substance is heat, one obtains

$$\frac{\partial T}{\partial t} + \frac{\partial \overline{u'T'}}{\partial \xi} = \frac{HW}{A\,\rho c_p} + \phi \tag{10}$$

in which T = water temperature, H = net addition of thermal energy to the water from the air per unit time and area, W and A = width and area of the parcel, respectively, or the width and area of the river at the location of the parcel, ρ = density of water, c_p = specific heat of water, and ϕ = additional source term to account for tributary inflow or heat sources. The solution procedure for equation 10 is identical to that for equation 1, except for the addition of the surface exchange term.

The rate of exchange of energy between the water and air is a complex subject which has been discussed many times. One of the first and most complete analyses of the processes involved has been presented by E. Anderson (1954). In general, the net exchange, H, can be expressed as the sum of several processes as

$$H = H_N - H_B - H_e - H_c \tag{11}$$

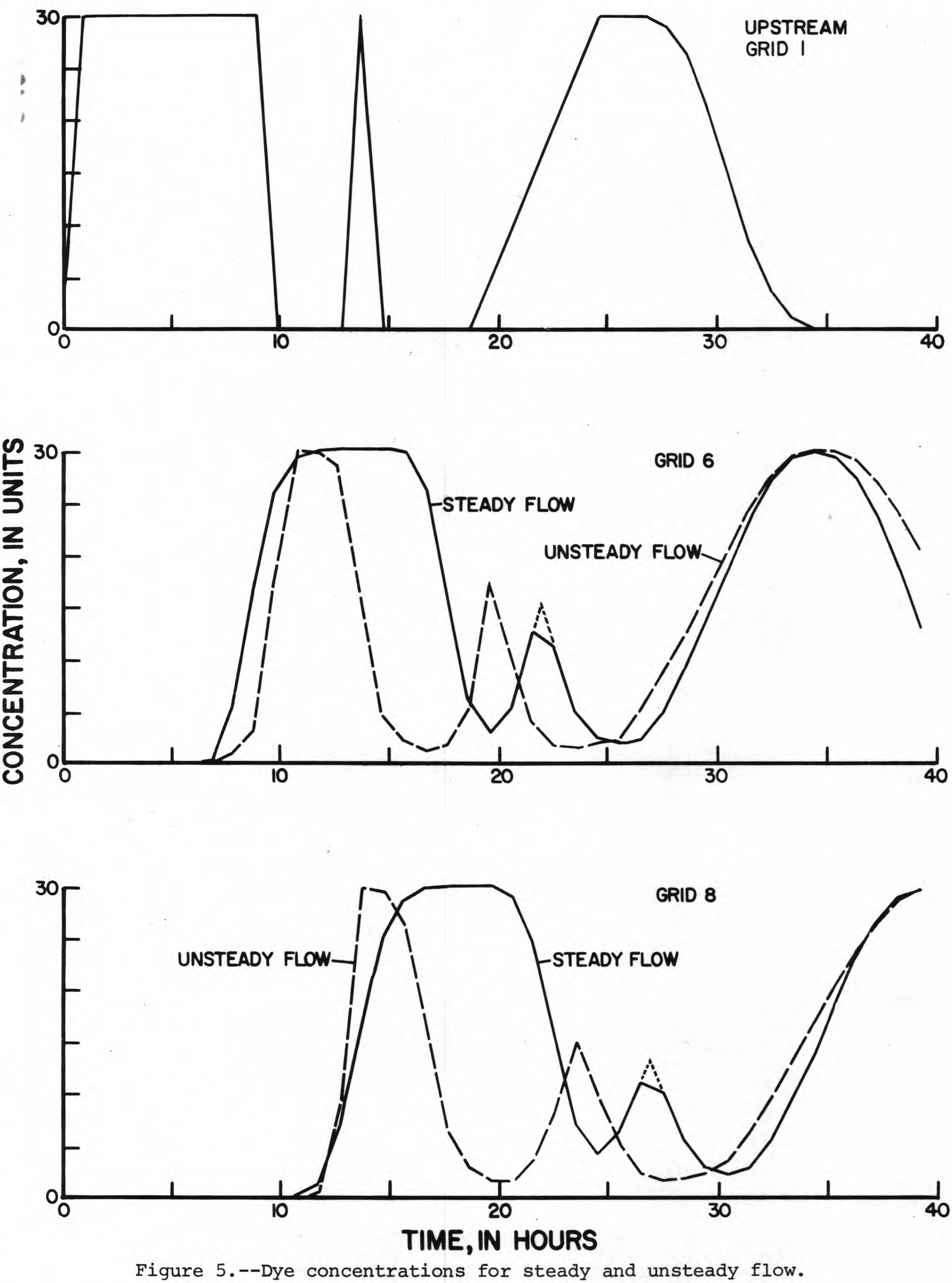


Figure 5.--Dye concentrations for steady and unsteady flow.

in which H_N = net heat flux caused by incoming radiation from the sun and the sky; H_B = heat flux caused by longwave radiation emitted by the water; H_e = heat flux utilized by evaporation; and H_c = heat flux conducted from the water to the air as sensible heat.

The net incoming radiation, H_N, is a completely independent variable which does not depend on the water temperature. Although difficult, a direct measurement of this component is possible.

The other three components, on the other hand, are dependent variables which are functions of the water temperature. In general, these components cannot be measured directly but must be calculated from expressions involving the water temperature and measurable meteorologic variables.

The longwave radiation emitted by a water surface can be accurately computed using the Stefan-Boltzman law for black-body radiation

$$H_B = \varepsilon\sigma(T + 273.16)^4 \tag{12}$$

in which ε = emissivity of water (0.97 unitless), σ = Stefan-Boltzman constant 1.171×10^{-7} [$cal/cm^2 d\ (K)^4$] and 273.16 converts to the Kelvin temperature scale, when the temperature, T, is given in degrees Celsius.

The thermal energy utilized by evaporation is expressed as

$$H_e = \rho L\psi\ (e_o - e_a) \tag{13}$$

in which ρ = density of water (1 g/cm^3), L = latent heat of vaporization (L = 595.9 - 0.545T cal/g), ψ = empirical function of windspeed (wind function) which relates the rate of evaporation to the vapor gradient $(e_o - e_a)$, e_o = saturation vapor pressure of air at a temperature equal to that of the water surface, in kilopascals, and e_a = vapor pressure of the air above the water, in kilopascals. The actual rate of evaporation is assumed to be determined from the semiempirical mass-transfer equation, or Dalton's law, as

$$E = \psi(e_o - e_a) \tag{14}$$

where E = evaporation rate in cm/d. The wind function is generally assumed to be of the form

$$\psi = \alpha + NV \tag{15}$$

in which α is a constant, N is the mass-transfer coefficient, and V is the windspeed in meters per second. From the thermal balance of a canal, Jobson (1977a) found the values of $\alpha = 0.302$ cm/d kPa and N = 0.113 cm/d (m/s) kPa. The value of e_o can be determined from the water temperature using the empirical equation

$$e_o = \exp\left[54.721 - 6788.6/(T + 273.16) - 5.0016 \ln (T + 273.16)\right] \tag{16}$$

in which the saturation vapor pressure is in kilopascals when the temperature, T, is in degrees Celsius.

Assuming the eddy diffusivities of heat and mass are identical, which leads directly to the Bowen ratio concept, the conduction term can be expressed as

$$H_c = \gamma \rho L \psi \; (T - T_a) \tag{17}$$

in which γ = the psychrometric constant [about 0.06 (kPa/°C)] and T_a = air temperature in degrees Celsius.

The evaluation of all the components which contribute to the net surface exchange requires a considerable amount of meteorologic data, net radiation (solar and atmospheric plus the reflected components of each), windspeed, vapor pressure of the air and air temperature. These data are difficult to obtain and can present significant data handling problems. The simplified temperature model, therefore, approximates the net surface exchange from the commonly available parameters of windspeed and air temperature, which is assumed to approximate the equlibrium temperature.

The assumption that air temperature can be used to approximate the equilibrium temperature is based on the observed fact that, if conditions remain stable for a long period of time, the water temperature usually approaches the air temperature within 1° or 2°C. This observation can be verified for natural streams unaffected by reservoirs or thermal additions, by plotting the monthly or weekly average water and air temperatures verses time. Figure 6 contains a plot of the mean water temperature in Pigeon Creek near Evansville, Ind. (Shampine, 1977), along with mean monthly air temperatures at Evansville, as reported by Thackston and Parker (1971, p. 76). Figure 7 illustrates the relationship between average water and air temperature for the Miami Canal, near Miami, Fla. (U.S. Geological Survey, 1973, p. 127). Finally, figure 8 illustrates the relationship for the Kansas River near Topeka, Kans. (Burns, 1975, p. 103). Lowham and others (1975, p. 27) states that the Green River averaged about 2°C warmer than the air temperature over a 22-year period and that the difference was nearly constant. According to Williams (1971) the water temperature of the Delaware River between Narrowsburg and Barryville normally relates well to the air temperature

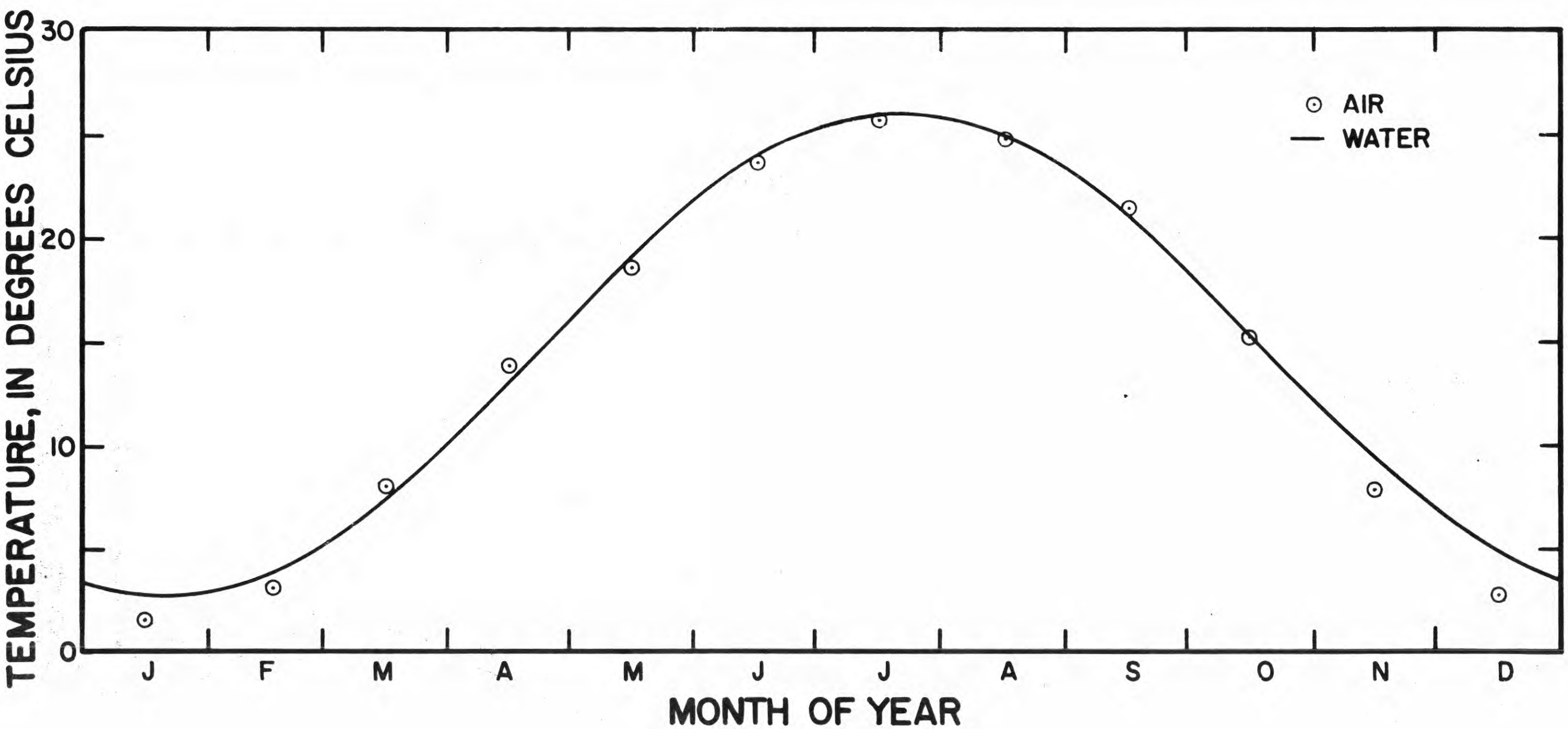


Figure 6.--Comparison of water temperature in Pigeon Creek to the mean monthly air temperature at Evansville, Ind.

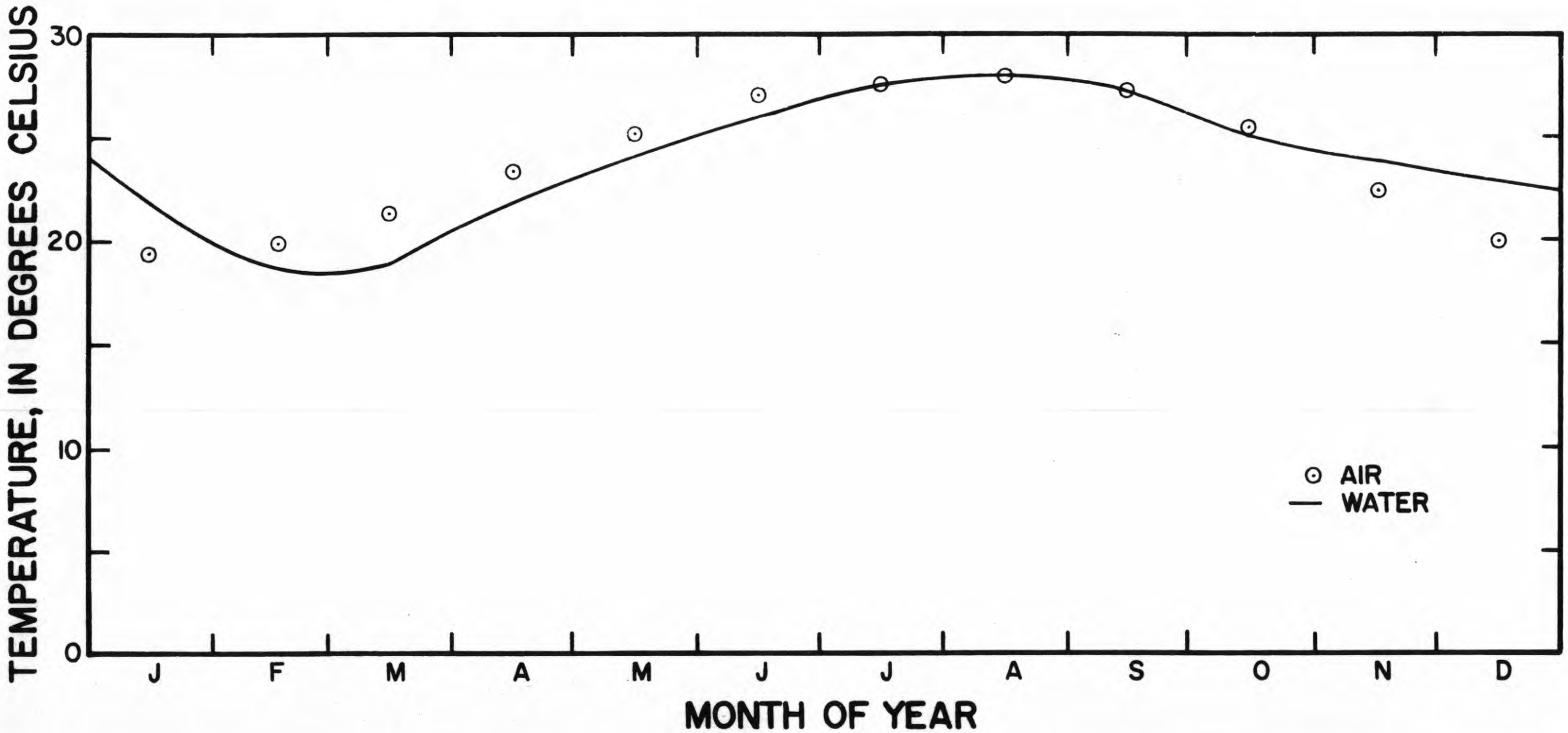


Figure 7.--Comparison of monthly average water temperature in Miami Canal at S-31 to monthly average air temperature at Miami, Fla.

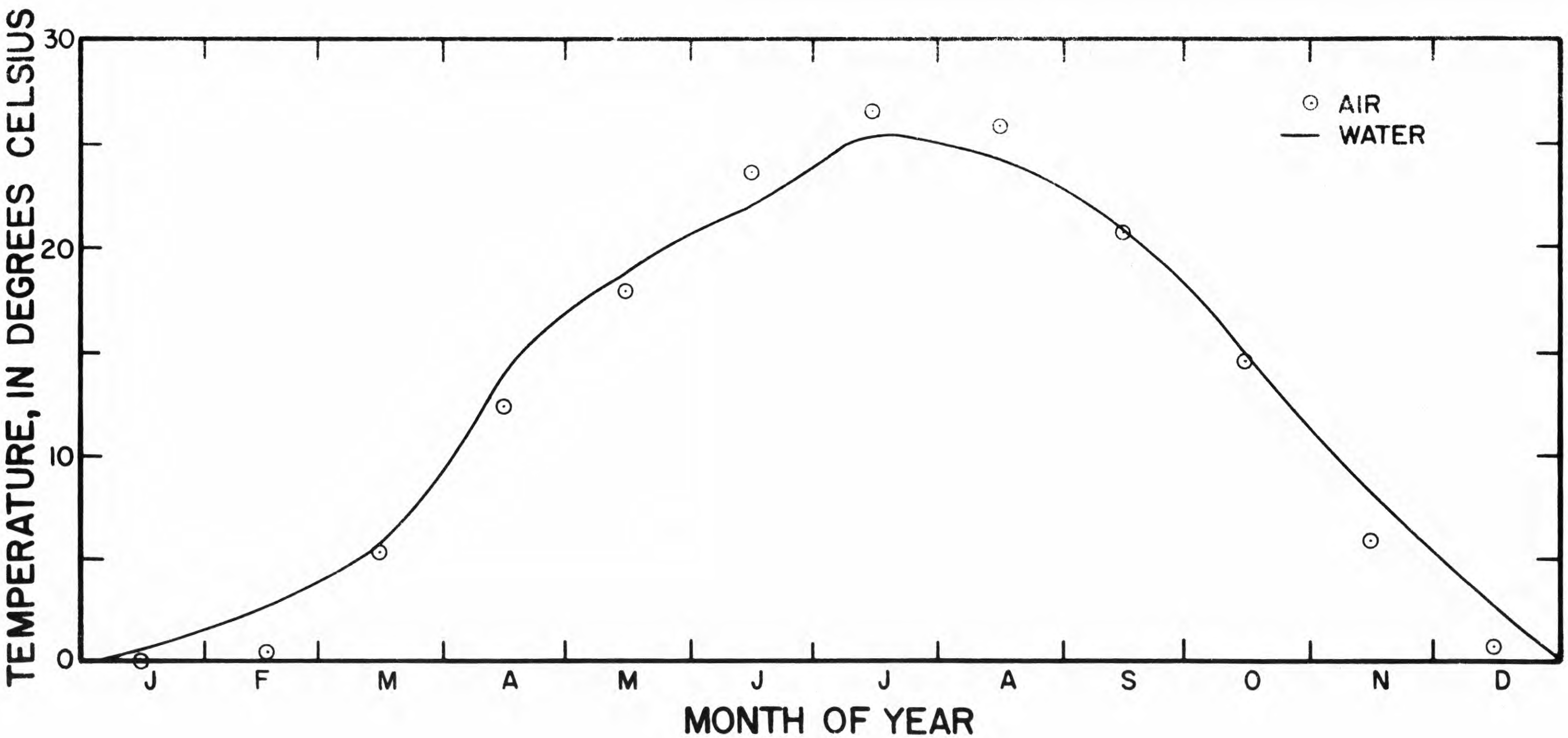


Figure 8.--Comparison of monthly mean temperature of the Kansas River at Topeka to monthly mean air temperature at Topeka, Kans.

at Port Jervis. After the analysis of water temperatures in 10 streams in Texas, Rawson (1970, p. 4) concludes that the monthly water and air temperatures seldom differ by more than 2°C and often differ by no more than 1°C. It is seen that the average natural water and air temperatures tend to be very nearly equal in many parts of the country. So "on the average," the difference between the natural air and water temperatures appears to be small.

Of course the diurnal range in air temperature is much larger than that of the water, so comparison of instantaneous temperatures is meaningless. A simplified expression for the net surface exchange is

$$H = -K\ (T - T_a) \tag{18}$$

in which K is a positive surface exchange coefficient. Notice that as $T = T_a$, $H = 0$ and no further temperature change occurs. If T is greater than T_a, H is negative, meaning the water is losing heat and $\partial T/\partial t$ is negative. Equation 18 has been used successfully to predict surface exchange on the Saint Lawrence River by Adams (1976) and it has been verified on a canal in the Netherlands by Sweers (1974).

The complete expression for the heat flux is (equations 11, 12, 13, 14, and 17)

$$H = H_N - \varepsilon\sigma(T + 273.16)^4 - \rho L\psi[(e_o - e_a) + \gamma(T - T_a)] \tag{19}$$

The empirical observation implies that at $T = T_a$, $H = 0$ or

$$H_N = \varepsilon\sigma(T_a + 273.16)^4 + \rho L\psi[e_o\Big|_{T_a} - e_a] \tag{20}$$

This is a statement that back radiation and evaporation just balance the net heat absorbed from incoming radiation. On the average, this is a reasonable assumption. In order for equation 18 to accurately represent the net heat exchange it must be valid when the water temperature differs from the air temperature as well as when the two are equal. To insure this, the change in heat exchange with a change in water temperature must be the same for both equations 18 and 19. Differentiating equations 18 and 19 with respect to water temperature and setting the slopes equal gives

$$\frac{\partial H}{\partial T} = -\ K = -\ 4\varepsilon\sigma(T + 273.16)^3 - \rho L\psi\left[\frac{\partial e_o}{\partial T} + \gamma\right]$$

from which K can be determined

$$K = 4\varepsilon\sigma(T + 273.16)^3 + \rho L\psi \left[\frac{\partial e_o}{\partial T} + \gamma\right] \tag{21}$$

in which the slope $\frac{\partial e_o}{\partial T}$ has been evaluated at the water temperature, because it is to serve as the reference temperature. An accurate empirical expression for the slope of the vapor pressure curve in kilopascals per degree Celsius is

$$\left.\frac{\partial e_o}{\partial T}\right|_T = 1.1532 \times 10^{11} \exp\left[-4271.1/(T + 242.63)\right]/(T + 242.63) \tag{22}$$

The simplified surface exchange equation is, therefore, equation 18 wherein the value of K is evaluated from equations 21 and 22. Although equation 18 appears linear in temperature, it really is not, because K is also a function of water temperature.

Expressing the conservation of thermal energy in a water parcel by use of equation 5, wherein the surface exchange is computed by use of equation 18, one obtains the equation

$$C = C_o - \int_o^t \frac{\partial(D_x \partial C/\partial\xi)}{\partial\xi} dt' + \int_o^t \Phi dt' + \int_o^t XK(C - T_a)dt' \tag{23}$$

in which C is temperature, and $XK = \frac{KW}{A\rho c_p}$ is the kinematic surface exchange coefficient. Equation 23 is identical to equation 5 except for the added decay term, which accounts for heat transfer at the air-water interface. The solution procedure is likewise identical except for the added steps necessary to evaluate the last integral. Basically, this is accomplished by the addition of two subroutines, one called DECAY, which evaluates the last integral, and one called FINK, which finds the value of the kinematic decay coefficient (XK). These subroutines are called at least once for each parcel at each time step. Subroutine DECAY subdivides the time step into smaller values (DTM) such that in the time DTM the temperature never changes by more than 10 percent of the remaining deficit (T - TA) or more than 0.3°C, whichever is larger. Since the value of XK may be different for each subreach, the subroutine DECAY is called each time a parcel passes an interior grid. For each partial time step a simple Runge-Kutta type integration is performed.

The basic program for the simplified temperature model is almost identical to the program for conservative transport with 3 exceptions. First, the additional parameters of top width, W(I), windspeed, V, air temperature, TA, and coefficients for the wind function A1, B1 must be read in. Second, an additional array PDC(K) is set up to keep track of the total temperature change due to surface exchange, and finally subroutine DECAY is called each time a parcel passes a grid point or stops in a subreach. A flow chart of subroutine DECAY is shown in figure 9. A listing of the code is shown in attachment B.

Table 1 contains a description of the data input, sequence and arrangement used for all models including the simplified temperature model. The simplified temperature model requires only the data cards or data with a "2" in column 2 of table 1. The input is the same as used in the conservative transport model except as explained below.

The first card, the information card, is identical to that used previously. The second data card, the header card, includes all information included previously plus the constant term in the wind function (A1), and the mass transfer coefficient in the wind function (B1), which are added to the end of the variable list. The format for the header card is 2I5, 2F10.2, 4I5, 2F10.2 (line 0036 in attachment B). From the thermal balance of the San Diego Aqueduct, Jobson (1977a) found the values A1 = .302 cm/d kPa and B1 = .113 cm/d (m/s) kPa.

The third set of cards are not required, and the fourth and fifth sets are identical to those described previously.

The sixth set of cards contains the top widths of the river, in meters, at each grid point. This group of cards was not needed in the conservative transport model. The format is the same as the input of the areas and coordinates, with the width at grid 1 given first. The format for these data is the same as for most other sets, 10X, 10F7.3, with the first 10 spaces a free field for card identification (line 0038, attachment B).

The seventh, eighth, and ninth sets of cards are identical to those used previously while sets 10-14 are not required.

Finally, the boundary and meteorological conditions are read with data set 15. At least one card is needed for each time step. The first card contains information relative to time 0 + Δt hours. Each card contains the upstream temperature (TUP) in degrees Celsius, the air temperature (TA) in degrees Celsius, the windspeed (V) in meters per second, and the temperature of each tributary (TRIB(N)) in degrees Celsius starting with the upstream most tributary. The format for the boundary condition cards is 10X, 10F7.3 (line 0038, attachment B). The upstream temperature, air temperature, and windspeed are input first, so if more than 7 tributaries exist, more than one card will be required for each time step. Tributary temperatures for tributaries number 8 through 17 would be input on the second card.

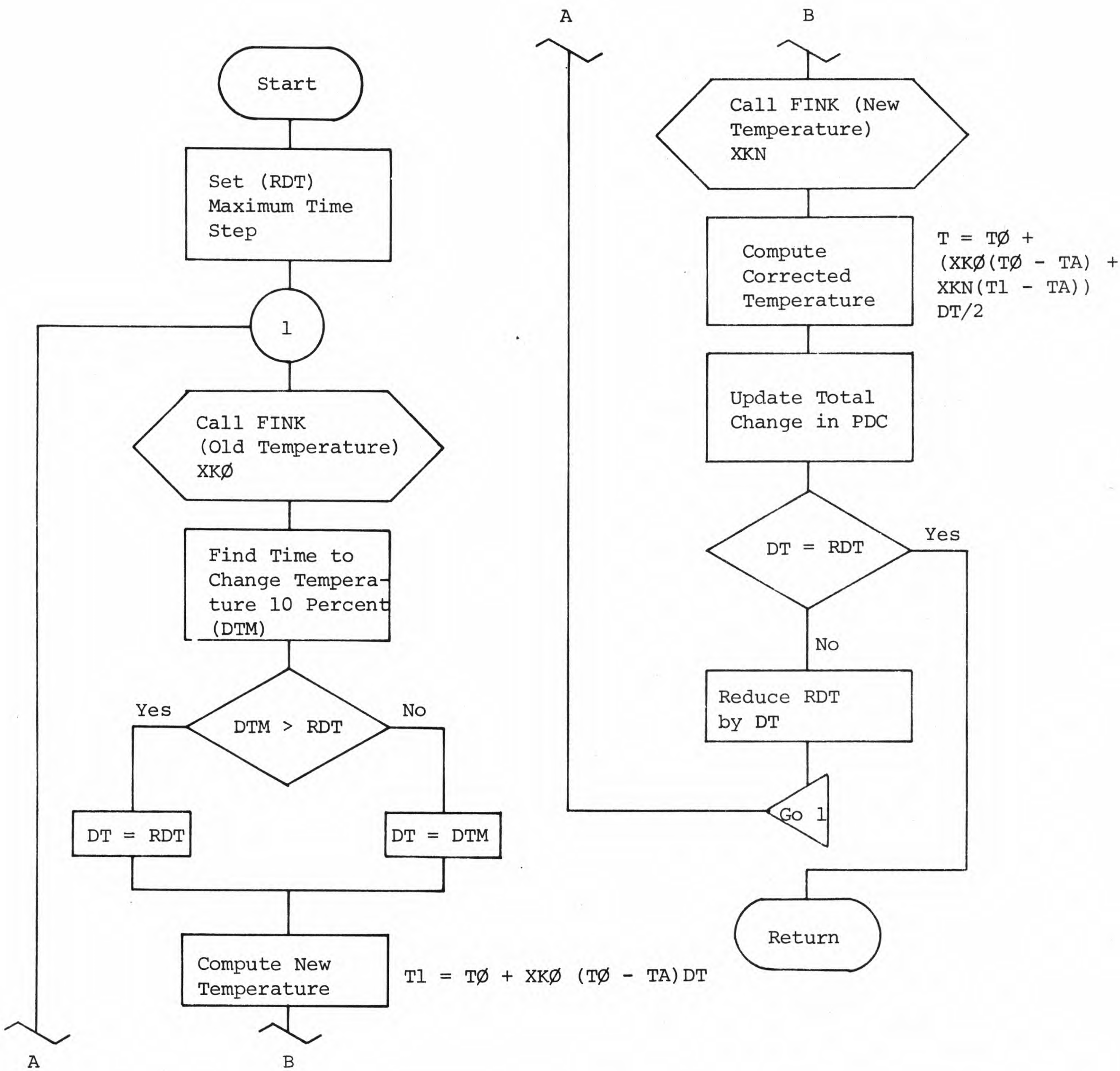


Figure 9.--Flow chart of subroutine DECAY in simplified temperature model. Variables ending in Ø designate old values. The value of XKN is evaluated at T1.

At the end of the program listed in attachment B is a listing of the data cards used in an example problem. The problem is identical to the one run for conservative transport except the data of upstream temperature, river width, air temperature, and windspeed have been added.

Finally, the output of the example problem is shown in attachment B. The first part of the output is self explanatory. The output labeled "Initial Conditions" lists the steady-state flow conditions in the steady-flow model. The model output is the third part of the listing. The first column is the time in days and hours. The next 6 columns refer to the interior grid IGØ (in this case grid 6). The second column is the temperature at grid 6 for the time in column 1. The traveltime is the time required for the parcel to traverse the distance from grid 1 to grid IGØ (6). If the model has been running less than the traveltime, this column represents the time the model has been running. The fourth column is the temperature the parcel had when it was at grid 1. Columns 5, 6, and 7 are the changes in the parcel temperature which occurred during its transit from grid 1 due to dispersion, tributary dilution, and surface exchange, respectively. The values in these columns were determined by evaluating the integrals on the right-hand side of equation 23. To illustrate, consider the output on day 2 at 16.00 hours. The parcel at grid 6 on day 2, hour 16.00, entered the system 8.45 hours earlier (day 2, 7.55 hours) with an initial temperature of 13.73°C. During its 8.45-hour transit from grid 1, dispersion had no measurable effect on its temperature, while tributary dilution increased its temperature by 0.09°C and heat exchange with the atmosphere increased its temperature by 6.22°C. The parcel, therefore, arrived at grid 6 with a temperature of 20.04°C as shown in column 2.

The last 6 columns contain the same information except that this information pertains to the downstream most grid (grid 8 in the example.) For example, the parcel which occupies grid 8 on day 2, hour 16.00, entered the system at grid 1 on day 2, hour 2.56, with a temperature of 10.94°C. During its 13.44-hour transit dispersion decreased its temperature by 0.03°C, tributary dilution increased its temperature by 0.25°C, and surface exchange increased its temperature by 9.92°C. The parcel arrived at grid 8 with a temperature of 10.94 - 0.03 + 0.25 + 9.92 = 21.08°C as shown in column 8.

COMPLETE TEMPERATURE MODEL

If meteorological data are available, the complete temperature model can give highly accurate results as shown by Jobson (1978), as well as Jobson and Keefer (1979). The additional data required for the complete temperature model include: incoming solar radiation, incoming atmospheric radiation, vapor pressure of the air, thermal heat capacity and diffusivity of the bed material, longitude, latitude, the Julian date, the meridian of the time zone, and for each subreach, the azimuth of the river, the effective barrier height of the trees along the banks, and the bank width (distance from the water edge to the trees).

The basic transport equation and solution scheme are identical to that used for the simplified temperature model (equation 10). But the complete equation set for the surface exchange (equations 11, 12, 13, 14, 15, and 17) is used instead of the simplified expression (eq. 18). In addition, the heat exchange between the water and the bed material is included. The bed conduction term is treated just like the surface exchange terms in the model.

The incoming solar and atmospheric radiation should be observed in an open area. Three percent of the atmospheric radiation is assumed to be reflected (E. Anderson, 1954, p. 98). The procedure used to estimate the part of the measured solar radiation actually absorbed by the water can be briefly explained as follows. The first step is to determine the part of the available solar radiation which would be absorbed providing no shading occurs. This shade-free absorption is calculated using an expression proposed by E. Anderson (1954, p. 85) for clear sky conditions.

$$RS = 1 - 1.18\ S_A^{-0.77} \qquad (24)$$

in which RS is the portion of the incoming solar radiation absorbed by the water and S_A is the altitude of the sun in degrees. Next, the shade-free absorption is reduced to account for shading of the water due to trees and banks. It is assumed that the shaded part of the water surface will absorb 20 percent of the incoming solar radiation and that the clear part will absorb at the rate indicated by eq. 24. The part of the water surface in any subreach to be shaded at any time of day is determined from the geometric relation between the elevation and azimuth of the sun, the azimuth of the subreach, the water surface width, the bank width, and the effective barrier height. The physical relationship between these terms is illustrated in figure 10. The river cross section is assumed to be symmetric about the centerline. At the beginning of the program the RS values, adjusted for shading, are computed for each subreach at 15-minute intervals throughout the day. In the temperature simulation the RS value for the subreach and time of day (to the nearest 15 minutes) is selected from the array which has been previously set up. A flow chart of subroutine CRS, which computes the RS values, is shown in figure 11.

The bed conduction term is evaluated in the manner outlined by Jobson (1977b). In this method the heat exchange between the water and the bed is estimated by considering the bed material to be a homogeneous

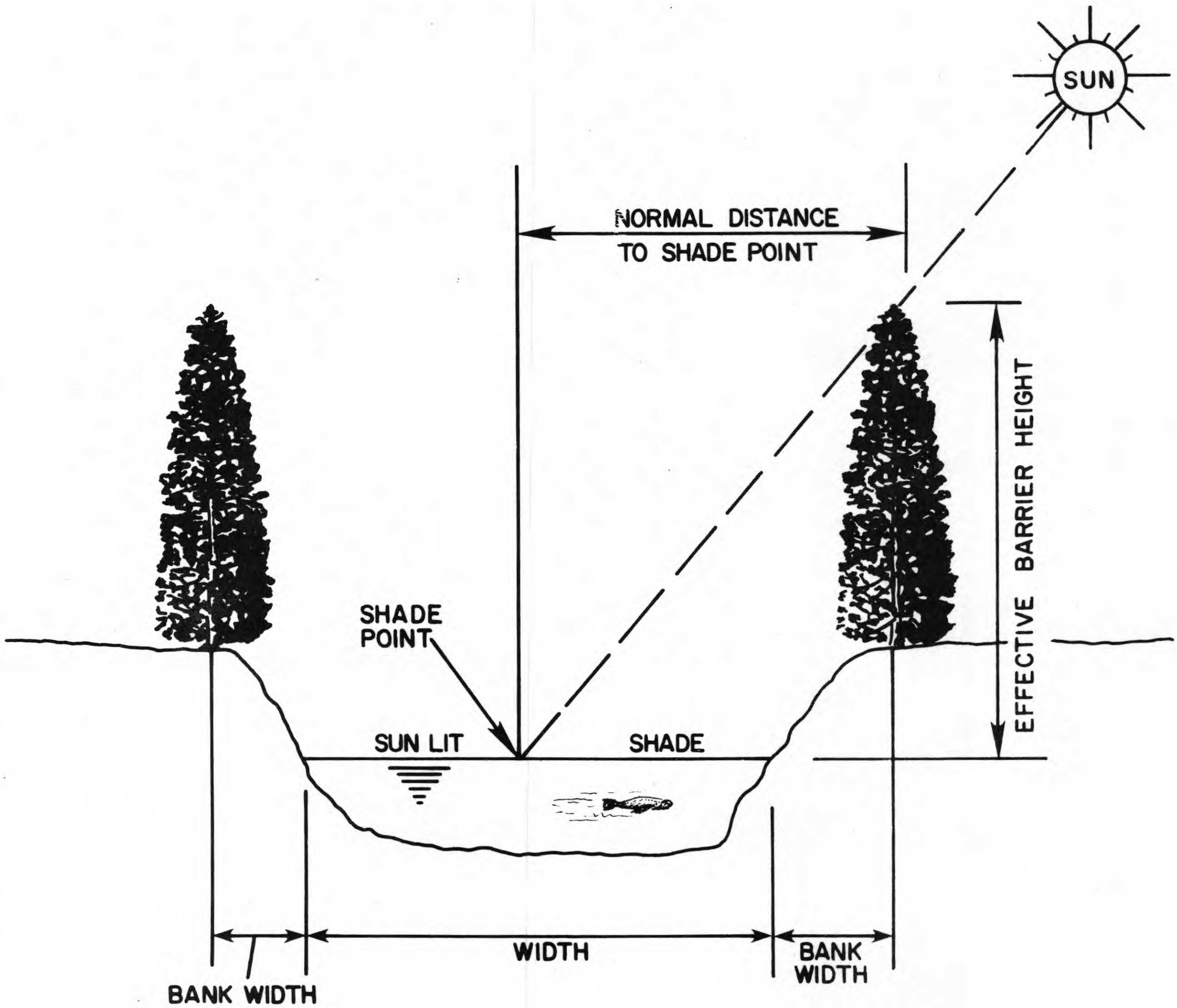


Figure 10.--Schematic of river cross section used to determine the part of the water surface to be shaded by bank vegetation.

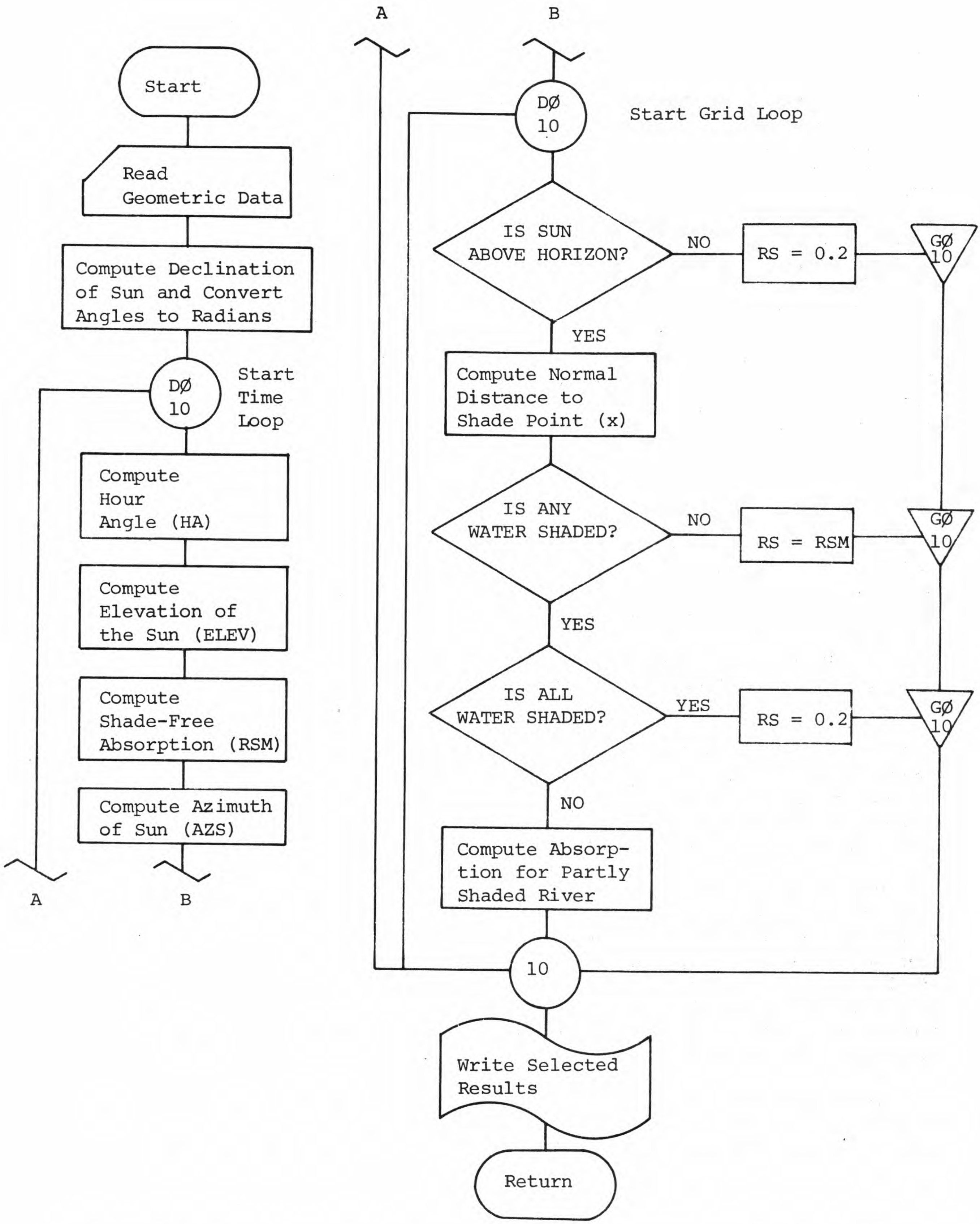


Figure 11.--Flow chart for subroutine CRS, which computes the absorption coefficients for solar radiation in the complete temperature model.

conducting medium with a surface temperature equal to that of the overlying water and the bottom, at some large distance below the bed, insulated. The heat flux into or out of the bed is then determined as a function of the past history of the water temperature. Only the thermal diffusivity and heat storage capacity of the soil need to be known. The heat flux from the bed to the water, which would occur at time t due to a unit decrease in surface temperature at time zero, is first computed for various values of t using standard formulas (Carslaw and Jaeger, 1959, p. 101.) These terms, called response function ordinates, describe the time variation of the response of the bed to a unit change in water temperature. They are computed once at the beginning of the program by use of subroutine BEDFX. The values are stored for later use in an array called RFØ(K).

Since water temperature fluctuations can be represented by a series of step changes, the superposition principle is used to determine the heat flux from the bed to the water for any temperature history of the water by use of the equation

$$\mathrm{BED(I)} = \sum_{K=J-s}^{J} \mathrm{RF\emptyset(J-K)*DBT(K,I)} \qquad (25)$$

in which BED(I) is the heat flux to the water from the bed at grid I and time JDT, DBT(K,I) is the change in water temperature which occurred at KDT and grid I, and s determines the memory length of the system. The program truncates the response function ordinates after 24 hours, so the memory of the system is limited to 24 hours. Because most water temperature variations are diurnal in nature and because the thermal diffusivity of most soils is such that the response function ordinate has reached nearly a constant value after 24 hours it is believed that a 24-hour memory is sufficient for modeling temperature in rivers. The temperatures at each grid point are determined by interpolation between parcels at each time step. A flow chart of subroutine BEDFX, which computes the response function ordinates, temperatures at each Eulerian grid, and the bed flux at each grid is shown in figure 12.

The complete temperature model is very similar to the simplified temperature model except: (a) additional meteorological data are required on the boundary condition cards; (b) subroutine FINK is more complex because it computes the total surface exchange from equations 11, 12, 13, 14, 15, and 17 rather than simply equations 18, 21, and 22; (c) the absorption coefficients for each time of day and grid point are computed by subroutine CRS; and (d) the flux of heat from the bed to the water is computed for each grid point and time step by subroutine BEDFX.

The input data cards for the complete temperature model are similar to those of the simplified temperature model. The first two data cards are, in fact, identical to those used in the simplified temperature

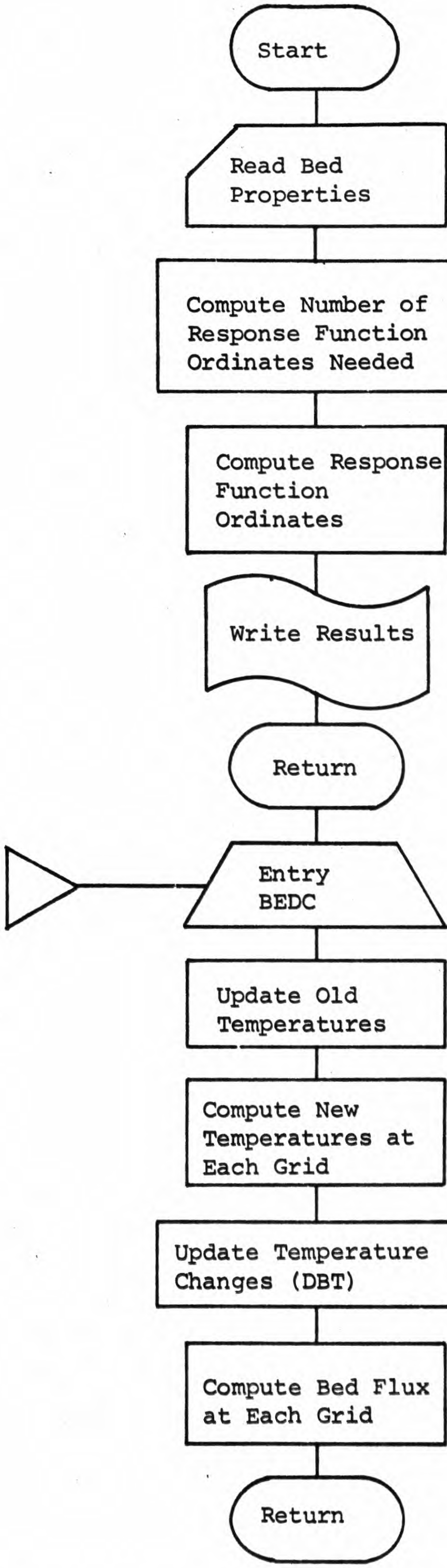


Figure 12.--Flow chart of subroutine BEDFX, which computes the response function ordinates, water temperatures at Eulerian grids, and the heat flux from the bed to the water.

model. The format statements for these two cards are given as lines 0038 and 0040 in the listing of the main program of attachment C. Table 1 summarizes data input arrangements for all models. Only those cards or variables indicated for model 3 in column 2 of table 1 are necessary.

The third set of cards (Table 1) are not needed and the fourth, fifth, sixth, seventh, eighth, and ninth sets are identical to those of the simplified temperature model.

Data sets 10 through 13 contain information necessary to compute the absorption coefficient for solar radiation. Set 10 contains the Julian data (JDAT), the latitude (PHI in degrees), the longitude (ALØN in degrees), and the longitude of the meridian of the time zone (TZM in degrees). The format is 10X,I7,3F7.1 (line 0006 in CRS of attachment C).

Data set 11 contains the azimuth of the river at each grid point measured clockwise from north in degrees. The format is 10X, 10F7.1 (line 0010 in CRS of attachment C).

Data set 12 contains the bank width of the river at each grid point expressed in meters. The bank width (BW) is the horizontal distance from the water's edge to the highest point in the shade barrier of the bank, see figure 10. The format for these data is also 10X, 10F7.1 (line 0010 in CRS of attachment C).

Data set 13 contains the effective barrier height, EBH, (figure 10) expressed in meters. The format for these data is also 10X, 10F7.1 (line 0010 in CRS of attachment C).

Data set 14 contains information necessary to compute the flux of heat from the bed. This card contains the thermal diffusivity of the bed (DIF in cm^2/h) and the heat storage capacity of the bed material [CV in $cal/(cm^3 °C)$]. The format is 10X,2F7.3 (line 0008 in BEDFX of attachment C). Braslavskii and Vikulina (1963) suggest values of DIF = 27.72 cm^2/h and CV = 0.68 $cal/(cm^3 °C)$ for saturated sand. Troxell and others (1956) reported values of DIF to range from 21.96 cm^2/h to 50.76 cm^2/h and CV = 0.55 $cal/(cm^2 °C)$ for concrete dams.

The final group of data cards (set 15) contains the boundary and meteorological data for each time step in the model. The first card in this group contains only the upstream temperature at the end of the first time step (TUP, in degrees Celsius), and meteorological data representative of conditions during the first time step. The meteorological data include the air temperature (TA, in degrees Celsius), the windspeed (V, in meters per second), the incoming solar radiation (HS, in calories per square centimeters per day), the incoming atmospheric radiation (HL, in calories per square centimeter per day), and the vapor pressure of the air (EA, in kilopascals). The read statement is given in line 0120 of attachment C and the standard format (10X, 10F7.3) is given in line 0040. If no tributaries are present, only one card will be required for each time step. If tributaries are present the temperature of each tributary inflow at the time step is provided on cards following the meteorologic data for each time step. The tributary inflow temperatures are provided in sequence working downstream with 10 tributaries on each card (line 0121 in attachment C). The standard format is used. Lines 0120 and 0121 are executed once for each time step in the model so meteorologic data for time step 1 should be followed by the tributary inflow temperature cards for time step 1, which in turn is followed by the meteorologic data card for time step 2, and so forth.

At the end of the program listed in attachment C is a listing of the data cards used to generate the example problem. The problem is identical to the one run for the simplified temperature model except for the added data necessary for the complete temperature model. The output of the example problem is also shown in attachment C. The first part of the output is self explanatory. The second part of the output lists the portion of the incoming solar radiation absorbed at each grid and each hour of the day from 5 a.m. to 7 p.m. The effective barrier height, bank width and azimuth of the river is also shown for each grid point. The third part of the output shows the response of the bed in cal/cm^{2}h to a unit change in water temperature for various times (lags) after the water temperature change occurred. For example, 5 hours after a unit decrease in water temperature occurs (lag 5 and DT = one hour) the bed would transfer heat to the water at a rate of 0.95 cal/cm^{2}h (RFØ = 0.95). If the time step size is less than 15 minutes the RFØ values will be tabulated at 15-minute intervals. The fourth part of the output is identical to that in previous programs in that it shows the hydraulic properties and initial temperature of the river at each grid point. The first column of the last part of the output is the current time in days and hours. The next 6 columns refer to the interior grid IGØ (in this case grid 6). The second column is the temperature at grid 6 for the current time in column 1. The traveltime is the time required for the parcel to traverse the distance from grid 1 to grid IGØ (6). If the model has run a sufficient time the fourth column is the temperature the parcel had when it was at grid 1. Columns 5, 6, and 7 are the changes in the parcel temperature which occurred during its transit from grid 1 due to dispersion, tributary dilution, and surface exchange (including bed conduction), respectively. To illustrate, consider the output on day 2 at 12.00 hours. The parcel at grid 6 on day 2, hour 12, entered the system 8.45 hours earlier (2 days, 3.55 hours) with an initial temperature of 12.22°C. During its 8.45-hour transit from grid 1, dispersion decreased its temperature by 0.02°C, while tributary dilution increased its temperature by 0.38°C and heat exchange with the atmosphere and bed increased its temperature by 2.16°C. The parcel, therefore, arrived at grid 6 with a temperature of 14.71°C as shown in column 2.

The last 6 columns contain the same information except that this information pertains to the downstream-most grid (grid 8 in the example). For example, the parcel which occupies grid 8 on day 2, hour 16.00, entered the system at grid 1 on day 2, hour 2.56, with a temperature of 12.67°C. During its 13.44-hour transit, dispersion decreased its temperature by 0.07°C, tributary dilution increased its temperature by 0.38°C, and heat exchange with the atmosphere and bed increased its temperature by 3.09°C. The parcel arrived at grid 8 with a temperature of 12.67 - 0.07 + 0.38 + 3.09 = 16.07°C as shown in column 8.

10-PARAMETER GENERAL TRANSPORT MODEL

Many water-quality parameters are interdependent. For example, the concentration of dissolved oxygen in a stream is a function of the concentration of several other parameters such as BOD, ammonia, nitrite, nitrate, and so forth. In order to model water quality, therefore, it is usually necessary to model several interdependent parameters simultaneously. This means that the conservation equation must be written for each constituent and then the equations must be solved simultaneously. The 10-parameter transport model was developed to accomplish this task.

To illustrate the procedure, a temperature, DO, BOD system will be used as an example. The first step is to write the transport equation, in the Lagrangian reference frame, for each constituent. For the temperature of a parcel, assuming the simplified temperature model is adequate,

$$\frac{\partial T}{\partial t} + \frac{\partial}{\partial \xi} D_x \frac{\partial T}{\partial \xi} = XK_{1,1} (T - T_a) - \Phi_T + S_T \tag{26}$$

in which T = temperature, $XK_{1,1}$ = XK of equation 23, S_T is a term to account for the production of heat within the water (generally zero), and all other terms are as defined in equation 23 except the tributary source term, Φ, has been subscripted.

For dissolved oxygen

$$\frac{\partial DO}{\partial t} + \frac{\partial}{\partial \xi} D_x \frac{\partial DO}{\partial \xi} = XK_{2,2}(DO - DO_S) + XK_{2,3}BOD + \Phi_D + S_D \tag{27}$$

in which DO = concentration of dissolved oxygen (mg/L), $XK_{2,2}$ = negative of the reaeration rate coefficient (commonly referred to as K_2), DO_S = saturation value of dissolved oxygen (which is a function of temperature), BOD = biochemical oxygen demand, $XK_{2,3}$ = the negative of the biochemical oxidation rate coefficient (commonly referred to as K_1), S_D = distributed source of dissolved oxygen in the water, and Φ_D = source of dissolved oxygen from point sources such as inflows.

For biochemical oxygen demand

$$\frac{\partial BOD}{\partial t} + \frac{\partial}{\partial \xi} D_x \frac{\partial BOD}{\partial \xi} = XK_{3,3}BOD + \Phi_B + S_B \tag{28}$$

in which $XK_{3,3}$ = the sum of the biochemical oxidation rate coefficient ($-K_1$) and the sedimentation rate coefficient for BOD, S_B = distributed sources of BOD in the water, and Φ_B = sources of BOD from tributaries or point sources.

Equations 26, 27, and 28 are similar in form and can be written in consistent, but general, notation as follows.

Temperature

$$\frac{\partial C_1}{\partial t} + \frac{\partial}{\partial \xi} D_x \frac{\partial C_1}{\partial \xi} = XK_{1,1}(C_1 - CR_{1,1}) + XK_{1,2}(C_2 - CR_{1,2})$$

$$+ XK_{1,3}(C_3 - CR_{1,3}) + S_1 + \Phi_1$$

DO

$$\frac{\partial C_2}{\partial t} + \frac{\partial}{\partial \xi} D_x \frac{\partial C_2}{\partial \xi} = XK_{2,1}(C_1 - CR_{2,1}) + XK_{2,2}(C_2 - CR_{2,2})$$

$$+ XK_{2,3}(C_3 - CR_{2,3}) + S_2 + \Phi_2$$

BOD

$$\frac{\partial C_3}{\partial t} + \frac{\partial}{\partial \xi} D_x \frac{\partial C_3}{\partial \xi} = XK_{3,1}(C_1 - CR_{3,1}) + XK_{3,2}(C_2 - CR_{3,2})$$

$$+ XK_{3,3}(C_3 - CR_{3,3}) + S_3 + \Phi_3 \tag{29}$$

in which C_1 = temperature, C_2 = DO, C_3 = BOD, and so forth. In particular, $XK_{1,2} = XK_{1,3} = XK_{2,1} = XK_{2,3} = XK_{3,1} = XK_{3,2} = 0$. The $CR_{L,N}$ values represent the reference concentrations. For example, $CR_{1,1}$ = TA, $CR_{2,2}$ = saturation value of DO (DO_S) and $CR_{3,3} = 0$. Equation 29 can then be written concisely in a form convenient for computational manipulation.

$$\frac{\partial C_L}{\partial t} + \frac{\partial}{\partial \xi} D_x \frac{\partial C_L}{\partial \xi} = S_L + \Phi_L + \sum_{N=1}^{M} XK_{L,N} (C_N - CR_{L,N}) \qquad (30)$$

The values of $XK_{L,N}$, $CR_{L,N}$, or S_L may be a function of time, space or even the concentrations of other constituents.

The approach to solving the M equations represented by 30 is the same as that used for the simplified temperature model, that is, in subroutine DECAY the time step is subdivided into smaller values (DTM) such that in the time DTM the concentration of no parameter changes by more than 10 percent of the remaining deficit ($C_N - CR_{L,N}$) or more than 0.3 units, whichever is larger. Since the values of $XK_{L,N}$ may differ from subreach to subreach, the subroutine DECAY is called each time a parcel passes an interior grid. For each part of the time step a simple Runge-Kutta type integration is performed. The value of each of the coefficients S_L, $XK_{L,N}$, $CR_{L,N}$ is determined in subroutine FINK just as in the simplified or complete temperature model. Subroutine FINK is called twice for each part of the time step so that the values of the coefficients are updated in the event that they are functions of the concentration of the other constituents.

Figures 13, 14, and 15 contain simplified flow charts of the 10-parameter transport model, subroutine DECAY, and subroutine FINK, respectively. In general, the only difference between this model and the simplified temperature model is that subscripts have been added to temperature variables to designate the particular parameter. For example, the old variable PT(K), the temperature of parcel K, becomes PT(L,K) in which L designates the particular constituent and K remains the parcel number. The program allows up to 10 constituents to be modeled, the number being modeled is designated by NEQ (number of equations). The model could be expanded to track more than 10 constituents simply by increasing the array sizes in the dimension and common statements. The model input and output is specifically set up assuming temperature will be modeled by the simplified model and will be constituent number one. Almost any model will require temperature, so this is not believed to be a serious limitation.

The main program and subroutine DECAY are completely general and simply solve equation 30 for any number of constituents. It is up to the modeler to define the coefficients S_L, $XK_{L,N}$, and $CR_{L,N}$ in subroutine

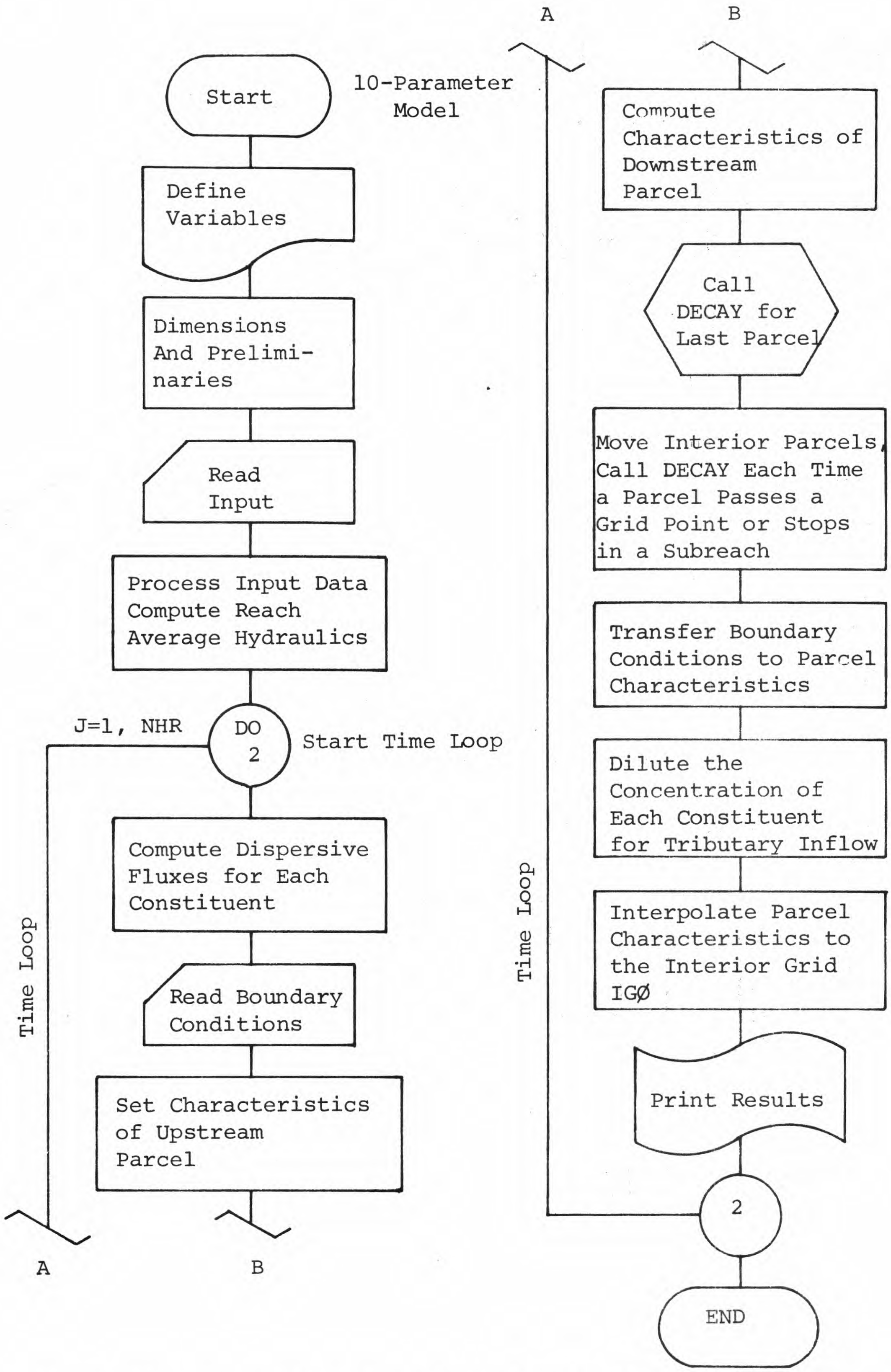


Figure 13.--Generalized flow chart for the 10-parameter transport model.

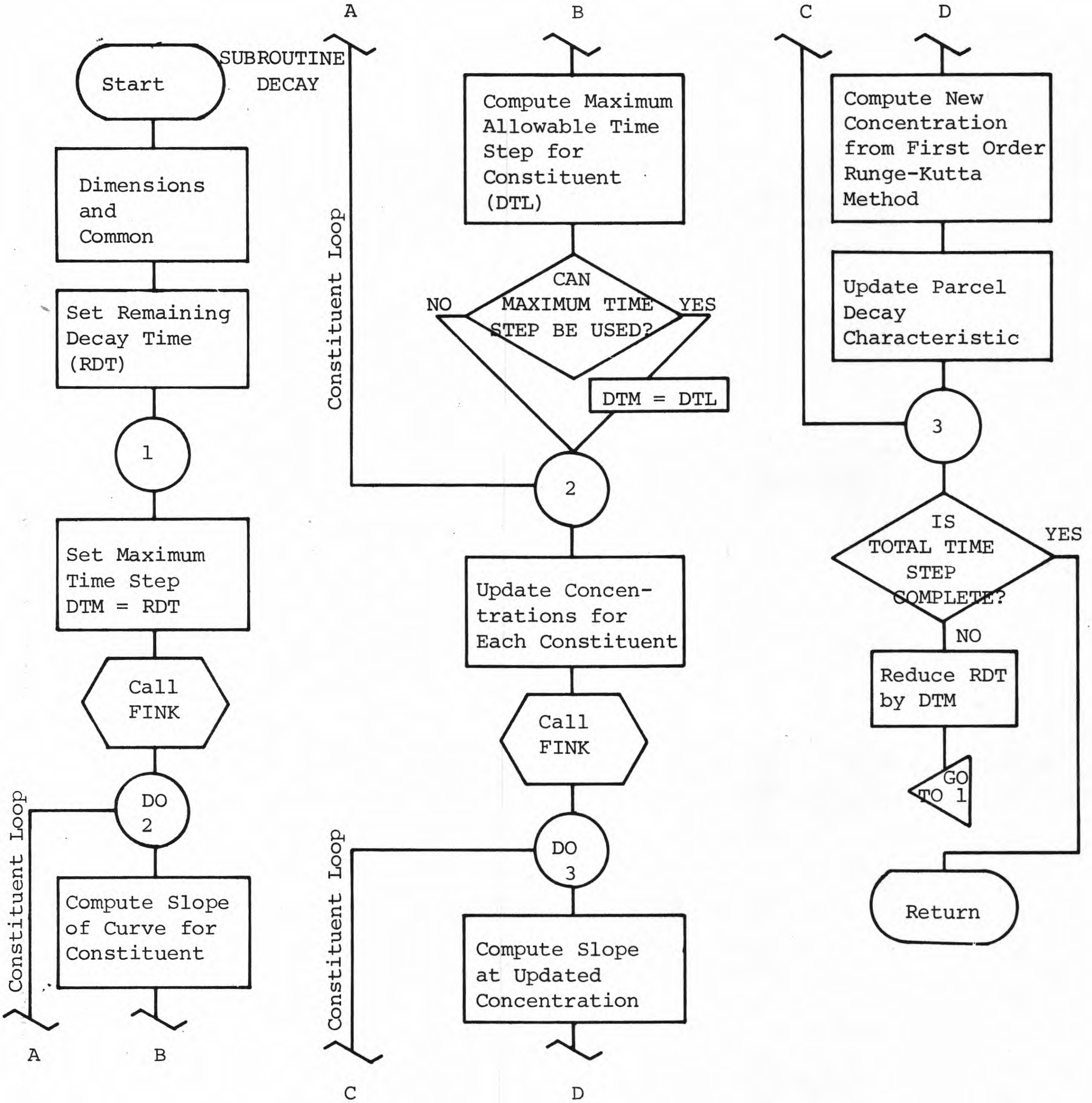


Figure 14.--Generalized flow chart for subroutine decay in the 10-parameter model.

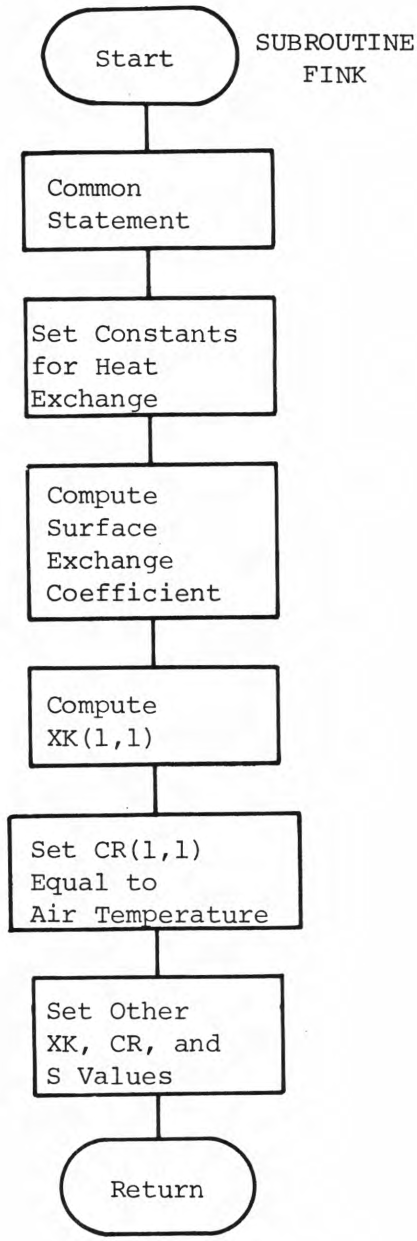


Figure 15.--Generalized flow chart for subroutine FINK in the 10-parameter model.

FINK such that equation 30 is a realistic description of the interaction of the constituents involved. These coefficients can be a function of the concentration of other constituents [PT(L,K)], air temperature (TA), windspeed (V), cross-sectional area of the stream [A(MX)], top width of the stream [W(MX)], velocity of the stream [U(MX)], or the time step number (J) since all these variables are carried into subroutine FINK by use of a common statement. The change in concentration of each constituent due to any other single constituent can be tabulated.

In order to illustrate how to set the program up for a particular problem, attachment D contains a complete listing of the program which has been set up to model 3 parameters, temperature (L=1), dissolved oxygen (L=2), and biochemical oxygen demand (L=3). All statements unique to these three parameters are in subroutine FINK. The temperature equation is developed first. Comparing equation 26 to equation 30 it is easily seen that all values of $XK_{1,N}$ are zero except $XK_{1,1}$ which is the surface exchange coefficient used formerly. Lines 3 through 10 of subroutine FINK compute the surface exchange coefficient. Notice that this coefficient is a function of the water temperature, and the windspeed, as well as the width and cross-sectional area of the river, which vary with time and location. The reference "concentration" for water temperature is the air temperature as seen in line 11. The source term for heat, S, is zero so no definition is required. All values of the XK's, CR's and S's are set equal to zero at the beginning of the program and will remain zero unless set otherwise in subroutine FINK.

The equation for dissolved oxygen (eq. 27) has more terms which are not zero. The river gains oxygen through reaeration at the surface with a rate dependent on the reaeration coefficient $XK_{2,2}$ and the difference between the dissolved oxygen concentration [PT(2,K)] and the saturation value for dissolved oxygen concentration ($CR_{2,2}$). The value of the reaeration coefficient is computed by use of an empirical formula in units of one per hour (Rathbun and Bennett, 1972, p. 58) in line 12. Notice this coefficient is also a function of the hydraulic properties of the stream. The saturation concentration of dissolved oxygen ($CR_{2,2}$) is computed as a nonlinear function of water temperature (statement 16). Oxygen is used up in the decay of the BOD. The rate coefficient is called $XK_{2,3}$ in the model and has been assigned a value of -0.1 per hour at 20°C (statement 14). The value is also corrected for temperature as shown in statement 13. The value assumed in this example is extremely large and should not be considered realistic. The large value was assumed so that a large part of the dissolved oxygen sag curve could be modeled in the 25-hour traveltime used in the example. The model suddenly stops the BOD decay when the dissolved oxygen level drops to 1 mg/L (statement 15). Again this is not necessarily a realistic representation of how the system behaves as the oxygen levels become very small, but it does illustrate how the model could be easily generalized to allow non-linear interactions.

Finally the equation for biochemical oxygen demand (BOD) (eq. 28) contains only one non-zero coefficient on the right side. The biochemical oxygen demand coefficient (K_1) is also used as $XK_{3,3}$. The value of $XK_{3,3}$ is set equal to the value of $XK_{2,3}$ in statement 17.

The example problem shown in attachment D has the same channel characteristics as used in the previous examples, except the upstream discharge is reduced to 6 m^3/s and the single tributary is assumed to occur at grid 2. The upstream temperature, as well as the air temperature and windspeed, are assumed to vary in the same manner as those assumed in the example for the simplified temperature model. The upstream concentration of DO and BOD are assumed constant at 10.0 and 2.0 mg/L, respectively. The tributary inflow of 0.65 m^3/s is assumed to have a constant temperature, DO, and BOD of 20°C, 3.0 mg/L and 100 mg/L, respectively.

The input cards for the 10-parameter model are similar to those for the previous models. The data input is summarized in table 1. The information card is identical to that used for all other models. The second data card contains the same information in the same format as in the temperature models, except that it has one additional parameter, the number of equations (parameters) to be modeled (NEQ). This number appears in columns 71-75, right justified. The format is given as statement number 0047 in the main program of attachment D.

The third set of cards contains labeling information and information about which part of the decay process the program is to tabulate. There must be one card for each parameter modeled (NEQ cards) and the cards must be in the same order as the equations to be modeled. That is, the label card for temperature must be first since temperature is always modeled as constituent number 1. For the example given above the dissolved oxygen card would be second and the BOD card would be third. Each card contains three items of information. The first is simply the parameter number (L), the second is an alphanumeric free field in which the parameter is named. In the example listed in attachment D the first parameter, temperature, is named TEMP, the second parameter, dissolved oxygen concentration, is named DO, and the third parameter, biochemical oxygen demand, is named BOD. The third item of information is a number which designates the particular decay process to be tabulated. The Lagrangian model integrates equation 30 with respect to time to obtain the parcel concentrations. The program is set up to retain the time integral of any single term of the summation on the right side of equation 30. The particular term N, which is to be tracked, is designated by the number listed as the third parameter on the same card. For example, in the problem of attachment D the first name card is

```
1        TEMP        1
```

for which the first parameter is named TEMP and the time integral of the first term of the sum on the right of equation 30 is to be tabulated.

In this case the other two terms are identically zero. The decay term in the output for temperature is the change in temperature due to surface exchange. In the example the decay term in the DO parameter represents the integral of the second term, reaeration.

The fourth, fifth, sixth, seventh, and eighth sets of cards are identical to those of all previous models.

The ninth set of cards contains the initial conditions (temperature or concentration) at each grid point. The initial temperatures (parameter 1) are read first just as in the previous models. The format is 10X, 10F7.3 (line 0051, attachment D) for each parameter. After the initial temperatures are read the initial values of the concentrations of parameter 2 are read starting with a new card, then the initial conditions for parameter 3, and so forth.

The final group of data cards, set 15, contains the boundary conditions and meteorological data for each time step of the model. The first card in this group contains the upstream temperature at the end of the first time step [TUP(1), in degrees C], the air temperature (TAX, in degrees C), representative of conditions during the first time step, the windspeed (VX, in meters per second), representative of conditions during the first time step, and the temperature of as many as seven tributaries [TRIB(1,N)X, in degrees C], representative of inflow conditions during the first time step. If more than 7 tributaries exist, the second card will contain the temperatures of up to 10 more tributaries. The format for all boundary condition cards is 10X, 10F7.3 (line 0051, attachment D). The tributary temperatures must be input in sequence starting with the upstream-most tributary. After all tributary temperatures for time step 1 are input, the next card contains the upstream concentration of parameter 2 at the end of time step 1 followed by up to 9 tributary concentrations representative of time step 1. If more than 9 tributaries exist, the additional tributary concentrations are input by additional cards just like the tributary temperatures. Following the input of all tributary concentrations of parameter 2, time step 1, the upstream concentrations of parameter 3 is input followed by the concentrations of parameter 3 in all tributaries. After all boundary conditions are input for time step 1 the process is repeated for time step 2 and so on.

At the end of the program listed in attachment D is a listing of the data cards used to generate the example problem. The problem is identical to the one run for the simplified temperature model except the upstream discharge has been cut in half, and the tributary is input at grid 2 instead of grid 5. The river cross-sections are assumed to be the same as before. The output of the example problem is also shown in attachment D. The first part of the output is self explanatory. The second part of the output contains the hydraulic and initial conditions at each grid. The initial values of all three parameters were assumed to be zero. The third part of the output contains the computed parameters for each time step where output is specified. The first line of each output step contains the time in days and hours, the traveltime from the upstream boundary to the output grid, either grid IGØ or the downstream end of the reach. If this traveltime is equal to the total time the model has run, the parcel was in the system at time zero. The second line contains information relative to parameter 1 as described by the headings. The name of the parameter is listed first followed by the concentration or temperature of the parcel which currently occupies the location of the indicated grid. The concentration of the parcel as it entered the system is given in the third column and the change in concentration of the parcel during its travel from the upstream boundary to the indicated grid due to dispersion, tributary dilution, and decay, respectively, are given next. The decay term represents only the change in concentration due to interaction with the constituent listed following the decay term. The values of these terms are determined by evaluating the integral with respect to time of the terms on the righthand side of equation 30. The decay term represents only the integral of one term of the sum, however, and the particular term is the one involving the dependent variable named after the decay column.

In order to illustrate, consider the output on day 2, hour 10.00. The parcel at grid 6 entered the system 15.90 hours earlier (day 1, hour 18.10) with an initial temperature of 9.08°C (column 3, line 2), an initial DO concentration of 10.0 mg/L (column 3, line 3), and an initial BOD concentration of 2.00 mg/L (column 3, line 4). During its 15.90-hour transit time, dispersion increased its temperature by 0.23°C (column 3, line 2), decreased its DO by 0.06 mg/L (column 3, line 3), and decreased its BOD by 0.09 mg/L (column 3, line 4). Meanwhile, the tributary inflow at grid 2 increased its temperature by 1.03°C (column 4, line 2), decreased its DO by 0.72 mg/L (column 4, line 3), and increased its BOD by 9.61 mg/L. Surface exchange increased its temperature by 7.76°C (column 5, line 2). Since the temperature is not dependent on DO or BOD (the second and third terms in the sum of eq. 30 for parameter 1 are zero) the temperature of the water as it arrived at grid 6 was 9.08 + 0.23 + 1.03 + 7.76 = 18.10°C as shown in column 2, line 2. Looking next at the BOD parameter, the decay which was tabulated is due to the BOD term. Like temperature there is only one non-zero term in the summation indicated in equation 30. Therefore, the parcel at grid 6 started with a BOD of 2.0 mg/L, lost 0.09 mg/L due to dispersion, gained 9.61 mg/L due to tributary inflow, and lost 7.22 mg/L due to aerobic decay so it arrived at grid 6 with a BOD concentration of 2.0 - 0.09 + 9.61 -7.22 = 4.30 mg/L as shown in column 2, line 4. The oxygen concentration, on the other hand, changes both due to reaeration (the second term in the sum) as well as due to BOD decay (the third term in the sum). Only one of these terms can be tabulated in the model. The reaeration term was selected and the model indicated that the parcel gained 5.29 mg/L of DO due to reaeration. The model could be rerun while tabulating the BOD decay of oxygen (changing the last number on the second input name card from a 2 to a 3) but since there is a one-to-one relationship between BOD decay and oxygen demand, this is not necessary (the sedimentation rate was assumed zero). It is obvious that the oxygen loss due to BOD decay is 7.22 mg/L. Therefore, the water parcel entered the system with a DO level of 10 mg/L, lost 0.06 mg/L due to dispersion with adjacent parcels, lost 0.72 mg/L due to tributary inflow, gained 5.29 mg/L due to reaeration, and lost 7.22 mg/L which was consumed by the BOD decay, therefore, it arrived at grid 6 with a DO level of 10 - 0.06 - 0.72 + 5.29 - 7.22 = 7.29 mg/L as shown in column 1, line 3.

The output at the downstream end (grid 8) is interpreted in the same way.

For purposes of this example, the characteristics of all parcels are written after the last time step by the addition of statements 0296 through 0305 to the main program. The longitudinal variation of the heat budget terms are plotted in figure 16 in which the computed temperature is plotted as the top curve. The bottom curve represents the temperature of the water parcel as it entered the system and the centerline represents the temperature a parcel would have had providing no surface exchange had taken place, that is, the initial temperature plus the change in temperature due to tributary inflow. Notice the warming of the tributary inflow is large when the initial river temperature is low and small when the initial river temperature is large since the tributary inflow temperature is assumed constant at 20°C and the tributary is not far downstream of the upper end of the reach. Since the river is generally swift in the upstream part and sluggish in the downstream part, surface exchange is more apparent near the downstream end.

The longitudinal variation of the dissolved oxygen budget terms are plotted in figure 17. Here the computed value is the bottom curve. The DO minimum is apparent at about river mile 349 (between grids 5 and 6). The upstream DO and the DO of the tributary inflow were assumed constant so the initial DO and the tributary inflow effect are not a function of distance as was the initial temperature. The amount of oxygen added to the river by reaeration and the amount used in satisfying the BOD are indicated in the figure.

Finally, the longitudinal variation of the BOD budget terms are shown in figure 18. In this case the effect of dispersion, which is always small, is also shown. This term was ignored in figures 16 and 17 although the computed values can be obtained from the listing.

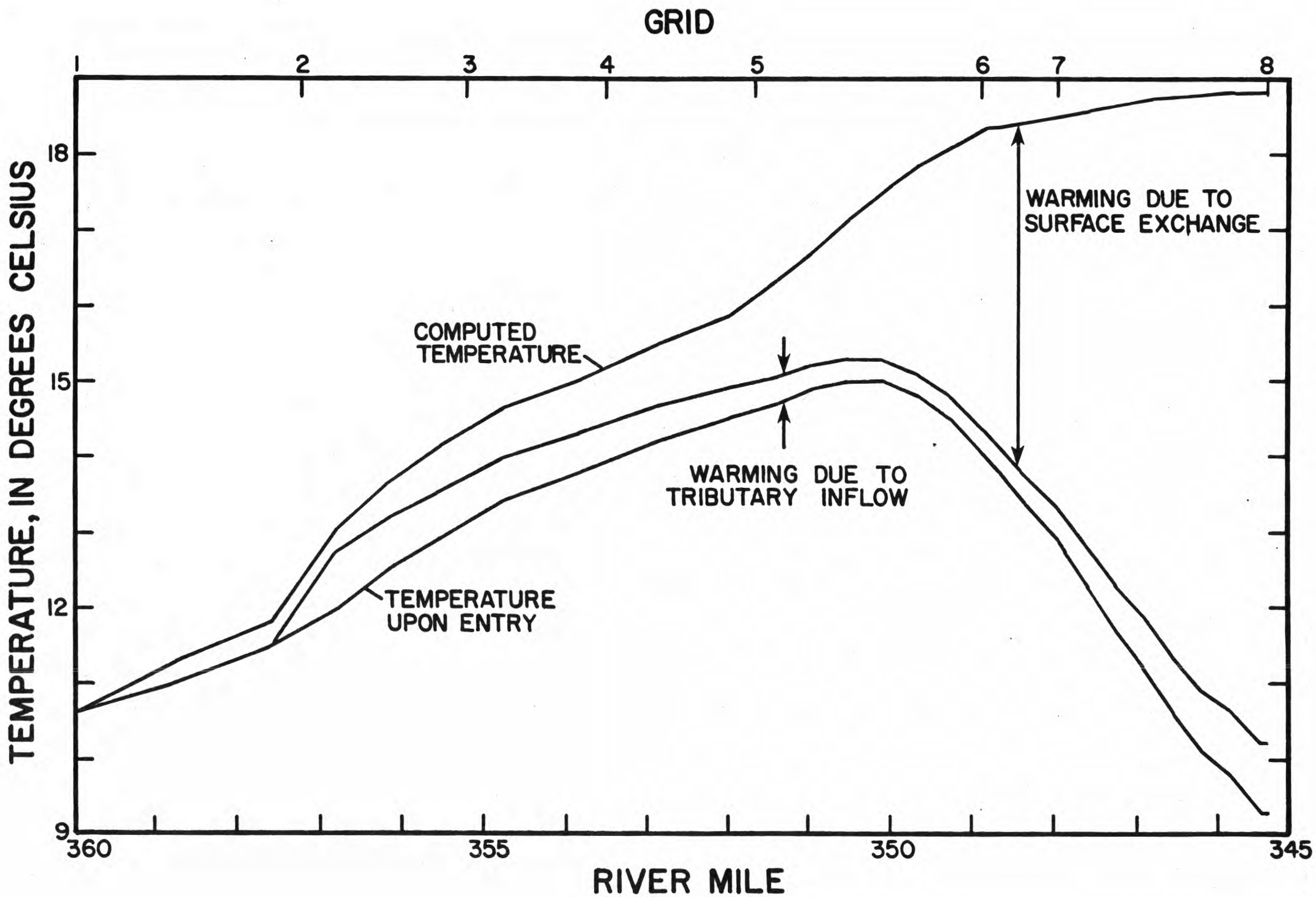


Figure 16.--Longitudinal variation in temperature for example problem, after 40 time steps.

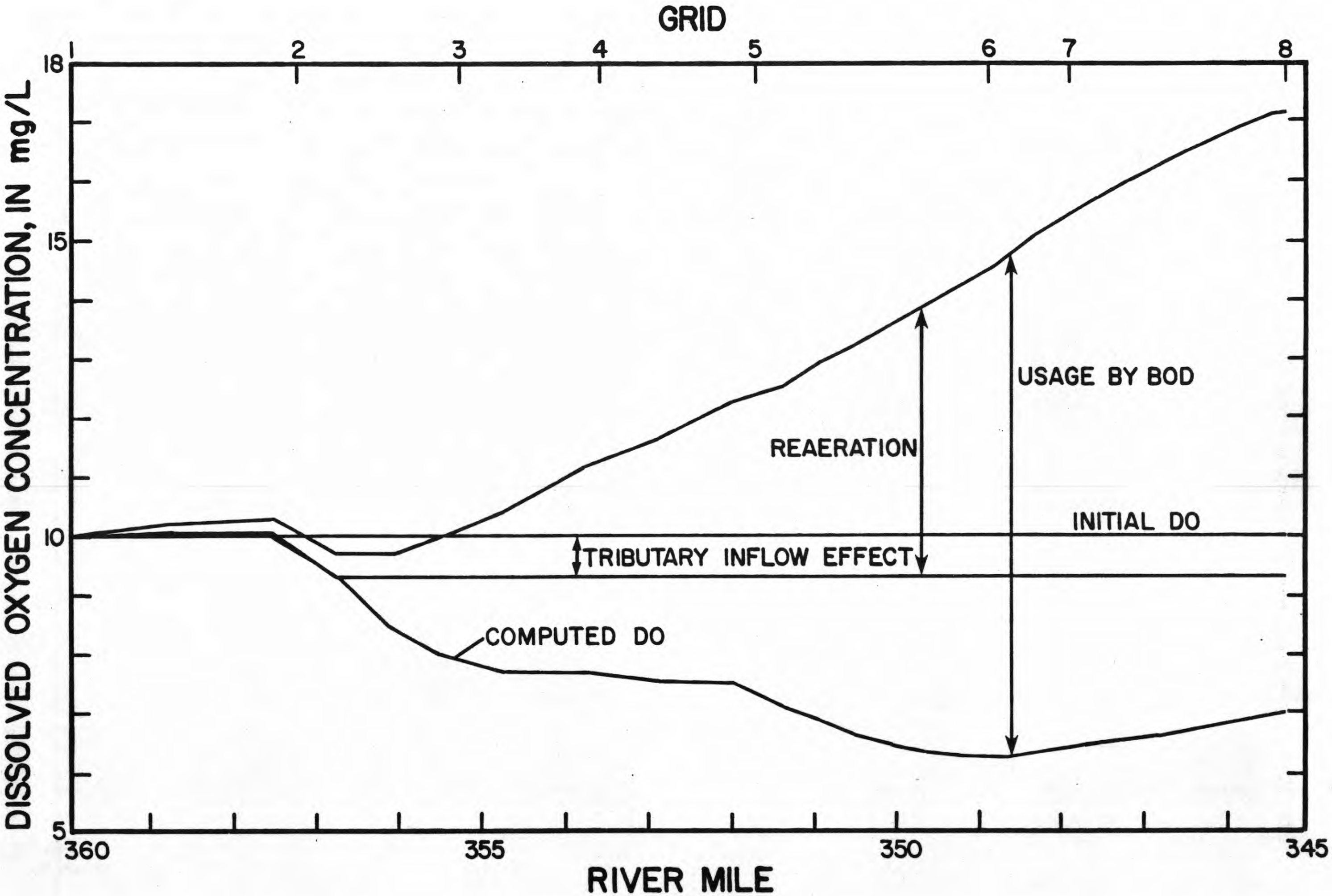


Figure 17.--Longitudinal variation in dissolved oxygen for example problem, after 40 time steps.

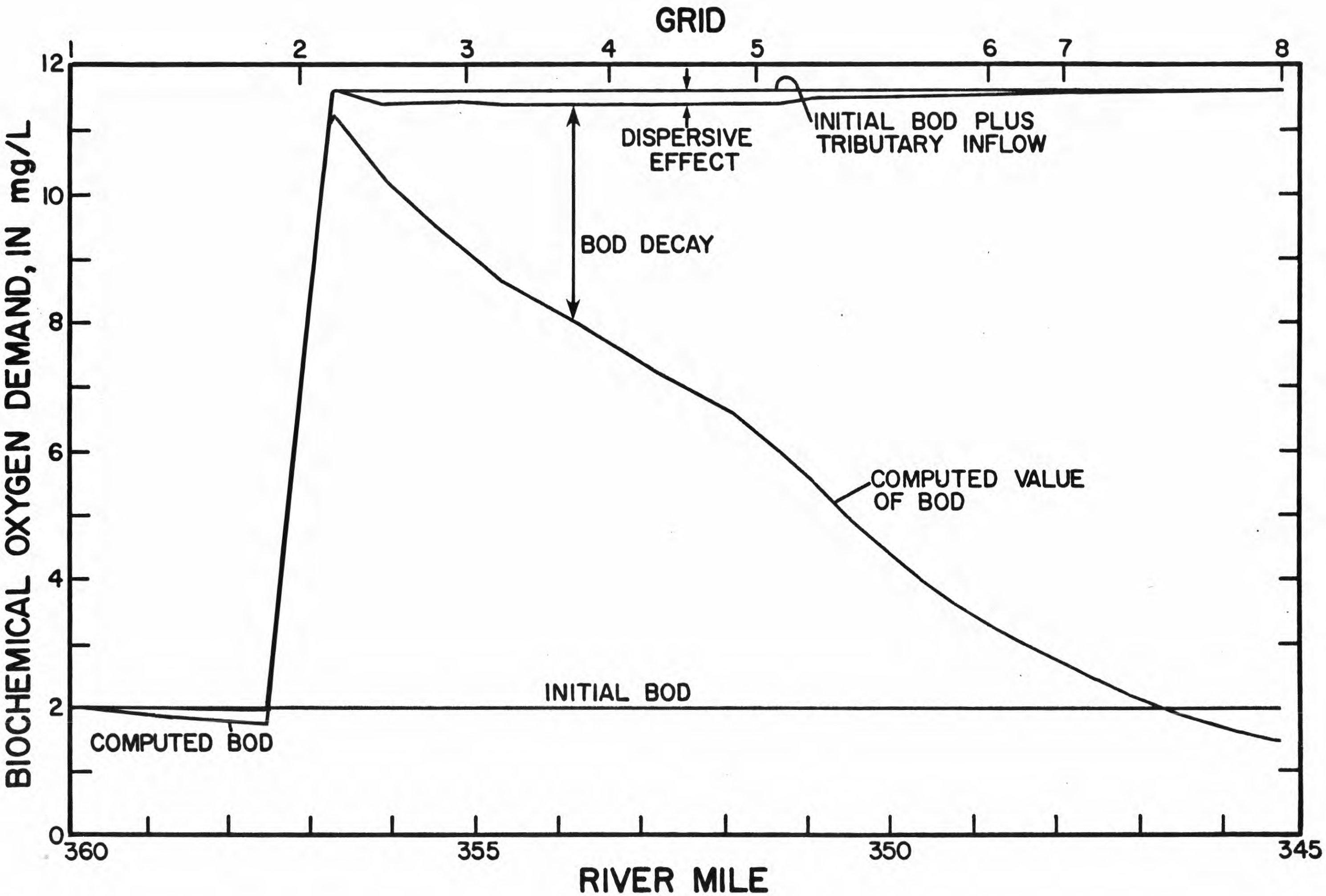


Figure 18.--Longitudinal variation in BOD for example problem, after 40 time steps.

By use of these data an analysis similar to that carried out above for the parcel at grid 6 on day 2, hour 12.00, can be performed for any parcel in the system at the end of the run. Figures like those shown in figures 16 through 18 can be extremely useful in calibrating models, especially more complex nutrient models.

GENERALIZATION OF THE MODEL FOR USE WITH UNSTEADY FLOW

The preceding 4 models, as presented so far, can only be used for steady flow. A significant advantage of the Lagrangian reference frame is that the generalization of the model to accept unsteady flow is simple and straightforward. Like any finite difference model, the Lagrangian model assumes the flow is steady during any single time step. The generalization, therefore, simply involves reading a new set of hydraulic conditions at each time step and computing the appropriate average conditions that apply during the time step and subreach.

Although generalizing the transport model to accept unsteady flow conditions is simple and straightforward, the generation of accurate hydraulic data (velocity, area, top width, and tributary inflow) at each grid point can be quite involved. Some type of a flow model must be used to determine these hydraulic variables. The one-dimensional linear-implicit model documented by Land (1978) is recommended. Under special conditions much simpler models may also give acceptable results. Whatever model is used, however, it must be able to predict the velocity, area, top width, and tributary inflow at each grid point and time step.

Because it is almost always desirable to run the transport model several times for the same flow conditions, it is recommended that the flow model be run independently of the transport model. After the flow model has been calibrated the computed results are stored for use with the transport model. These results could be stored on computer cards but because of the many data involved, it is usually desirable to store the results on a magnetic disk.

Only four modifications are necessary to allow any of the preceding four models to handle unsteady flow. The first modification is that the second comment card in the deck should be changed to read ". . . transport in unsteady flow" instead of "in steady flow". The second modification in the "Process Input Data" section is to read the complete flow field for time zero. This read statement should be placed right after the statement "1 continue." The third modification is the major one but still only involves adding 15 cards. This modification computes the average velocity, area and width associated with each subreach during each time step. It also computes the average value of the tributary inflow at each grid point. This is accomplished by adding the group of cards shown in figure 19 to the deck immediately after the time step DO statement (see table 2 for statement numbers). The average value of the velocity, for example, in any subreach represents the average of four values, the old and the new values at each end of the subreach. The fourth correction involves adding a data definition statement after the program to give the computer sufficient information to find the flow data which has been stored on a magnetic disk. These four corrections are summarized in table 2. All data input needed for the steady flow models are also needed for the unsteady models, although some data, the area, top width, and tributary flow input from cards, are not used.

In order to illustrate the operation of the unsteady program, an example is given for the conservative transport model. The characteristics of the assumed channel are shown in figure 20. Each section was assumed trapezoidal in shape with the bottom width as shown at the bottom of figure 20 and with side slopes of 2 horizontal to 1 vertical. The center portion of figure 20 shows the water depth for a steady flow of 12.3 m^3/s and a tributary inflow at grid 5 of 0.65 m^3/s. The Manning's roughness coefficient was assumed to be constant at 0.025. The profile of the bed is shown at the top of figure 20. The bed profile was computed such that the areas and velocities at 12 m^3/s would very closely match the values assumed in the first 3 examples.

The shape of the assumed inflow hydrograph is shown on the top part of figure 21. This hydrograph was routed through the reach using the routing model presented by Dawdy and others (1978). The resulting hydrographs at grids 4 and 8 are also shown on figure 21. The kinematic-wave routing model of Dawdy and others was selected for use here because of its simplicity, but it is not necessarily recommended for general use in flow routing. The model was modified slightly such that it used a tabular form of the stage-discharge curve at each section rather than the analytic form assumed by Dawdy and others. The stage-discharge relation of each section was determined by use of a backwater program for various steady flow rates. The depth at the downstream end was assumed to be at normal depth for the channel section with a slope of 0.00015. A listing of the flow model with input and output data is shown in attachment E. The output data were stored on magnetic disk to be used by the transport model.

The conservative transport model was then modified, as outlined above, and run for this unsteady flow condition. A listing of the modified program, along with the output, is shown in attachment F. The output format is identical to that discussed previously. The variation of concentration with time at grids 1, 6, and 8 is shown in figure 5 for both the steady and unsteady flow cases. The low flow preceding the rise in the hydrograph slowed the arrival of the first concentration front at grid 6. At grid 8, on the other hand, the flood wave had

```
C
C     Compute reach average FLOW
C
      DO 7 I = 1, INX
      U(I) = FLOW(1,I) + FLOW(1,I+1)
      A(I) = FLOW(2,I) + FLOW(2,I+1)
      W(I) = FLOW(3,I) + FLOW(3,I+1)
    7 QT(I) = FLOW(4,I)
      READ (65,6500)((FLOW(K,I),K=1,4)I=1,NXSEC)
 6500 FORMAT(8F10.3)
      DO 12 I = 1, INX
      U(I) = (U(I) + FLOW(1,I) + FLOW(1,I+1))*0.25
      A(I) = (W(I) + FLOW(2,I) + FLOW(2,I+1))*0.25
      W(I) = (W(I) + FLOW(3,I) + FLOW(3,I+1))*0.25
   12 QT(I) = (QT(I) + FLOW(4,I))*0.5
```

Figure 19.--Code to compute time and subreach average values of flow conditions for use in the unsteady state model.

TABLE 2.--Modifications to steady transport programs for unsteady flow simulations

	Statement preceding the required modification				Modification
	Conservative transport	Simplified temperature	Complete temperature	10 parameter	
1	Replaces first comment card				Change program name to indicate unsteady flow.
2	0059	0066	0068	0081	Read in complete flow field FLOW(K,I) at time zero.
3	0083	0091	0095	0106	Compute reach and time averaged velocities, area, depths, tributary inflow values for each subreach or grid point.
4	JCL	JCL	JCL	JCL	Add a data definition card to define the flow data file.

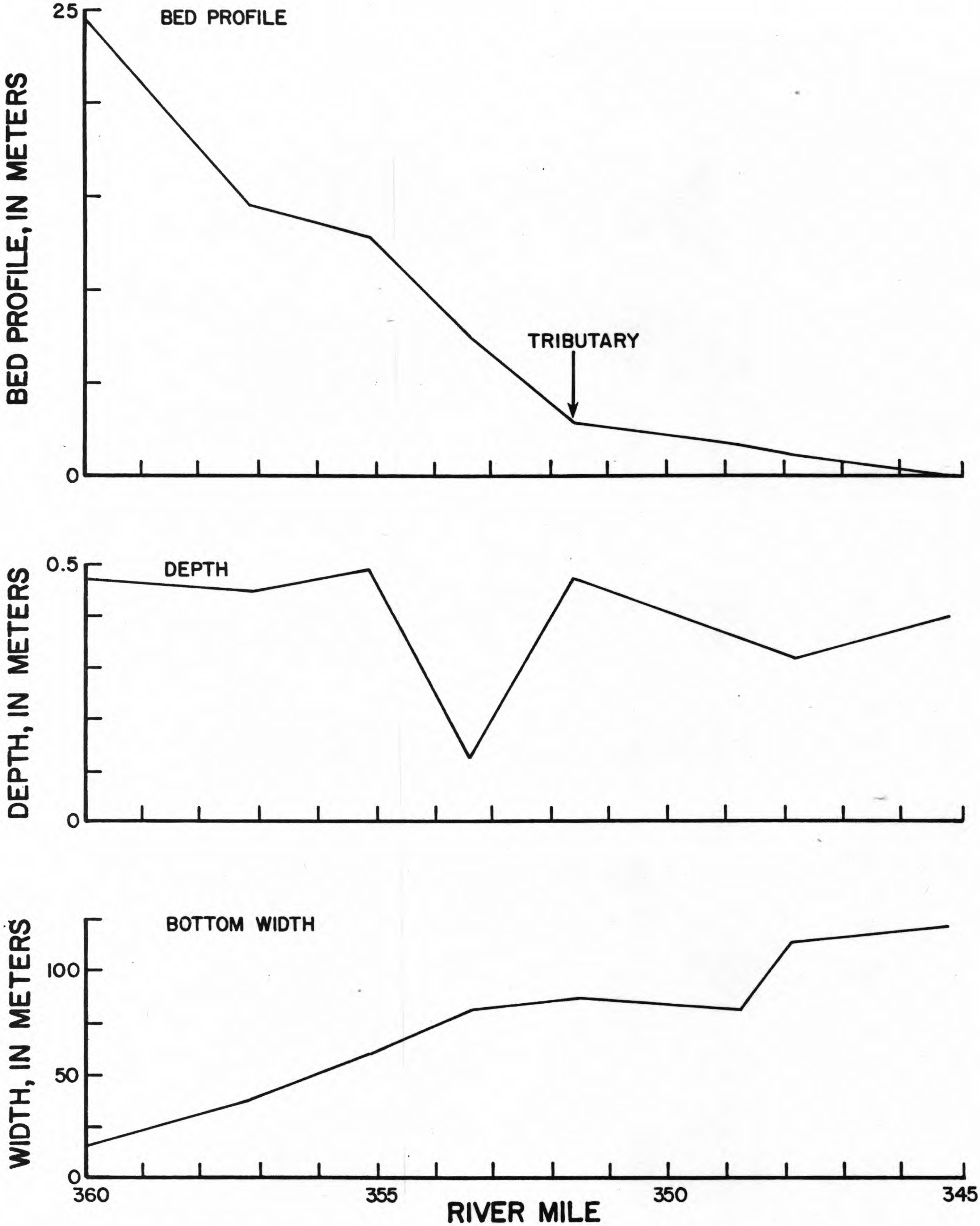


Figure 20.--Characteristics of the assumed channel used in all example problems.

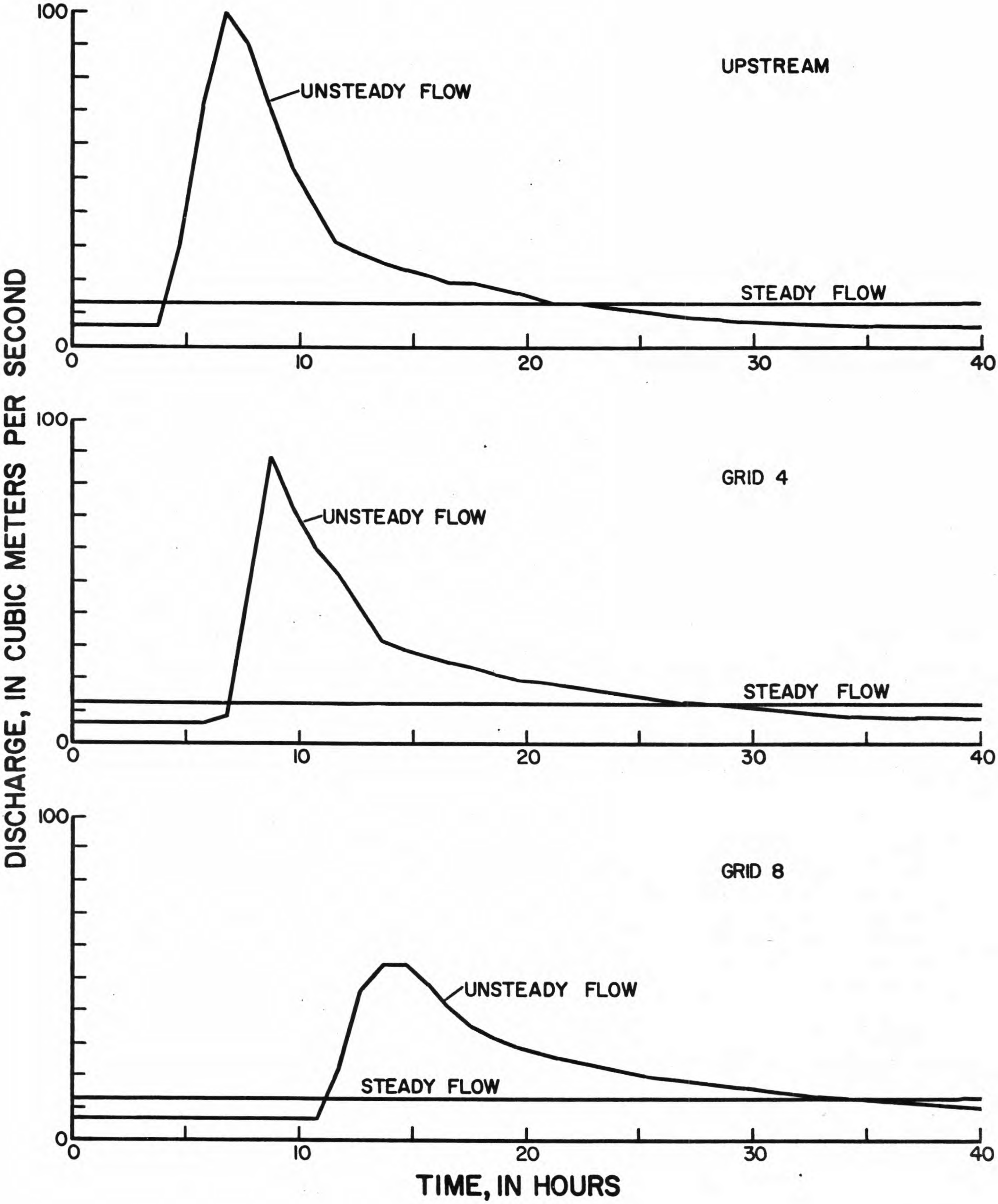


Figure 21.--Flow hydrographs for steady and unsteady runs.

overtaken the concentration front and the concentration rise occurred sooner for the unsteady flow case than for the steady flow case. Because of the rapid movement of the flood wave through the system, the width of the first concentration pulse was significantly shortened by the unsteady flow. The center dye pulse, injected on the recession of the hydrograph, traversed the system more rapidly under unsteady flow conditions because of the higher velocities. The third pulse, injected after most of the hydrograph rise had passed, was not affected significantly.

Modification of the other three models to allow for unsteady flow is accomplished in the same manner, as shown in table 2. Examples of these modifications will not be presented here.

SUMMARY

The 10-parameter transport model, modified for unsteady flow computation, is a general highly versatile modeling tool. Its main advantages are: it is conceptually and mathematically easy to understand, use, and modify; it is very accurate; it is very stable numerically; and it allows the tabulation of the effect of any individual process on the modeled output. This tabulation is extremely useful in model calibration and allows the model to be more effectively used as an aid in understanding natural systems.

If a single constituent is to be modeled, such as a conservative substance or heat, one of the simpler models can be used. It is recommended that a user who is not familiar with the model start with the conservative transport model and after mastering this model, progress through the other models becoming familiar with each in turn.

If the transport problem can be solved assuming steady flow conditions, the work is reduced by at least 50 percent because the operation of a flow model is generally the most complex part of the entire modeling effort in unsteady flows.

The transport models discretize the river into a number of subreaches separated by grid points. For steady flow applications only the discharge at the upstream end of the reach and the cross-sectional properties at the grid points (area, width, and tributary inflow) are needed as hydraulic input. For unsteady flow applications a streamflow model must be used to calculate the hydraulic properties at each grid point and time step. In addition to hydraulic data the model requires the concentrations of the modeled substances at the upstream end of the reach and in each tributary for discrete time steps. Certain rate coefficients and/or meteorological data are required to model specific substances.

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ATTACHMENT A

Conservative Transport in Steady Flow

```
      C*****************************I-D  TRANSPORT MODEL****************
      C****************CONSERVATIVE TRANSPORT IN STEADY FLOW******************
      C                                                ********
      C     DEFINITIONS
      C
      C     PXU,PXD,PX(K)= POSITION OF LAGRANGIAN PARTICLE (U/S,D/S,
      C          PARCEL K) IN EULERIAN GRID UNITS
      C     PTU,PTD,PT(K)= CONCENTRATION OF LAGRANGIAN PARCEL
      C     PVU,PVD,PV(K)= VOLUME OF LAGRANGIAN PARCEL
      C     PHU,PHD,PH(K)= TIME THE PARCEL ENTERED THE SYSTEM
      C     PTRU,PTRD,PTR(K)= CHANGE IN CONCENTRATION DUE
      C          TO TRIBUTARY INFLOW
      C     PTIU,PTID,PTI(K)=CONCENTRATION OF PARCEL AS IT ENTERED THE SYSTEM
      C     PDFU,PDFD,PDF(K)=CHANGE IN PARCEL CONCENTRATION DUE TO DISPERSION
      C     FLOW(L,I)= FLOW FIELD INFORMATION L AT EULERIAN GRID I
      C             L=1 FOR FLOW VELOCITY IN METERS/HOUR
      C             L=2 FOR FLOW AREA IN SQUARE METERS
      C             L=3 FOR TOP WIDTH IN METERS
      C             L=4 FOR TRIBUTARY INFLOW IN CU METERS/SECOND
      C     U(I)= AVERAGE VELOCITY IN SUBREACH I IN METERS / HOUR
      C     A(I)=AVERAGE AREA IN SUBREACH , IN SQUARE METERS
      C     X(I)= X COORDINATE OF EULERIAN GRID I IN RIVER MILES
      C     DX(I)= DISTANCE BETWEEN GRID I AND I+1
      C     DQQ(I)= DISPERSION FACTOR (DISP/(U*U*DT))
      C     DQ(K)= FLOWRATE BETWEEN PARCEL K AND K+1 DUE TO VELOCITY GRADIENTS
      C     DF(K)=CONCENTRATION CHANGE OF PARCLE K DURING DT DUE TO DISPERSION
      C     TUP= OBSERVED CONCENTRATION AT UPSTREAM END OF REACH
      C     QT(I)= TRIBUTARY INFLOW IN CUBIC METERS PER SECOND AT GRID I
      C     TRIB(I)= OBSERVED CONCENTRATION OF TRIBUTARY INFLOW AT GRID I
      C     Q = DISCHARGE AT UPSTREAM END IN CUBIC METERS PER SECOND
      C     DT= TIME STEP SIZE (IN HOURS)
      C     PDX= PART OF EULERIAN SUBREACH REMAINING TO BE TRAVERSED
      C     PDT= TIME REQUIRED TO TRAVERSE THE REMAINING PART OF THE SUBREACH
      C     RDT= TIME REMAINING FOR MOVEMENT
      C     NXSEC= NUMBER OF EULERIAN GRIDS
      C     INX= NXSEC-1
      C     NS= NUMBER OF PARCLES IN THE SYSTEM
      C     LNS= NS-1
      C     LP= LAST PARCLE TO STAY IN THE SYSTEM AT D/S END
      C     MX= GRID U/S OF PARCLE
      C     IGT(N)= GRID NUMBER FOR TRIBUTARY INFLOW
      C     NPT(I)= NUMBER OF PARCELS TO PASS GRID IGT(N) DURING DT
      C     KPG(N,M)= PARCEL NUMBER OF PARCEL TO PASS GRID IGT(N) DURING DT
      C     NHR= NUMBER OF TIME STEPS
      C     NTRIB= NUMBER OF ACTUAL TRIBUTARIES
      C     IGO= GRID NUMBER WHERE OUTPUT IS DESIRED
      C     IOUT= NUMBER OF TIME STEPS BETWEEN OUTPUT LISTINGS
      C     JTS= NUMBER OF TIME STEPS FROM MIDNIGHT TO TIME ZERO IN MODEL
      C      TITLE(20)= TITLE OF PROGRAM,80 CHARACTERS MAX.
      C
      C  PRELIMINARIES (STATEMENTS 0001-0025, LABEL STATEMENTS 20-39)
      C
0001        DIMENSION PX(500),PV(500),PT(500),PH(500),PTR(500),PTI(500)
0002        DIMENSION  DX(50),U(50),A(50),FLOW(4,50),W(50)
0003        DIMENSION DQQ(50),QT(50),TRIB(50),IGT(50),KPG(20,50),NPT(50)
0004        DIMENSION PDF(500),DQ(500),DF(500),TITLE(20)
0005        DOUBLE PRECISION X(51)
      C
```

```
      C      MAXIMUM VALUE OF NXSEC IS 50
      C
      C      STEP 6 TO 24 ARE TO ZERO ARRAYS.
0006         DO 4 K=1,500
0007         PX(K)= 0.0
0008         PT(K)= 0.0
0009         PV(K)= 0.0
0010         PH(K)= 0.0
0011         PTR(K)= 0.0
0012         PDF(K)= 0.0
0013         PT1(K)= 0.0
0014         DQ(K)= 0.0
0015       4 DF(K)= 0.0
0016         DO 5 I=1,50
0017         X(I)= 0.0
0018         DQQ(I)= 0.0
0019         QT(I)= 0.0
0020         FLOW(4,I)=0.0
0021         TRIB(I)= 0.0
0022         IGT(I)= 0.0
0023         DX(I)= 0.0
0024         U(I)= 0.0
0025       5 A(I)= 0.0
      C
      C      READ INPUT (STATEMENTS 0026-0046)********************************
      C
0026         READ(5,1000)(TITLE(K),K=1,20)
0027    1000 FORMAT(20A4)
0028         WRITE(6,3003) (TITLE(K),K=1,20)
0029    3003 FORMAT(1H1,20X,20A4)
0030         WRITE(6,3002)
0031    3002 FORMAT (//)
0032         READ(5,1005) NXSEC,NHR,DT,Q,IGO,IOUT,NTRIB,JTS
0033    1005 FORMAT(2I5,2F10.2,4I5)
0034         READ(5,1006) (X(I),I=1,NXSEC)
0035    1006 FORMAT(10X,10F7.3)
0036         READ(5,1006)(FLOW(2,I),I=1,NXSEC)
0037         IF (NTRIB.EQ.0) GO TO 8
0038         DO 7 N=1,NTRIB
0039         READ(5,1010) IGT(N),QTT
0040    1010 FORMAT(10X,I7,F7.2)
0041         I= IGT(N)
0042       7 FLOW(4,I)=QTT
0043       8 READ(5,1006) (DQQ(I),I=1,NXSEC)
0044         READ(5,1006) (PT(I),I=1,NXSEC)
0045         WRITE(6,3005) NHR,DT,NXSEC,Q,IGO,NXSEC,IOUT
0046    3005 FORMAT(' MODEL IS TO RUN',I5,' TIME STEPS EACH',F10.2,' HOURS LONG
            1. THE RIVER IS DISCRETIZED BY',I5,' GRID POINTS.',/,' THE INITIAL
            2UPSTREAM DISCHARGE IS CONSTANT AT',F10.2,' CUBIC METERS PER SECOND
            3.',/,' THE PRINTOUT WILL BE GIVEN FOR GRIDS',I5,' AND',I5,' FOR
            4EACH',I5,' TIME STEPS.')
      C
      C      PROCESS INPUT DATA (STATEMENTS 0047-0082)***********************
      C
0047         XUP=X(1)
0048         X(NXSEC+1)=X(NXSEC)
0049         DO 1 I=1,NXSEC
0050         DX(I)=(X(I)-X(I+1))*1609.34
```

```
0051              X(I)=(XUP-X(I))*1609.34
0052              PX(I)=FLOAT(I)
0053              PH(I)= FLOAT(JTS)*DT
0054              PTI(I)=PT(I)
0055              PDF(I)= 0.0
0056              PTR(I)= 0.0
0057              FLOW(1,I)=3600.0*Q/FLOW(2,I)
0058              Q= Q+FLOW(4,I)
0059            1 CONTINUE
0060              INX=NXSEC-1
0061              PV(1)= FLOW(2,1)*(DX(1)+DT*FLOW(1,1))/2.0
0062              DO 3 I=1,INX
0063              U(I)=(FLOW(1,I)+FLOW(1,I+1))/2.0
0064              A(I)=(FLOW(2,I)+FLOW(2,I+1))/2.0
0065              QT(I)=FLOW(4,I)
0066            3 PV(I+1)= FLOW(2,I+1)*(DX(I)+DX(I+1))/2.0
0067              PV(NXSEC)= FLOW(2,NXSEC)*(DX(INX))/2.0
0068              NS=NXSEC
0069              WRITE(6,3002)
0070              WRITE (6,3004)
0071         3004 FORMAT(1H0,50X,'INITIAL  CONDITIONS')
0072              WRITE(6,3002)
0073              WRITE(6,3010)
0074         3010 FORMAT(3X,'GRID  RIVER  VELOCITY    AREA    TRIB. FLOW  DISP FACT
                 1   INITIAL',/,10X,'MILE      M/HR   SQ METERS  CU M/SEC',6X,'DQQ',
                 28X,'CONC')
0075              DO 9 I=1,NS
0076              RM=XUP-X(I)/1609.34
0077              WRITE(6,3011) I,RM,FLOW(1,I),FLOW(2,I),QT(I),PT(I)
0078         3011 FORMAT(4X,I2,1X,F7.3,3X,F7.0,3X,F8.1,2X,F9.2,14X,F7.2)
0079              IF(I.LT.NS) WRITE(6,3007) DQQ(I)
0080         3007 FORMAT(50X,F5.2)
0081            9 CONTINUE
0082              WRITE(6,3002)
            C
            C     START TIME LOOP ****************************************************
            C
0083              DO 2 J=1,NHR
            C
            C
            C     COMPUTE DISPERSION FLUXES (STATEMENTS 0084-0107, LABEL
            C           STATEMENTS 80-99)*******************************************
            C
            C    COMPUTE DISPERSIVE Q'S
0084              LNS=NS-1
0085              DO 80 K=1,LNS
0086              IX=(PX(K)+PX(K+1))/2.0
0087           80 DQ(K)=ABS(DQQ(IX)*U(IX)*A(IX))
            C     SET DQ=0 AT TRIBUTARY
0088              K=0
0089              DO 85 N=1,NTRIB
0090              XR=IGT(N)
0091           81 K=K+1
0092              IF(PX(K).LT.XR) GO TO 81
0093              K= K-1
0094           85 DQ(K)= 0.0
            C    LIMIT DQ TO FORCE STABILITY
0095              DO 82 K=1,NS
```

```
0096          IF(K.EQ.1) GO TO 83
0097          RATIO=DQ(K-1)*DT/PV(K)
0098          IF(RATIO.GT.0.35) DQ(K-1)=0.35*PV(K)/DT
0099          IF(K.EQ.NS) GO TO 82
0100       83 RATIO=DQ(K)*DT/PV(K)
0101          IF(RATIO.GT.0.35) DQ(K)=0.35*PV(K)/DT
0102       82 CONTINUE
      C       IF(J.LT.5)WRITE(6,3000) (DQ(K),K=1,LNS)
      C     DISPERSE HEAT
0103          DF(1)=DQ(1)*(PT(2)-PT(1))*DT/PV(1)
0104          DO 84 K=2,LNS
0105          DF(K)=(DQ(K-1)*(PT(K-1)-PT(K))+DQ(K)*(PT(K+1)-PT(K)))*DT/PV(K)
0106       84 IF(ABS(DF(K)).LT.1.0E-6) DF(K)=0.0
0107          DF(NS)=DQ(NS-1)*(PT(NS-1)-PT(NS))*DT/PV(NS)
      C       IF(J.LT.5) WRITE(6,3000) (DF(K),K=1,NS)
      C
      C       SET UPSTREAM BOUNDRY (STATEMENTS 0108-0115, LABEL STATEMENTS
      C               40-59)****************************************************
      C
      C     READ BOUNDARY CONDITIONS
0108          READ(5,1006) TUP,(TRIB(IGT(N)),N=1,NTRIB)
0109          PXU=1.0
0110          PTU=TUP
0111          PVU= FLOW(1,1)*FLOW(2,1)*DT
0112          PHU= DT*FLOAT(J+JTS)
0113          PTRU= 0.0
0114          PTIU=TUP
0115          PDFU=0.0
      C       IF(J.LT.7) WRITE(6,3000) PXU,PTU,PVU,PHJ,PTRU
      C
      C       SET D/S BOUNDARY (STATEMENTS 0116-0142, LABEL STATEMENTS 60-79)
      C
0116          MX=NXSEC-1
0117          RDT=DT
0118       60 PDT=DX(MX)/U(MX)
0119          IF(PDT.GE.RDT)GO TO 61
0120          RDT=RDT-PDT
0121          MX=MX-1
0122          GO TO 60
0123       61 XP=FLOAT(MX)+1.0-RDT/PDT
      C       FIND PARCEL U/S OF XP
0124          LP=NS-1
0125       62 IF(PX(LP).LT.XP)GO TO 63
0126          LP=LP-1
0127          GO TO 62
0128       63 NS=LP+2
0129          PX(NS)=FLOAT(NXSEC)
      C       FIND OLD CONCENTRATION OF PARCEL WHICH WILL FALL OUT
0130          MX=IFIX(XP)
0131          XP=X(MX)+DX(MX)*(XP-FLOAT(MX))
0132          MX=IFIX(PX(LP))
0133          XL=X(MX)+DX(MX)*(PX(LP)-FLOAT(MX))
0134          MX=IFIX(PX(LP+1))
0135          XR=X(MX)+DX(MX)*(PX(LP+1)-FLOAT(MX))
0136          COF=(XP-XL)/(XR-XL)
0137          PT(NS)=(PT(LP)+DF(LP))*(1.0-COF)+(PT(LP+1)+DF(LP+1))*COF
0138          PV(NS)= 10.0
0139          PH(NS)= PH(LP)*(1.0-COF)+PH(LP+1)*COF
```

```
0140              PTR(NS)= PTR(LP)*(1.0-COF)+PTR(LP+1)*COF
0141              PTI(NS)=PTI(LP)*(1.0-COF)+PTI(LP+1)*COF
0142              PDF(NS)=(PDF(LP)+DF(LP))*(1.0-COF)+(PDF(LP+1)+DF(LP+1))*COF
            C     IF(J.LT.7)WRITE(6,3000) RDT,PDT,XP,XL,XR,COF,PT(NS),PH(NS),
            C    $PTR(NS),PDF(NS)
            C     IF(J.LT.7)WRITE(6,3001) LP,NS
            C
            C     MOVE INTERIOR PARCELS (STATEMENTS 0143-0171, LABEL STATEMENTS
            C             100-119)**********************************************
            C
            C
0143              LNS=NS-1
0144              DO 103 I=1,NXSEC
0145          103 NPT(I)= 0
0146              DO 100 KK=2,LNS
0147              K=LNS+2-KK
0148              KO=K-1
0149              XOLD=PX(KO)
0150              MX=IFIX(XOLD)
0151              RDT=DT
0152              PDX=FLOAT(MX+1)-PX(KO)
0153          102 PDT=PDX*DX(MX)/J(MX)
0154              IF(PDT.GE.RDT) GO TO 101
            C    PASSED GRID
0155              RDT=RDT-PDT
0156              MX=MX+1
0157              XOLD=FLOAT(MX)
0158              PDX=1.0
0159              NPT(MX)= NPT(MX)+1
0160              KPG(NPT(MX),MX)=K
0161              GO TO 102
0162          101 CONTINUE
            C    STOPPED IN SUBREACH
0163              PX(K)=XOLD+RDT*J(MX)/DX(MX)
0164              PT(K)=PT(KO)+DF(KO)
0165              PV(K)=PV(KO)
0166              PH(K)=PH(KO)
0167              PTR(K)=PTR(KO)
0168              PTI(K)=PTI(KO)
0169              PDF(K)=PDF(KO)+DF(KO)
            C     IF(J.LT.7) WRITE(6,3001) K,KO,MX,(NPT(I),I=1,NXSEC)
0170         3001 FORMAT(' ',12I10)
            C     IF(J.LT.7)WRITE(6,3000) XOLD,RDT,PDT,PDX,PX(K),PT(K),PV(K),PH(K),PTR(K)
0171          100 CONTINUE
            C
            C     TRANSFER BOUNDARY CONDITIONS TO PARCEL CHARACTERISTICS(STATEMENTS
            C             0172-0178)****************************************
            C
0172              PX(1)=PXU
0173              PT(1)=PTU
0174              PV(1)=PVU
0175              PH(1)=PHU
0176              PTR(1)=PTRU
0177              PTI(1)=PTIU
0178              PDF(1)=PDFU
            C
            C     DILUTE FOR TRIBUTARY INFLOW (STATEMENTS 0179-0214, LABEL
            C             STATEMENTS 120-129)**********************************
```

```
              C
0179                IF(NTRIB.EQ.0) GO TO 123
0180                K=0
0181                DO 123 N=1,NTRIB
0182                I= IGT(N)
              C     IF(J.LT.7) WRITE(6,3001)K,N,NTRIB,IGT(N),I,NPT(I)
0183                IF(NPT(I).EQ.0)GO TO 120
0184                VOL=0.0
0185                M=NPT(I)
0186                DO 121 K=1,M
0187                KK=KPG(K,I)
0188            121 VOL=VOL+PV(KK)
0189                DO 122 K=1,M
0190                KK=KPG(K,I)
0191                COF=PV(KK)/VOL
0192                DEL=(TRIB(I)*COF*QT(I)*3600.0*DT+PT(KK)*PV(KK))/(PV(KK)+QT(I)
                   $*3600.0*COF*DT)-PT(KK)
0193                IF(QT(I).LE.0.0)DEL=0.0
0194                PT(KK)=PT(KK)+DEL
0195                PTR(KK)=PTR(KK)+DEL
0196                PV(KK)=PV(KK)+COF*QT(I)*DT*3600.0
              C     IF(J.LT.10)WRITE(6,3000)VOL,COF,PT(KK),PTR(KK),PV(KK),DEL
              C     IF(J.LT.10) WRITE(6,3001)K,KK
0197            122 CONTINUE
0198                GO TO 123
0199            120 CONTINUE
              C
              C     FIND NEAREST PARCEL
              C
0200            124 K=K+1
0201                IF(PX(K).LT.FLOAT(I))GO TO 124
0202                MX=IFIX(PX(K))
0203                XR=X(MX)+(PX(K)-FLOAT(MX))*DX(MX)-X(I)
0204                K=K-1
0205                MX=IFIX(PX(K))
0206                XL=X(I)-X(MX)-(PX(K)-FLOAT(MX))*DX(MX)
0207                IF(XR.LT.XL)K=K+1
0208                DEL=(TRIB(I)*QT(I)*3600.0*DT+PT(K)*PV(K))/(PV(K)+QT(I)*3600.0*DT)
                   $-PT(K)
0209                IF(QT(I).LE.0.0)DEL=0.0
0210                PT(K)=PT(K)+DEL
0211                PTR(K)=PTR(K)+DEL
0212                PV(K)=PV(K)+QT(I)*DT*3600.0
              C     IF(J.LT.10) WRITE(6,3000)XR,XL,PT(K),PV(K),PTR(K),DEL
              C     IF(J.LT.10) WRITE(6,3001)K,MX,I
0213                K= K-1
0214            123 CONTINUE
              C
              C     FIND CONCENTRATIONS AT IGO (STATEMENTS 0215-0228, LABEL
              C             STATEMENTS 130-139)*****************************************
              C
0215                TIME= FLOAT(J+JTS)*DT
0216                K= 0
0217            130 K= K+1
0218                IF(PX(K).LE.FLOAT(IGO)) GO TO 130
0219                IX= IFIX(PX(K))
0220                XR= X(IX)+DX(IX)*(PX(K)-FLOAT(IX))-X(IGO)
0221                IX= IFIX(PX(K-1))
```

```
0222              XL= X(IGO)-X(IX)-DX(IX)*(PX(K-1)-FLOAT(IX))
0223              COF= XL/(XL+XR)
0224              CIGO= PT(K-1)+COF*(PT(K)-PT(K-1))
0225              CIIGO= PTI(K-1)+COF*(PTI(K)-PTI(K-1))
0226              CDIGO= PDF(K-1)+COF*(PDF(K)-PDF(K-1))
0227              CTIGO= PTR(K-1)+COF*(PTR(K)-PTR(K-1))
0228              TTIGO= TIME             -PH(K-1)-COF*(PH(K)-PH(K-1))
            C
            C     WRITE RESULTS (STATEMENTS 0229-0241. LABEL STATEMENTS 140-149)
            C
0229              IF(J.EQ.1)WRITE(6,2000) IGO,NXSEC
0230              IF(MOD(J,IOUT).EQ.0) GO TO 140
0231              GO TO 2
0232          140 IC=J/IOUT
0233              IF(MOD(IC,50).EQ.0) WRITE(6,2000) IGO,NXSEC
0234         2000 FORMAT(6X,'TIME',7X,'CONC AT',3X,'TRAVEL  PARCEL',3X,'CHANGE IN PA
                 1RCEL',16X,'CONC AT',3X,'TRAVEL  PARCEL   CHANGE IN PARCEL',/,5X,'D
                 2AY HOUR',6X,'GRID',5X,'TIME',3X,'CONC AT',4X,'CONC DUE TO',21X,'GR
                 3ID',5X,'TIME   CONC AT',4X,'CONC DUE TO',/,16X,I5,7X,'HOUR',4X,
                 4'ENTRY',6X,'DISP',5X,'TRIB',15X,I4,7X,'HOUR',4X,'ENTRY',6X,
                 5'DISP',5X,'TRIB')
0235              IDAY= (TIME/24.0)+1
0236              HR= TIME-FLOAT(IDAY-1)*24.0
0237              TT= TIME-PH(NS)
0238              WRITE(6,2001)IDAY,HR,CIGO,TTIGO,CIIGO,CDIGO,CTIGO,PT(NS),TT,
                 #PTI(NS),PDF(NS),PTR(NS)
0239         2001 FORMAT(5X,I2,1X,F5.2,4X,F7.2,2X,F7.2,2X,F7.2,3X,F7.2,2X,F7.2,15X,
                 $F7.2,2X,F7.2,2X,F7.2,3X,F7.2,2X,F7.2)
0240         3000 FORMAT(' ',10E12.5)
0241            2 CONTINUE
0242              END
```

Input Data for

Conservative Transport in Steady Flow

```
    MODEL DOCUMENTATION FOR A CONSERVATIVE SUBSTANCE IN STEADY FLOW
      8    40         1.00        12.00      6     1     1     4
RIVER MILE 360.00 357.18 355.15 353.41 351.61 349.78 347.86 345.21
AREA    1        8.0    17.6    30.4    10.2    42.0    29.4    36.8    48.2
TREB  1            5    0.65
DQQ VALUES      0.05    0.05    0.05    0.05    0.05    0.05    0.05    0.05
INIT CONC1       0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
BC1             30.0     0.0
BC2             30.0     0.0
BC3             30.0     0.0
BC4             30.0     0.0
BC5             30.0    35.0
BC6             30.0    35.0
BC7             30.0    35.0
BC8             30.0    35.0
BC9             30.0    35.0
BC10             0.0    35.0
BC11             0.0    35.0
BC12             0.0    35.0
BC13             0.0    35.0
BC14            30.0    35.0
BC15             0.0    35.0
BC16             0.0    35.0
BC17             0.0    35.0
BC18             0.0    35.0
BC19             0.0    35.0
BC20             5.0    35.0
BC21            10.0    35.0
BC22            15.0    35.0
BC23            20.0    35.0
BC24            25.0    35.0
BC25            30.0    35.0
BC26            30.0    35.0
BC27            30.0    35.0
BC28            29.0    35.0
BC29            26.5    35.0
BC30            21.5    35.0
BC31            15.0    35.0
BC32             8.5    35.0
BC33            3.75    35.0
BC34             1.0    35.0
BC35             0.0    35.0
BC36             0.0    35.0
BC37             0.0    35.0
BC38             0.0    35.0
BC39             0.0    35.0
BC40             0.0    35.0
```

Output of

Conservative Transport in Steady Flow

MODEL DOCUMENTATION FOR A CONSERVATIVE SUBSTANCE IN STEADY FLOW

MODEL IS TO RUN 40 TIME STEPS EACH 1.00 HOURS LONG. THE RIVER IS DISCRETIZED BY 8 GRID POINTS.
THE INITIAL UPSTREAM DISCHARGE IS CONSTANT AT 12.00 CUBIC METERS PER SECOND.
THE PRINTOUT WILL BE GIVEN FOR GRIDS 6 AND 8 FOR EACH 1 TIME STEPS.

INITIAL CONDITIONS

GRID	RIVER MILE	VELOCITY M/HR	AREA SQ METERS	TRIB. FLOW CU M/SEC	DISP FACT DQQ	INITIAL CONC
1	360.000	5400.	8.0	0.0		0.0
					0.05	
2	357.180	2455.	17.6	0.0		0.0
					0.05	
3	355.150	1421.	30.4	0.0		0.0
					0.05	
4	353.410	4235.	10.2	0.0		0.0
					0.05	
5	351.610	1029.	42.0	0.65		0.0
					0.05	
6	348.780	1549.	29.4	0.0		0.0
					0.05	
7	347.860	1237.	36.8	0.0		0.0
					0.05	
8	345.210	945.	48.2	0.0		0.0

TIME DAY	TIME HOUR	CONC AT GRID 6	TRAVEL TIME HOUR	PARCEL CONC AT ENTRY	CHANGE IN PARCEL CONC DUE TO DISP	TRIB	CONC AT GRID 8	TRAVEL TIME HOUR	PARCEL CONC AT ENTRY	CHANGE IN PARCEL CONC DUE TO DISP	TRIB
1	5.00	0.0	1.00	0.0	0.0	0.0	0.0	1.00	0.0	0.0	0.0
1	6.00	0.0	2.00	0.0	0.0	0.0	0.0	2.00	0.0	0.0	0.0
1	7.00	0.0	3.00	0.0	0.0	0.0	0.0	3.00	0.0	0.0	0.0
1	8.00	0.0	4.00	0.0	0.0	0.0	0.0	4.00	0.0	0.0	0.0
1	9.00	0.00	5.00	0.0	0.00	0.0	0.0	5.00	0.0	0.0	0.0
1	10.00	0.11	6.00	0.0	0.11	-0.00	0.0	6.00	0.0	0.0	0.0
1	11.00	0.52	7.00	0.0	0.52	-0.01	0.00	7.00	0.0	0.00	0.0
1	12.00	5.47	8.00	0.0	4.48	0.99	0.00	8.00	0.0	0.00	0.0
1	13.00	16.90	8.45	16.59	-0.70	1.01	0.00	9.00	0.0	0.00	0.0
1	14.00	26.24	8.45	30.00	-4.16	0.39	0.03	10.00	0.0	0.03	0.0
1	15.00	29.41	8.45	30.00	-0.87	0.28	0.44	11.00	0.0	0.44	-0.00
1	16.00	30.11	8.45	30.00	-0.14	0.26	1.55	12.00	0.0	1.56	-0.01
1	17.00	30.24	8.45	30.00	-0.02	0.26	7.00	13.00	0.0	6.00	1.00
1	18.00	30.25	8.45	30.00	-0.00	0.26	16.83	13.44	16.88	-1.04	1.00
1	19.00	30.24	8.45	30.00	-0.01	0.26	25.18	13.44	30.00	-5.21	0.39
1	20.00	29.84	8.45	30.00	-0.42	0.27	28.86	13.44	30.00	-1.42	0.28
1	21.00	26.32	8.45	30.00	-4.10	0.42	29.95	13.44	30.00	-0.31	0.26
1	22.00	15.25	8.45	13.41	0.75	1.09	30.20	13.44	30.00	-0.06	0.26
1	23.00	5.87	8.45	0.0	4.21	1.66	30.24	13.44	30.00	-0.02	0.26
2	0.0	3.05	8.45	0.0	1.28	1.77	30.12	13.44	30.00	-0.14	0.26
2	1.00	5.46	8.45	0.0	3.93	1.64	29.07	13.44	30.00	-1.19	0.27
2	2.00	12.89	8.45	16.59	-4.83	1.13	24.57	13.44	30.00	-5.85	0.43
2	3.00	11.19	8.45	13.41	-3.44	1.23	15.20	13.44	13.12	0.98	1.10
2	4.00	5.00	8.45	0.0	3.32	1.68	7.02	13.44	0.0	5.36	1.66
2	5.00	2.51	8.45	0.0	0.73	1.78	4.26	13.44	0.0	2.49	1.77
2	6.00	1.99	8.45	0.0	0.20	1.80	6.60	13.44	0.0	4.97	1.64
2	7.00	2.54	8.45	0.0	0.78	1.77	11.24	13.44	16.88	-6.76	1.12
2	8.00	5.03	8.45	2.77	0.63	1.63	10.11	13.44	13.12	-4.25	1.24
2	9.00	9.10	8.45	7.77	-0.07	1.40	5.49	13.44	0.0	3.81	1.68
2	10.00	13.70	8.45	12.77	-0.21	1.14	2.92	13.44	0.0	1.14	1.78
2	11.00	18.41	8.45	17.77	-0.24	0.89	2.27	13.44	0.0	0.48	1.80
2	12.00	23.08	8.45	22.77	-0.31	0.63	3.01	13.44	0.0	1.25	1.77
2	13.00	27.17	8.45	27.77	-1.00	0.40	5.49	13.44	2.81	1.04	1.63
2	14.00	29.40	8.45	30.00	-0.89	0.28	9.37	13.44	7.81	0.17	1.39
2	15.00	29.92	8.45	30.00	-0.35	0.27	13.88	13.44	12.81	-0.07	1.14
2	16.00	29.33	8.45	29.45	-0.42	0.30	18.55	13.44	17.81	-0.15	0.88
2	17.00	27.44	8.45	27.62	-0.58	0.40	23.08	13.44	22.81	-0.36	0.63
2	18.00	23.86	8.45	23.73	-0.48	0.60	26.87	13.44	27.81	-1.34	0.40
2	19.00	18.77	8.45	17.90	-0.02	0.89	29.06	13.44	30.00	-1.22	0.28
2	20.00	13.15	8.45	11.40	0.54	1.20	29.65	13.44	30.00	-0.62	0.27

ATTACHMENT B

Simplified Temperature Model in Steady Flow

```
C****************************I-D TRANSPORT MODEL*********************************C
C************SIMPLIFIED TEMPERATURE MODEL IN STEADY FLOW****************
C                                        ********
C      DEFINITIONS
C
C      PXU,PXD,PX(K)= POSITION OF LAGRANGIAN PARTICLE (U/S,D/S,
C           PARCEL K) IN EULERIAN GRID UNITS
C      PTU,PTD,PT(K)= TEMPERATURE OF LAGRANGIAN PARCEL
C      PVU,PVD,PV(K)= VOLUME OF LAGRANGIAN PARCEL
C      PHU,PHD,PH(K)= TIME THE PARCEL ENTERED THE SYSTEM
C      PTRU,PTRD,PTR(K)= CHANGE IN TEMPERATURE DUE TO TRIBUTARY INFLOW
C      PTIU,PTID,PTI(K)=  TEMPERATURE OF PARCEL AS IT ENTERED THE SYSTEM
C      PDFU,PDFD,PDF(K)=CHANGE IN PARCEL TEMPERATURE DUE TO DISPERSION
C      PDCU,PDCD,PDC(K)= TEMPERATURE CHANGE OF PARCEL DUE TO SURFACE
C         EXCHANGE
C      FLOW(L,I)= FLOW FIELD INFORMATION L AT GRID I
C               L=1 FOR FLOW VELOCITY IN METERS PER HR.
C               L=2 FOR FLOW AREA IN SQUARE METERS
C               L=3 FOR TOP WIDTH IN METERS
C               L=4 FOR TRIBUTARY INFLOW IN CU METERS/SECOND
C      U(I)= AVERAGE VELOCITY IN SUBREACH I IN METERS / HOUR
C      A(I)=AVERAGE AREA IN SUBREACH  IN SQUARE METERS
C      W(I)= AVERAGE TOP WIDTH IN SUBREACH I  IN METERS
C      X(I)= X COORDINATE OF EULERIAN GRID I
C      DX(I)= DISTANCE BETWEEN GRID I AND I+1
C      DQQ(I)= DISPERSION FACTOR (DISP/(U*U*DT))
C      DQ(K)= FLOWRATE BETWEEN PARCEL K AND K+1 DUE TO VELOCITY GRADIENTS
C      DF(K)=  TEMPERATURE CHANGE OF PARCLE K DURING DT DUE TO DISPERSION
C      TUP= OBSERVED TEMPERATURE AT UPSTREAM END OF REACH
C      QT(I)= TRIBUTARY INFLOW IN CUBIC METERS PER SECOND AT GRID I
C      TRIB(I)= OBSERVED TEMPERATURE OF TRIBUTARY INFLOW AT GRID I
C      Q= DISCHARGE AT UPSTREAM END IN CUBIC METERS PER SECOND
C      DT= TIME STEP SIZE (IN HOURS)
C      PDX= PART OF EULERIAN SUBREACH REMAINING TO BE TRAVERSED
C      PDT= TIME REQUIRED TO TRAVERSE THE REMAINING PART OF THE SUBREACH
C      RDT= TIME REMAINING FOR MOVEMENT
C      A1= CONSTANT IN WIND FUNCTION (MM/DAY KPA)
C      B1= MASS TRANSFER COEFFICIENT (MM/DAY KPA(M/S))
C      V= WIND SPEED IN M/S
C      TA= AIR TEMPERATURE IN DEGREES C
C      XK= SURFACE EXCHANGE COEFFICIENT
C      NXSEC= NUMBER OF EULERIAN GRIDS
C      INX= NXSEC-1
C      NS= NUMBER OF PARCLES IN THE SYSTEM
C      LNS= NS-1
C      LP= LAST PARCLE TO STAY IN THE SYSTEM AT D/S END
C      MX= GRID U/S OF PARCLE
C      IGT(N)= GRID NUMBER FOR TRIBUTARY INFLOW
C      NPT(I)= NUMBER OF PARCELS TO PASS GRID IGT(N) DURING DT
C      KPG(N,M)= PARCEL NUMBER OF PARCEL TO PASS GRID IGT(N) DURING DT
C      NHR= NUMBER OF TIME STEPS
C      NTRIB= NUMBER OF ACTUAL TRIBUTARIES
C      IGO= GRID NUMBER WHERE OUTPUT IS DESIRED
C      IOUT= NUMBER OF TIME STEPS BETWEEN OUTPUT LISTINGS
C      JTS= NUMBER OF TIME STEPS FROM MIDNIGHT TO TIME ZERO IN MODEL
C        TITLE(20)= TITLE OF PROGRAM,  80 CHARACTERS MAX
C
C   PRELIMINARIES (STATEMENTS 0001-0028,LABEL STATEMENTS 20-39)*******
```

```
              C
0001                DIMENSION PX(500),PV(500),PT(500),PH(500),PTR(500),PTI(500),
                   @PDC(500)
0002                DIMENSION DQQ(50),QT(50),TRIB(50),IGT(50),KPG(20,50),NPT(50)
0003                DIMENSION PDF(500),DQ(500),DF(500),TITLE(20)
0004                DIMENSION  DX(50),U(50),A(50),FLOW(4,50),W(50)
0005                DOUBLE PRECISION X(51)
0006                COMMON  XK,PDC,PT,TA,V,A,W,A1,B1
              C
              C     MAXIMUM VALUE OF NXSEC IS 50
              C
              C     STEP 7 TO 27 ARE TO ZERO ARRAYS.
0007                DO 4 K=1,500
0008                PX(K)= 0.0
0009                PT(K)= 0.0
0010                PV(K)=0.0
0011                PH(K)= 0.0
0012                PTR(K)= 0.0
0013                PDF(K)= 0.0
0014                PTI(K)= 0.0
0015                DQ(K)= 0.0
0016                PDC(K)= 0.0
0017              4 DF(K)= 0.0
0018                DO 5 I=1,50
0019                X(I)= 0.0
0020                DQQ(I)= 0.0
0021                QT(I)= 0.0
0022                FLOW(4,I)=0.0
0023                TRIB(I)= 0.0
0024                IGT(I)= 0.0
0025                DX(I)= 0.0
0026                U(I)= 0.0
0027                W(I)= 0.0
0028              5 A(I)= 0.0
              C
              C     READ INPUT (STATEMENTS 0029-0052)********************************
              C
0029                READ(5,1000)(TITLE(K),K=1,20)
0030           1000 FORMAT(20A4)
0031                WRITE(6,3003) (TITLE(K),K=1,20)
0032           3003 FORMAT(1H1,20X,20A4)
0033                WRITE(6,3002)
0034           3002 FORMAT (//)
0035                READ(5,1005) NXSEC,NHR,DT,Q,IGO,IOUT,NTRIB,JTS,A1,B1
0036           1005 FORMAT(2I5,2F10.2,4I5,2F10.2)
0037                READ(5,1006) (X(I),I=1,NXSEC)
0038           1006 FORMAT(10X,10F7.3)
0039                READ(5,1006)(FLOW(2,I),I=1,NXSEC)
0040                READ(5,1006)(FLOW(3,I),I=1,NXSEC)
0041                IF (NTRIB.EQ.0) GO TO 8
0042                DO 7 N=1,NTRIB
0043                READ(5,1010) IGT(N),QTT
0044           1010 FORMAT(10X,I7,F7.2)
0045                I= IGT(N)
0046              7 FLOW(4,I)=QTT
0047              8 READ(5,1006) (DQQ(I),I=1,NXSEC)
0048                READ(5,1006) (PT(I),I=1,NXSEC)
0049                WRITE(6,3005) NHR,DT,NXSEC,Q,IGO,NXSEC,IOUT
```

```
0050          3005 FORMAT(' MODEL IS TO RUN',I5,' TIME STEPS EACH',F10.2,' HOURS LONG
                  1. THE RIVER IS DISCRETIZED BY',I5,' GRID POINTS.',/,' THE INITIAL
                  2UPSTREAM DISCHARGE IS CONSTANT AT',F10.2,' CUBIC METERS PER SECOND
                  3.',/,' THE PRINTOUT WILL BE GIVEN FOR GRIDS',I5,' AND',I5,' FOR
                  4EACH',I5,' TIME STEPS.')
0051               WRITE(6,1007) A1,B1
0052          1007 FORMAT(1H0,'THE WIND FUNCTION IS',F10.2,'+',F10.2,'*V IN MM/DAY KP
                  $A.')
              C
              C       PROCESS INPUT DATA (STATEMENTS 0053-0090)*********************
              C
0053               XUP=X(1)
0054               X(NXSEC+1)=X(NXSEC)
0055               DO 1 I=1,NXSEC
0056               DX(I)=(X(I)-X(I+1))*1609.34
0057               X(I)=(XUP-X(I))*1609.34
0058               PX(I)=FLOAT(I)
0059               PH(I)=FLOAT(JTS)*DT
0060               PTI(I)=PT(I)
0061               PDF(I)= 0.0
0062               PTR(I)= 0.0
0063               PDC(I)= 0.0
0064               FLOW(1,I)=3600.0*Q/FLOW(2,I)
0065               Q= Q+FLOW(4,I)
0066             1 CONTINUE
0067               INX=NXSEC-1
0068               PV(1)= FLOW(2,1)*(DX(1)+DT*FLOW(1,1))/2.0
0069               DO 3 I=1,INX
0070               U(I)=(FLOW(1,I)+FLOW(1,I+1))/2.0
0071               A(I)=(FLOW(2,I)+FLOW(2,I+1))/2.0
0072               W(I)=(FLOW(3,I)+FLOW(3,I+1))/2.0
0073               QT(I)=FLOW(4,I)
0074             3 PV(I+1)= FLOW(2,I+1)*(DX(I)+DX(I+1))/2.0
0075               PV(NXSEC)= FLOW(2,NXSEC)*(DX(INX))/2.0
0076               NS=NXSEC
0077               WRITE(6,3002)
0078               WRITE (6,3004)
0079          3004 FORMAT(1H0,50X,'INITIAL  CONDITIONS')
0080               WRITE(6,3002)
0081               WRITE(6,3010)
0082          3010 FORMAT(3X,'GRID  RIVER  VELOCITY   AREA   TOP WIDTH  TRIB. FLOW
                  1  DISP FACT   INITIAL',/,10X,'MILE     M/HR   SQ METERS   METERS',
                  25X,'CU M/SEC      DQQ',8X,'TEMP')
0083               DO 9 I=1,NS
0084               RM=XUP-X(I)/1609.34
0085               WRITE(6,3011) I,RM,FLOW(1,I),FLOW(2,I),FLOW(3,I),QT(I),PT(I)
0086          3011 FORMAT(4X,I2,1X,F7.3,3X,F7.0,1X,F8.1,2X,F9.2,5X,F7.2,15X,F7.2)
0087               IF(I.LT.NS) WRITE(6,3007) DQQ(I)
0088          3007 FORMAT(63X,F5.2)
0089             9 CONTINUE
0090               WRITE(6,3002)
              C
              C       START TIME LOOP ******************************************************
              C
0091               DO 2 J=1,NHR
              C
              C       COMPUTE DISPERSION FLUXES (STATEMENTS 0092-0115),
              C                 LABEL STATEMENTS 80-99*********************************
```

```
                C
                C     COMPUTE DISPERSIVE Q'S
0092                  LNS=NS-1
0093                  DO 80 K=1,LNS
0094                  IX=(PX(K)+PX(K+1))/2.0
0095               80 DQ(K)=ABS(DQQ(IX)*U(IX)*A(IX))
                C     SET DQ=0 AT TRIBUTARY
0096                  K=0
0097                  DO 85 N=1,NTRIB
0098                  XR=IGT(N)
0099               81 K=K+1
0100                  IF(PX(K).LT.XR) GO TO 81
0101                  K= K-1
0102               85 DQ(K)= 0.0
                C     LIMIT DQ TO FORCE STABILITY
0103                  DO 82 K=1,NS
0104                  IF(K.EQ.1) GO TO 83
0105                  RATIO=DQ(K-1)*DT/PV(K)
0106                  IF(RATIO.GT.0.35) DQ(K-1)=0.35*PV(K)/DT
0107                  IF(K.EQ.NS) GO TO 82
0108               83 RATIO=DQ(K)*DT/PV(K)
0109                  IF(RATIO.GT.0.35) DQ(K)=0.35*PV(K)/DT
0110               82 CONTINUE
                C     IF(J.LT.5)WRITE(6,3000) (DQ(K),K=1,LNS)
                C     DISPERSE HEAT
0111                  DF(1)=DQ(1)*(PT(2)-PT(1))*DT/PV(1)
0112                  DO 84 K=2,LNS
0113                  DF(K)=(DQ(K-1)*(PT(K-1)-PT(K))+DQ(K)*(PT(K+1)-PT(K)))*DT/PV(K)
0114               84 IF(ABS(DF(K)).LT.1.0E-6) DF(K)=0.0
0115                  DF(NS)=DQ(NS-1)*(PT(NS-1)-PT(NS))*DT/PV(NS)
                C     IF(J.LT.5) WRITE(6,3000) (DF(K),K=1,NS)
                C
                C     SET UPSTREAM BOUNDARY (STATEMENTS 0116-0124,LABEL STATEMENTS
                C            40-59)*****************************************************
                C
                C     READ BOUNDARY CONDITIONS
0116                  READ(5,1006) TUP,TA,V,(TRIB(IGT(N)),N=1,NTRIB)
0117                  PXU=1.0
0118                  PTU=TUP
0119                  PVU= FLOW(1,1)*FLOW(2,1)*DT
0120                  PHU= DT*FLOAT(J+JTS)
0121                  PTRU= 0.0
0122                  PTIU=TUP
0123                  PDFU=0.0
0124                  PDCU= 0.0
                C     IF(J.LT.7) WRITE(6,3000) PXU,PTU,PVU,PHU,PTRU
                C
                C     SET D/S BOUNDARY (STATEMENTS 0125-0154,LABEL STATEMENTS 60-79)**
                C
0125                  MX=NXSEC-1
0126                  RDT=DT
0127               60 PDT=DX(MX)/U(MX)
0128                  IF(PDT.GE.RDT)GO TO 61
0129                  RDT=RDT-PDT
0130                  MX=MX-1
0131                  GO TO 60
0132               61 XP=FLOAT(MX)+1.0-RDT/PDT
                C     FIND PARCEL U/S OF XP
```

```
0133              LP=NS-1
0134           62 IF(PX(LP).LT.XP)GO TO 63
0135              LP=LP-1
0136              GO TO 62
0137           63 NS=LP+2
0138              PX(NS)=FLOAT(NXSEC)
            C     FIND OLD CONCENTRATION OF PARCEL WHICH WILL FALL OUT
0139              MX=IFIX(XP)
0140              XP=X(MX)+DX(MX)*(XP-FLOAT(MX))
0141              MX=IFIX(PX(LP))
0142              XL=X(MX)+DX(MX)*(PX(LP)-FLOAT(MX))
0143              MX=IFIX(PX(LP+1))
0144              XR=X(MX)+DX(MX)*(PX(LP+1)-FLOAT(MX))
0145              COF=(XP-XL)/(XR-XL)
0146              PT(NS)=(PT(LP)+DF(LP))*(1.0-COF)+(PT(LP+1)+DF(LP+1))*COF
0147              PV(NS)= PV(LP+1)
0148              PH(NS)= PH(LP)*(1.0-COF)+PH(LP+1)*COF
0149              PTR(NS)= PTR(LP)*(1.0-COF)+PTR(LP+1)*COF
0150              PTI(NS)=PTI(LP)*(1.0-COF)+PTI(LP+1)*COF
0151              PDF(NS)=(PDF(LP)+DF(LP))*(1.0-COF)+(PDF(LP+1)+DF(LP+1))*COF
0152              PDC(NS)=PDC(LP)*(1.0-COF)+PDC(LP+1)*COF
            C     IF(J.LT.7)WRITE(6,3000) RDT,PDT,XP,XL,XR,COF,PT(NS),PH(NS),
            C    $PTR(NS),PDF(NS),PDC(NS)
0153              MX= (IFIX(PX(LP))+NXSEC)/2
            C     IF(J.LT.7)WRITE(6,3001) LP,NS,MX
0154              CALL DECAY(DT,NS,MX,J)
            C
            C     MOVE INTERIOR PARCELS (STATEMENTS 0155-0186,LABEL STATEMENTS
            C             100-119)***********************************************
            C
            C
0155              LNS=NS-1
0156              DO 103 I=1,NXSEC
0157          103 NPT(I)= 0
0158              DO 100 KK=2,LNS
0159              K=LNS+2-KK
0160              KO=K-1
0161              XOLD=PX(KO)
0162              MX=IFIX(XOLD)
0163              RDT=DT
0164              PDX=FLOAT(MX+1)-PX(KO)
0165          102 PDT=PDX*DX(MX)/J(MX)
0166              IF(PDT.GE.RDT) GO TO 101
            C    PASSED GRID
0167              CALL DECAY(PDT,KO,MX,J)
0168              RDT=RDT-PDT
0169              MX=MX+1
0170              XOLD=FLOAT(MX)
0171              PDX=1.0
0172              NPT(MX)= NPT(MX)+1
0173              KPG(NPT(MX),MX)=K
0174              GO TO 102
0175          101 CONTINUE
            C    STOPPED IN SUBREACH
0176              CALL DECAY(RDT,KO,MX,J)
0177              PX(K)=XOLD+RDT*J(MX)/DX(MX)
0178              PT(K)=PT(KO)+DF(KO)
0179              PV(K)= PV(KO)
```

```
0180                PH(K)=PH(KO)
0181                PTR(K)=PTR(KO)
0182                PTI(K)=PTI(KO)
0183                PDF(K)=PDF(KO)+DF(KO)
0184                PDC(K)= PDC(KO)
             C      IF(J.LT.7) WRITE(6,3001) K,KO,MX,(NPT(I),I=1,NXSEC)
0185          3001 FORMAT(' ',12I10)
             C      IF(J.LT.7)WRITE(6,3000) XOLD,RDT,PDT,PDX,PX(K),PT(K),PV(K),PH(K),
             C     $PTR(K),PDC(K)
0186           100 CONTINUE
             C
             C      TRANSFER BOUNDARY CONDITIONS TO PARCEL CHARACTERISTICS(STATEMENTS
             C                 0187-0194********************************************
             C
0187                PX(1)=PXU
0188                PT(1)=PTU
0189                PV(1)=PVU
0190                PH(1)=PHU
0191                PTR(1)=PTRU
0192                PTI(1)=PTIU
0193                PDF(1)=PDFU
0194                PDC(1)= PDCU
             C
             C      DILUTE FOR TRIBUTARY INFLOW (STATEMENTS 0195-0230,LABEL
             C              STATEMENTS 120-129)***************************************
             C
0195                IF(NTRIB.EQ.0) GO TO 123
0196                K=0
0197                DO 123 N=1,NTRIB
0198                I= IGT(N)
             C      IF(J.LT.7) WRITE(6,3001)K,N,NTRIB,IGT(N),I,NPT(I)
0199                IF(NPT(I).EQ.0)GO TO 120
0200                VOL=0.0
0201                M=NPT(I)
0202                DO 121 K=1,M
0203                KK=KPS(K,I)
0204           121 VOL=VOL+PV(KK)
0205                DO 122 K=1,M
0206                KK=KPS(K,I)
0207                COF=PV(KK)/VOL
0208                DEL=(TRIB(I)*COF*QT(I)*3600.0*DT+PT(KK)*PV(KK))/(PV(KK)+QT(I)
                   $*3600.0*COF*DT)-PT(KK)
0209                IF(QT(I).LE.0.0)DEL=0.0
0210                PT(KK)=PT(KK)+DEL
0211                PTR(KK)=PTR(KK)+DEL
0212                PV(KK)=PV(KK)+COF*QT(I)*DT*3600.0
             C      IF(J.LT.10)WRITE(6,3000)VOL,COF,PT(KK),PTR(KK),PV(KK),DEL
             C      IF(J.LT.10) WRITE(6,3001)K,KK
0213           122 CONTINUE
0214                GO TO 123
0215           120 CONTINUE
             C
             C      FIND NEAREST PARCEL
             C
0216           124 K=K+1
0217                IF(PX(K).LT.FLOAT(I))GO TO 124
0218                MX=IFIX(PX(K))
0219                XR=X(MX)+(PX(K)-FLOAT(MX))*DX(MX)-X(I)
```

```
0220             K=K-1
0221             MX=IFIX(PX(K))
0222             XL=X(I)-X(MX)-(PX(K)-FLOAT(MX))*DX(MX)
0223             IF(XR.LT.XL)K=K+1
0224             DEL=(TRIB(I)*QT(I)*3600.0*DT+PT(K)*PV(K))/(PV(K)+QT(I)*3600.0*DT)
                $-PT(K)
0225             IF(QT(I).LE.0.0)DEL=0.0
0226             PT(K)=PT(K)+DEL
0227             PTR(K)=PTR(K)+DEL
0228             PV(K)=PV(K)+QT(I)*DT*3600.0
           C     IF(J.LT.10) WRITE(6,3000)XR,XL,PT(K),PV(K),PTR(K),DEL
           C     IF(J.LT.10) WRITE(6,3001)K,MX,1
0229             K= K-1
0230         123 CONTINUE
           C
           C     FIND CONCENTRATIONS AT IGO (STATEMENTS 0231-0245,LABEL
           C           STATEMENTS 130-139)*****************************************
           C
0231             TIME=FLOAT(J+JTS)*DT
0232             K= 0
0233         130 K= K+1
0234             IF(PX(K).LE.FLOAT(IGO)) GO TO 130
0235             IX= IFIX(PX(K))
0236             XR= X(IX)+DX(IX)*(PX(K)-FLOAT(IX))-X(IGO)
0237             IX= IFIX(PX(K-1))
0238             XL= X(IGO)-X(IX)-DX(IX)*(PX(K-1)-FLOAT(IX))
0239             COF= XL/(XL+XR)
0240             CIGO= PT(K-1)+COF*(PT(K)-PT(K-1))
0241             CIIGO= PTI(K-1)+COF*(PTI(K)-PTI(K-1))
0242             CDIGO= PDF(K-1)+COF*(PDF(K)-PDF(K-1))
0243             CTIGO= PTR(K-1)+COF*(PTR(K)-PTR(K-1))
0244             DCIGO= PDC(K-1)+COF*(PDC(K)-PDC(K-1))
0245             TTIGO= TIME- PH(K-1)-COF*(PH(K)-PH(K-1))
           C
           C     WRITE RESULTS (STATEMENTS 0246-0258,LABEL STATEMENTS 140-149)***
           C
0246             IF(J.EQ.1)WRITE(6,2000) IGO,NXSEC
0247             IF(MOD(J,IOUT).EQ.0) GO TO 140
0248             GO TO 2
0249         140 IC=J/IOUT
0250             IF(MOD(IC,50).EQ.0) WRITE(6,2000) IGO,NXSEC
0251        2000 FORMAT(6X,'TIME',7X,'TEMP AT   TRAVEL  PARCEL    CHANGE  IN  PARC
                1EL  TEMP',6X,'TEMP AT   TRAVEL  PARCEL    CHANGE  IN  PARCEL  TEM
                2P',/,5X,'DAY HOUR',6X,'GRID     TIME   TEMP AT',12X,'DUE  TO',17X,
                3'GRID     TIME   TEMP AT',12X,'DUE  TO',/,17X,I5,6X,'HOUR    ENTRY
                4      DISP     TRIB     DECAY',7X,I5,6X,'HOUR     ENTRY        DISP',
                55X,'TRIB      DECAY')
0252             IDAY= (TIME/24.0)+1
0253             HR= TIME-FLOAT(IDAY-1)*24.0
0254             TT= TIME-PH(NS)
0255             WRITE(6,2001)IDAY,HR,CIGO,TTIGO,CIIGO,CDIGO,CTIGO,DCIGO,PT(NS),TT,
                #PTI(NS),PDF(NS),PTR(NS),PDC(NS)
0256        2001 FORMAT(5X,I2,1X,F5.2,4X,F7.2,2X,F7.2,2X,F7.2,3X,F7.2,2X,F7.2,F9.2,
                $5X,F7.2,2X,F7.2,2X,F7.2,3X,F7.2,2X,2F9.2)
0257        3000 FORMAT(' ',10E12.5)
0258           2 CONTINUE
0259             END
```

```
FORTRAN IV G1  RELEASE 2.0              DECAY              DATE = 80288              12/36/06

                    SUBROUTINE DECAY (DT,K,MX,J)
                    COMMON  XK,PDC(500),PT(500),TA
                    RDT=DT
                  1 DTM= RDT
                    CALL FINK (K,MX)
              C     FIND MAXIMUM DECAY TIME STEP
                    SUM= XK*(PT(K)-TA)
                    DTL= RDT
                    REF= PT(K)-TA
                    IF(SUM.NE.0.0.AND.ABS(REF).GT.0.3) DTL=ABS(0.1*REF/SUM)
                    IF(DTL.LT.DTM) DTM=DTL
                    COM= 0.999*RDT
                    IF(DTM.GT.COM) DTM= RDT
              C     UPDATE TEMPERATURE
                    PT1= PT(K)
                    PT(K)= PT(K)+SUM*DTM
              C     IF(J.LT.6) WRITE(6,1000) PT1,PT(K),SUM,DTM,XK
               1000 FORMAT(' DECAY OUTPUT',8E12.5)
                    CALL FINK (K,MX)
                    SUM2= XK*(PT(K)-TA)
                    PT(K)= PT1+0.5*DTM*(SUM+SUM2)
                    PDC(K)=PDC(K)+0.5*(SUM+SUM2)*DTM
              C     IF(J.LT.6) WRITE(6,1000) XK,SUM2,PT(K),PDC(K)
                    IF(DTM.EQ.RDT) GO TO 5
                    RDT= RDT-DTM
                    GO TO 1
                  5 RETURN
                    END
```

```
      SUBROUTINE FINK(K,MX)
      COMMON  XK,PDC(500),PT(500),TA,V,A(50),W(50),A1,B1
      CPR= 100.0
      SIG= 1.171E-7/24.0
      AL= 595.9-0.545*PT(K)
      PSI= (A1+B1*V)/(24.0*10.0)
      TAB= PT(K)+273.16
      DFT=1.1532E11*EXP(-4271.1/(PT(K)+242.63))/((PT(K)+242.63)**2)
      XKX= 4.0*0.97*SIG*(TAB**3)+AL*PSI*(DFT+0.06)
      XK= -XKX*W(MX)/(A(MX)*CPR)
      RETURN
      END
```

Input Data for

Simplified Temperature Model in Steady Flow

```
MODEL DOCUMENTATION FOR THE SIMPLIFIED TEMPERATURE MODEL
   8   40        1.00      12.00      6    2    1    8        3.01        1.13
RIVER MILE 360.00 357.18 355.15 353.41 351.61 348.78 347.86 345.21
AREA    1     8.0   17.6   30.4   10.2   42.0   29.4   36.8   48.2
WIDTH   1    17.1   39.5   61.9   81.8   89.1   82.5  115.4  123.2
TREB   1        5   0.65
DQQ VALUES   0.05   0.05   0.05   0.05   0.05   0.05   0.05   0.05
INIT CONC1    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
BC1          1.30   28.0   1.90   20.0
BC 2         4.80   26.0   1.90   20.0
BC3          8.00   24.0   2.00   20.0
BC4         11.00   22.0   1.80   20.0
BC5         12.10   19.0   1.70   20.0
BC6         11.80   16.0   1.60   20.0
BC7         11.00   13.0   1.50   20.0
BC8         10.20   12.0   1.60   20.0
BC9          9.60   10.0   1.70   20.0
BC10         9.10   10.0   1.60   20.0
BC11         8.90   10.0   1.50   20.0
BC12         8.80   11.0   1.40   20.0
BC13         8.90   12.0   1.30   20.0
BC14         9.10   13.0   1.30   20.0
BC15         9.30   15.0   1.20   20.0
BC16         9.80   16.0   1.20   20.0
BC17        10.10   18.0   1.30   20.0
BC18        10.60   20.0   1.40   20.0
BC19        11.20   21.0   1.50   20.0
BC20        11.70   23.0   1.60   20.0
BC21        12.30   25.0   1.50   20.0
BC22        12.90   27.0   1.40   20.0
BC23        13.40   29.0   1.50   20.0
BC24        14.00   30.0   1.60   20.0
BC25        14.50   30.0   1.70   20.0
BC26        14.80   30.0   1.80   20.0
BC27        15.00   29.0   1.70   20.0
BC28        15.00   29.0   1.80   20.0
BC29        14.90   28.0   1.90   20.0
BC30        14.70   27.0   1.80   20.0
BC31        14.50   26.0   1.90   20.0
BC32        14.20   24.0   2.00   20.0
BC33        13.80   22.0   2.10   20.0
BC34        13.40   21.0   2.20   20.0
BC35        12.90   19.0   2.30   20.0
BC36        12.50   18.0   2.50   20.0
BC37        12.00   16.0   2.40   20.0
BC38        11.50   15.0   2.40   20.0
BC39        11.00   14.0   2.30   20.0
BC40        10.60   13.0   2.50   20.0
```

Output of

Simplified Temperature Model in Steady Flow

MODEL DOCUMENTATION FOR THE SIMPLIFIED TEMPERATURE MODEL

MODEL IS TO RUN 40 TIME STEPS EACH 1.00 HOURS LONG. THE RIVER IS DISCRETIZED BY 8 GRID POINTS.
THE INITIAL UPSTREAM DISCHARGE IS CONSTANT AT 12.00 CUBIC METERS PER SECOND.
THE PRINTOUT WILL BE GIVEN FOR GRIDS 6 AND 8 FOR EACH 2 TIME STEPS.

THE WIND FUNCTION IS 3.01+ 1.13*V IN MM/DAY KPA.

INITIAL CONDITIONS

GRID	RIVER MILE	VELOCITY M/HR	AREA SQ METERS	TOP WIDTH METERS	TRIB. FLOW CU M/SEC	DISP FACT DQQ	INITIAL TEMP
1	360.000	5400.	8.0	17.10	0.0		0.0
						0.05	
2	357.180	2455.	17.6	39.50	0.0		0.0
						0.05	
3	355.150	1421.	30.4	61.90	0.0		0.0
						0.05	
4	353.410	4235.	10.2	81.80	0.0		0.0
						0.05	
5	351.610	1029.	42.0	89.10	0.65		0.0
						0.05	
6	349.780	1549.	29.4	82.50	0.0		0.0
						0.05	
7	347.860	1237.	36.8	115.40	0.0		0.0
						0.05	
8	345.210	945.	48.2	123.20	0.0		0.0

TIME DAY	TIME HOUR	TEMP AT GRID 6	TRAVEL TIME HOUR	PARCEL TEMP AT ENTRY	CHANGE IN PARCEL TEMP DUE TO DISP	CHANGE IN PARCEL TEMP DUE TO TRIB	CHANGE IN PARCEL TEMP DUE TO DECAY	TEMP AT GRID 8	TRAVEL TIME HOUR	PARCEL TEMP AT ENTRY	CHANGE IN PARCEL TEMP DUE TO DISP	CHANGE IN PARCEL TEMP DUE TO TRIB	CHANGE IN PARCEL TEMP DUE TO DECAY
1	10.00	2.39	2.00	0.0	-0.00	0.0	2.40	2.56	2.00	0.0	0.00	0.0	2.56
1	12.00	5.05	4.00	0.0	-0.20	1.10	4.15	4.61	4.00	0.0	0.00	0.0	4.61
1	14.00	6.35	6.00	0.0	0.05	0.42	5.87	5.81	6.00	0.0	0.00	0.0	5.81
1	16.00	6.85	8.00	0.0	0.09	0.71	6.05	6.33	8.00	0.0	0.16	0.0	6.17
1	18.00	8.22	8.45	3.24	0.26	0.67	4.05	7.42	10.00	0.0	-0.77	1.66	6.53
1	20.00	10.89	8.45	9.65	-0.31	0.48	1.06	7.54	12.00	0.0	0.11	0.49	6.93
1	22.00	11.90	8.45	11.93	-0.24	0.43	-0.22	8.32	13.44	0.73	0.50	0.77	6.32
2	0.0	11.62	8.45	10.56	0.04	0.48	0.54	10.58	13.44	6.60	-0.04	0.57	3.45
2	2.00	11.69	8.45	9.32	0.07	0.51	1.79	12.87	13.44	11.62	-0.54	0.43	1.36
2	4.00	12.45	8.45	8.84	0.04	0.50	3.06	13.93	13.44	11.35	-0.10	0.46	2.22
2	6.00	13.82	8.45	9.01	0.00	0.46	4.35	14.81	13.44	9.86	0.07	0.50	4.38
2	8.00	15.63	8.45	9.58	-0.01	0.39	5.68	16.24	13.44	8.99	0.07	0.51	6.67
2	10.00	17.43	8.45	10.38	0.01	0.30	6.73	17.90	13.44	8.86	0.04	0.48	8.52
2	12.00	18.88	8.45	11.48	-0.02	0.21	7.22	19.38	13.44	9.21	0.03	0.43	9.71
2	14.00	19.79	8.45	12.63	-0.03	0.13	7.05	20.50	13.44	9.97	-0.02	0.35	10.21
2	16.00	20.04	8.45	13.73	0.00	0.09	6.22	21.08	13.44	10.94	-0.03	0.25	9.92
2	18.00	19.60	8.45	14.67	-0.01	0.07	4.88	20.92	13.44	12.04	-0.02	0.17	8.74
2	20.00	18.57	8.45	15.00	-0.01	0.09	3.48	20.17	13.44	13.18	-0.02	0.11	6.89
2	22.00	17.13	8.45	14.79	0.03	0.15	2.16	19.00	13.44	14.28	-0.04	0.07	4.68
3	0.0	15.67	8.45	14.33	0.03	0.21	1.10	17.63	13.44	14.91	-0.03	0.08	2.67

ATTACHMENT C

Complete Temperature Model in Steady Flow

```
C*****************************I-D  TRANSPORT MODEL****************
C**************COMPLETE TEMPERATURE MODEL IN STEADY FLOW*****************
C                                        ********
C      DEFINITIONS
C
C      PXU,PXD,PX(K)= POSITION OF LAGRANGIAN PARTICLE (U/S,D/S,
C           PARCEL K) IN EULERIAN GRID UNITS
C      PTU,PTD,PT(K)= TEMPERATURE OF LAGRANGIAN PARCEL
C      PVU,PVD,PV(K)= VOLUME OF LAGRANGIAN PARCEL
C      PHU,PHD,PH(K)= TIME THE PARCEL ENTERED THE SYSTEM
C      PTRU,PTRD,PTR(K)= CHANGE IN TEMPERATURE DUE TO TRIBUTARY INFLOW
C      PTIU,PTID,PTI(K)=  TEMPERATURE OF PARCEL AS IT ENTERED THE SYSTEM
C      PDFU,PDFD,PDF(K)=CHANGE IN PARCEL TEMPERATURE DUE TO DISPERSION
C      PDCU,PDCD,PDC(K)= TEMPERATURE CHANGE OF PARCEL DUE TO SURFACE
C         EXCHANGE
C      FLOW(L,I)= FLOW FIELD INFORMATION L AT GRID I
C              L=1 FOR FLOW VELOCITY IN METERS PER HR.
C              L=2 FOR FLOW AREA IN SQUARE METERS
C              L=3 FOR TOP WIDTH IN METERS
C              L=4 FOR TRIBUTARY INFLOW IN CU METERS/SECOND
C      U(I)= AVERAGE VELOCITY IN SUBREACH I IN METERS / HOUR
C      A(I)=AVERAGE AREA IN SUBREACH  IN SQUARE METERS
C      W(I)= AVERAGE TOP WIDTH IN SUBREACH I  IN METERS
C      X(I)= X COORDINATE OF EULERIAN GRID I IN RIVER MILES
C      DX(I)= DISTANCE BETWEEN GRID I AND I+1
C      DQQ(I)= DISPERSION FACTOR (DISP/(U*U*DT))
C      DQ(K)= FLOWRATE BETWEEN PARCEL K AND K+1 DUE TO VELOCITY GRADIENTS
C      DF(K)=  TEMPERATURE CHANGE OF PARCLE K DURING DT DUE TO DISPERSION
C      TUP= OBSERVED TEMPERATURE AT UPSTREAM END OF REACH
C      QT(I)= TRIBUTARY INFLOW IN CUBIC METERS PER SECOND AT GRID I
C      TRIB(I)= OBSERVED TEMPERATURE OF TRIBUTARY INFLOW AT GRID I
C      Q= DISCHARGE AT UPSTREAM END IN CUBIC METERS PER SECOND
C      DT= TIME STEP SIZE (IN HOURS)
C      PDX= PART OF EULERIAN SUBREACH REMAINING TO BE TRAVERSED
C      PDT= TIME REQUIRED TO TRAVERSE THE REMAINING PART OF THE SUBREACH
C      RDT= TIME REMAINING FOR MOVEMENT
C      A1= CONSTANT IN WIND FUNCTION (MM/DAY KPA)
C      B1= MASS TRANSFER COEFFICIENT (MM/DAY KPA(M/S))
C      V= WIND SPEED IN M/S
C      TA= AIR TEMPERATURE IN DEGREES C
C      HS= INCOMING SOLAR RADIATION CAL/SQ. CM/DAY
C      HL= INCOMING ATMOSPHERIC RADIATION CAL/SQ. CM/DAY
C      EA= VAPOR PRESSURE OF AIR IN KPA
C      RS(J,I)= PORTION OF INCOMING SOLAR RADIATION ABSORBED BY WATER
C           AT TIME J DT AND AT GRID I
C      BED(I)= HEAT FLOW FROM THE BED TO THE WATER IN CAL/SQ CM/DAY AT
C             GRID I
C      AZ(I)= AZIMUTH OF RIVER AT GRID I IN DEGREES CLOCKWISE FROM NORTH
C      BW(I)= BANK WIDTH AT GRID I IN METERS
C      EBH(I)= EFFECTIVE BARRIER HEIGHT AT I IN METERS
C      H= TOTAL SURFACE EXCHANGE INCLUDING BED CONDUCTION
C      JRS= TIME STEP FOR RS VALUES TO NEAREST 15 MINUTES
C      NXSEC= NUMBER OF EULERIAN GRIDS
C      INX= NXSEC-1
C      NS= NUMBER OF PARCLES IN THE SYSTEM
C      LNS= NS-1
C      LP= LAST PARCLE TO STAY IN THE SYSTEM AT D/S END
C      MX= GRID U/S OF PARCLE
```

```
                C      IGT(N)= GRID NUMBER FOR TRIBUTARY INFLOW
                C      NPT(I)= NUMBER OF PARCELS TO PASS GRID IGT(N) DURING DT
                C      KPG(N,M)= PARCEL NUMBER OF PARCEL TO PASS GRID IGT(N) DURING DT
                C      NHR= NUMBER OF TIME STEPS
                C      NTRIB= NUMBER OF ACTUAL TRIBUTARIES
                C      IGO= GRID NUMBER WHERE OUTPUT IS DESIRED
                C      IOUT= NUMBER OF TIME STEPS BETWEEN OUTPUT LISTINGS
                C      JTS= NUMBER OF TIME STEPS FROM MIDNIGHT TO TIME ZERO IN MODEL
                C       TITLE(20)= TITLE OF PROGRAM,  80 CHARACTERS MAX
                C
                C   PRELIMINARIES (STATEMENTS 0001-0030, LABEL STATEMENTS 20-39)******
                C
 0001                  DIMENSION PX(500),PV(500),PT(500),PH(500),PTR(500),PTI(500),
                      @PDC(500)
 0002                  DIMENSION  DX(50),U(50),A(50),FLOW(4,50),W(50)
 0003                  DIMENSION DQQ(50),QT(50),TRIB(50),IGT(50),KPG(20,50),NPT(50)
 0004                  DIMENSION PDF(500),DQ(500),DF(500),TITLE(20)
 0005                  DOUBLE PRECISION X(51)
 0006                  COMMON/B/ X,DX,PX
 0007                  COMMON  H,PDC,PT
 0008                  COMMON/A/TA,V,A,W,A1,B1,HS,HL,EA,RS,FLOW
                C
                C      MAXIMUM VALUE OF NXSEC IS 50
                C
                C      STEP 9 TO 28 ARE TO ZERO ARRAYS.
 0009                  DO 4 K=1,500
 0010                  PX(K)= 0.0
 0011                  PT(K)= 0.0
 0012                  PV(K)=0.0
 0013                  PH(K)= 0.0
 0014                  PTR(K)= 0.0
 0015                  PDF(K)= 0.0
 0016                  PTI(K)= 0.0
 0017                  DQ(K)= 0.0
 0018                  PDC(K)= 0.0
 0019                4 DF(K)= 0.0
 0020                  DO 5 I=1,50
 0021                  X(I)= 0.0
 0022                  DQQ(I)= 0.0
 0023                  QT(I)= 0.0
 0024                  FLOW(4,I)=0.0
 0025                  TRIB(I)= 0.0
 0026                  IGT(I)= 0.0
 0027                  DX(I)= 0.0
 0028                  U(I)= 0.0
 0029                  W(I)= 0.0
 0030                5 A(I)= 0.0
                C
                C      READ INPUT (STATEMENTS 0031-0054)
                C
 0031                  READ(5,1000)(TITLE(K),K=1,20)
 0032             1000 FORMAT(20A4)
 0033                  WRITE(6,3003) (TITLE(K),K=1,20)
 0034             3003 FORMAT(1H1,20X,20A4)
 0035                  WRITE(6,3002)
 0036             3002 FORMAT (//)
 0037                  READ(5,1005) NXSEC,NHR,DT,Q,IGO,IOUT,NTRIB,JTS,A1,B1
 0038             1005 FORMAT(2I5,2F10.2,4I5,2F10.2)
```

```
0039              READ(5,1006) (X(I),I=1,NXSEC)
0040         1006 FORMAT(10X,10F7.3)
0041              READ(5,1006)(FLOW(2,I),I=1,NXSEC)
0042              READ(5,1006)(FLOW(3,I),I=1,NXSEC)
0043              IF (NTRIB.EQ.0) GO TO 8
0044              DO 7 N=1,NTRIB
0045              READ(5,1010) IGT(N),QTT
0046         1010 FORMAT(10X,I7,F7.2)
0047              I= IGT(N)
0048            7 FLOW(4,I)=QTT
0049            8 READ(5,1006) (DQQ(I),I=1,NXSEC)
0050              READ(5,1006) (PT(I),I=1,NXSEC)
0051              WRITE(6,3005) NHR,DT,NXSEC,Q,IGO,NXSEC,IOUT
0052         3005 FORMAT(' MODEL IS TO RUN',I5,' TIME STEPS EACH',F10.2,' HOURS LONG
                 1. THE RIVER IS DISCRETIZED BY',I5,' GRID POINTS.',/,' THE INITIAL
                 2UPSTREAM DISCHARGE IS CONSTANT AT',F10.2,' CUBIC METERS PER SECOND
                 3.',/,' THE PRINTOUT WILL BE GIVEN FOR GRIDS',I5,' AND',I5,' FOR
                 4EACH',I5,' TIME STEPS.')
0053              WRITE(6,1007) A1,B1
0054         1007 FORMAT(1H ,'THE WIND FUNCTION IS',F10.2,'+',F10.2,'*V IN MM/DAY KP
                 $A.')
            C
            C     PROCESS INPUT DATA (STATEMENTS 0055-0094)**********************
            C
0055              XUP=X(1)
0056              X(NXSEC+1)=X(NXSEC)
0057              DO 1 I=1,NXSEC
0058              DX(I)=(X(I)-X(I+1))*1609.34
0059              X(I)=(XUP-X(I))*1609.34
0060              PX(I)=FLOAT(I)
0061              PH(I)=FLOAT(JTS)*DT
0062              PTI(I)=PT(I)
0063              PDF(I)= 0.0
0064              PTR(I)= 0.0
0065              PDC(I)= 0.0
0066              FLOW(1,I)=3600.0*Q/FLOW(2,I)
0067              Q= Q+FLOW(4,I)
0068            1 CONTINUE
0069              INX=NXSEC-1
0070              PV(1)= FLOW(2,1)*(DX(1)+DT*FLOW(1,1))/2.0
            C
0071              CALL CRS(NXSEC)
0072              CALL BEDFX(NXSEC,DT)
            C
0073              DO 3 I=1,INX
0074              U(I)=(FLOW(1,I)+FLOW(1,I+1))/2.0
0075              A(I)=(FLOW(2,I)+FLOW(2,I+1))/2.0
0076              W(I)=(FLOW(3,I)+FLOW(3,I+1))/2.0
0077              QT(I)=FLOW(4,I)
0078            3 PV(I+1)= FLOW(2,I+1)*(DX(I)+DX(I+1))/2.0
0079              PV(NXSEC)= FLOW(2,NXSEC)*(DX(INX))/2.0
0080              NS=NXSEC
0081              WRITE(6,3002)
0082              WRITE (6,3004)
0083         3004 FORMAT(1H0,50X,'INITIAL  CONDITIONS')
0084              WRITE(6,3002)
0085              WRITE(6,3010)
0086         3010 FORMAT(3X,'GRID  RIVER  VELOCITY    AREA    TOP WIDTH   TRIB. FLOW
```

```
                1  DISP FACT   INITIAL',/,10X,'MILE      M/HR   SQ METERS   METERS',
                25X,'CJ M/SEC      DQQ',8X,'TEMP')
0087               DO 9 I=1,NS
0088               RM=XUP-X(I)/1609.34
0089               WRITE(6,3011) I,RM,FLOW(1,I),FLOW(2,I),FLOW(3,I),QT(I),PT(I)
0090          3011 FORMAT(4X,I2,1X,F7.3,3X,F7.0,1X,F8.1,2X,F9.2,5X,F7.2,15X,F7.2)
0091               IF(I.LT.NS) WRITE(6,3007) DQQ(I)
0092          3007 FORMAT(63X,F5.2)
0093             9 CONTINUE
0094               WRITE(6,3002)
          C
          C        START TIME LOOP ***************************************************
          C
0095               DO 2 J=1,NHR
          C
          C        COMPUTE DISPERSION FLUXES (STATEMENTS 0096-0119, LABEL
          C               STATEMENTS 80-99****************************************
          C
          C      COMPUTE DISPERSIVE Q'S
0096               LNS=NS-1
0097               DO 80 K=1,LNS
0098               IX=(PX(K)+PX(K+1))/2.0
0099            80 DQ(K)=ABS(DQQ(IX)*U(IX)*A(IX))
          C        SET DQ=0 AT TRIBUTARY
0100               K=0
0101               DO 85 N=1,NTRIB
0102               XR=IGT(N)
0103            81 K=K+1
0104               IF(PX(K).LT.XR) GO TO 81
0105               K= K-1
0106            85 DQ(K)= 0.0
          C      LIMIT DQ TO FORCE STABILITY
0107               DO 82 K=1,NS
0108               IF(K.EQ.1) GO TO 83
0109               RATIO=DQ(K-1)*DT/PV(K)
0110               IF(RATIO.GT.0.35) DQ(K-1)=0.35*PV(K)/DT
0111               IF(K.EQ.NS) GO TO 82
0112            83 RATIO=DQ(K)*DT/PV(K)
0113               IF(RATIO.GT.0.35) DQ(K)=0.35*PV(K)/DT
0114            82 CONTINUE
          C        IF(J.LT.5)WRITE(6,3000) (DQ(K),K=1,LNS)
          C      DISPERSE HEAT
0115               DF(1)=DQ(1)*(PT(2)-PT(1))*DT/PV(1)
0116               DO 84 K=2,LNS
0117               DF(K)=(DQ(K-1)*(PT(K-1)-PT(K))+DQ(K)*(PT(K+1)-PT(K)))*DT/PV(K)
0118            84 IF(ABS(DF(K)).LT.1.0E-6) DF(K)=0.0
0119               DF(NS)=DQ(NS-1)*(PT(NS-1)-PT(NS))*DT/PV(NS)
          C        IF(J.LT.5) WRITE(6,3000) (DF(K),K=1,NS)
          C
          C        SET UPSTREAM BOUNDARY (STATEMENTS 0120-0129, LABEL
          C            STATEMENTS 40-59)******************************************
          C
          C      READ BOUNDARY CONDITIONS
0120               READ(5,1006) TUP,TA,V,HS,HL,EA
0121               IF(NTRIB.GT.0)READ(5,1006)(TRIB(IGT(N)),N=1,NTRIB)
0122               PXU=1.0
0123               PTU=TUP
0124               PVU= FLOW(1,1)*FLOW(2,1)*DT
```

```
0125             PHU= DT*FLOAT(J+JTS)
0126             PTRU= 0.0
0127             PTIU=TUP
0128             PDFU=0.0
0129             PDCU= 0.0
           C     IF(J.LT.7) WRITE(6,3000) PXU,PTU,PVU,PHU,PTRU,TA
           C
           C     SET D/S BOUNDARY (STATEMENTS 0130-0161, LABEL
           C             STATEMENTS 60-79)*******************************************
           C
0130             MX=NXSEC-1
0131             RDT=DT
0132          60 PDT=DX(MX)/U(MX)
0133             IF(PDT.GE.RDT)GO TO 61
0134             RDT=RDT-PDT
0135             MX=MX-1
0136             GO TO 60
0137          61 XP=FLOAT(MX)+1.0-RDT/PDT
           C     FIND PARCEL U/S OF XP
0138             LP=NS-1
0139          62 IF(PX(LP).LT.XP)GO TO 63
0140             LP=LP-1
0141             GO TO 62
0142          63 NS=LP+2
0143             PX(NS)=FLOAT(NXSEC)
           C     FIND OLD CONCENTRATION OF PARCEL WHICH WILL FALL OUT
0144             MX=IFIX(XP)
0145             XP=X(MX)+DX(MX)*(XP-FLOAT(MX))
0146             MX=IFIX(PX(LP))
0147             XL=X(MX)+DX(MX)*(PX(LP)-FLOAT(MX))
0148             MX=IFIX(PX(LP+1))
0149             XR=X(MX)+DX(MX)*(PX(LP+1)-FLOAT(MX))
0150             COF=(XP-XL)/(XR-XL)
0151             PT(NS)=(PT(LP)+DF(LP))*(1.0-COF)+(PT(LP+1)+DF(LP+1))*COF
0152             PV(NS)= PV(LP+1)
0153             PH(NS)= PH(LP)*(1.0-COF)+PH(LP+1)*COF
0154             PTR(NS)= PTR(LP)*(1.0-COF)+PTR(LP+1)*COF
0155             PTI(NS)=PTI(LP)*(1.0-COF)+PTI(LP+1)*COF
0156             PDF(NS)=(PDF(LP)+DF(LP))*(1.0-COF)+(PDF(LP+1)+DF(LP+1))*COF
0157             PDC(NS)=PDC(LP)*(1.0-COF)+PDC(LP+1)*COF
           C     IF(J.LT.7)WRITE(6,3000) RDT,PDT,XP,XL,XR,COF,PT(NS),PH(NS),
           C    $PTR(NS),PDF(NS),PDC(NS)
0158             MX= (IFIX(PX(LP))+NXSEC)/2
           C     IF(J.LT.7)WRITE(6,3001) LP,NS,MX
0159             TIME= FLOAT(J+JTS)*DT/24.0
0160             JRS= IFIX((TIME-IFIX(TIME)  +0.0052)*96.0)
0161             CALL DECAY(DT,NS,MX,J,JRS)
           C
           C     MOVE INTERIOR PARCELS (STATEMENTS 0162-0193, LABEL
           C           STATEMENTS 100-119)*******************************************
           C
           C
0162             LNS=NS-1
0163             DO 103 I=1,NXSEC
0164         103 NPT(I)= 0
0165             DO 100 KK=2,LNS
0166             K=LNS+2-KK
0167             KO=K-1
```

```
0168              XOLD=PX(KO)
0169              MX=IFIX(XOLD)
0170              RDT=DT
0171              PDX=FLOAT(MX+1)-PX(KO)
0172          102 PDT=PDX*DX(MX)/J(MX)
0173              IF(PDT.GE.RDT) GO TO 101
            C    PASSED GRID
0174              CALL DECAY(PDT,KO,MX,J,JRS)
0175              RDT=RDT-PDT
0176              MX=MX+1
0177              XOLD=FLOAT(MX)
0178              PDX=1.0
0179              NPT(MX)= NPT(MX)+1
0180              KPG(NPT(MX),MX)=K
0181              GO TO 102
0182          101 CONTINUE
            C    STOPPED IN SUBREACH
0183              CALL DECAY(RDT,KO,MX,J,JRS)
0184              PX(K)=XOLD+RDT*J(MX)/DX(MX)
0185              PT(K)=PT(KO)+DF(KO)
0186              PV(K)= PV(KO)
0187              PH(K)=PH(KO)
0188              PTR(K)=PTR(KO)
0189              PTI(K)=PTI(KO)
0190              PDF(K)=PDF(KO)+DF(KO)
0191              PDC(K)= PDC(KO)
            C     IF(J.LT.7) WRITE(6,3001) K,KO,MX,(NPT(I),I=1,NXSEC)
0192         3001 FORMAT(' ',12I10)
            C     IF(J.LT.7)WRITE(6,3000) XOLD,RDT,PDT,PDX,PX(K),PT(K),PV(K),PH(K),
            C    $PTR(K),PDC(K)
0193          100 CONTINUE
            C
            C     TRANSFER BOUNDARY CONDITIONS TO PARCEL CHARACTERISTICS(STATEMENTS
            C             0194-0201)**********************************************
            C
0194              PX(1)=PXU
0195              PT(1)=PTU
0196              PV(1)=PVU
0197              PH(1)=PHU
0198              PTR(1)=PTRU
0199              PTI(1)=PTIU
0200              PDF(1)=PDFU
0201              PDC(1)= PDCU
            C
            C     DILUTE FOR TRIBUTARY INFLOW (STATEMENTS 0202-0235, LABEL
            C     ******DILUTE FOR TRIBUTARY INFLOW (STATEMENTS 0201-0234,REFERENCE
            C             STATEMENTS 120-129)****************************************
            C
0202              IF(NTRIB.EQ.0) GO TO 123
0203              K=0
0204              DO 123 N=1,NTRIB
0205              I= IGT(N)
            C     IF(J.LT.7) WRITE(6,3001)K,N,NTRIB,IGT(N),I,NPT(I)
0206              IF(NPT(I).EQ.0)GO TO 120
0207              VOL=0.0
0208              M=NPT(I)
0209              DO 121 K=1,M
0210              KK=KPG(K,I)
```

```
0211            121 VOL=VOL+PV(KK)
0212                DO 122 K=1,M
0213                KK=KPS(K,I)
0214                COF=PV(KK)/VOL
0215                DEL=(TRIB(I)*COF*QT(I)*3600.0*DT+PT(KK)*PV(KK))/(PV(KK)+QT(I)
                   $*3600.0*COF*DT)-PT(KK)
0216                IF(QT(I).LE.0.0)DEL=0.0
0217                PT(KK)=PT(KK)+DEL
0218                PTR(KK)=PTR(KK)+DEL
0219                PV(KK)=PV(KK)+COF*QT(I)*DT*3600.0
               C    IF(J.LT.10)WRITE(6,3000)VOL,COF,PT(KK),PTR(KK),PV(KK),DEL
               C    IF(J.LT.10) WRITE(6,3001)K,KK
0220            122 CONTINUE
0221                GO TO 123
0222            120 CONTINUE
               C
               C    FIND NEAREST PARCEL
               C
0223            124 K=K+1
0224                IF(PX(K).LT.FLOAT(I))GO TO 124
0225                MX=IFIX(PX(K))
0226                XR=X(MX)+(PX(K)-FLOAT(MX))*DX(MX)-X(I)
0227                K=K-1
0228                MX=IFIX(PX(K))
0229                XL=X(I)-X(MX)-(PX(K)-FLOAT(MX))*DX(MX)
0230                IF(XR.LT.XL)K=K+1
0231                DEL=(TRIB(I)*QT(I)*3600.0*DT+PT(K)*PV(K))/(PV(K)+QT(I)*3600.0*DT)
                   $-PT(K)
0232                IF(QT(I).LE.0.0)DEL=0.0
0233                PT(K)=PT(K)+DEL
0234                PTR(K)=PTR(K)+DEL
0235                PV(K)=PV(K)+QT(I)*DT*3600.0
               C    IF(J.LT.10) WRITE(6,3000)XR,XL,PT(K),PV(K),PTR(K),DEL
               C    IF(J.LT.10) WRITE(6,3001)K,MX,I
0236                K= K-1
0237            123 CONTINUE
               C
               C    FIND CONCENTRATIONS AT IGO (STATEMENTS 0238-0253, LABEL
               C            STATEMENTS 130-139)******************************************
               C
0238                TIME=FLOAT(J+JTS)*DT
0239                K= 0
0240            130 K= K+1
0241                IF(PX(K).LE.FLOAT(IGO)) GO TO 130
0242                IX= IFIX(PX(K))
0243                XR= X(IX)+DX(IX)*(PX(K)-FLOAT(IX))-X(IGO)
0244                IX= IFIX(PX(K-1))
0245                XL= X(IGO)-X(IX)-DX(IX)*(PX(K-1)-FLOAT(IX))
0246                COF= XL/(XL+XR)
0247                CIGO= PT(K-1)+COF*(PT(K)-PT(K-1))
0248                CIIGO= PTI(K-1)+COF*(PTI(K)-PTI(K-1))
0249                CDIGO= PDF(K-1)+COF*(PDF(K)-PDF(K-1))
0250                CTIGO= PTR(K-1)+COF*(PTR(K)-PTR(K-1))
0251                DCIGO= PDC(K-1)+COF*(PDC(K)-PDC(K-1))
0252                TTIGO= TIME- PH(K-1)-COF*(PH(K)-PH(K-1))
0253                CALL BEDC(NS)
               C
               C    WRITE RESULTS (STATEMENTS 0254-0265, LABEL
```

```
C              STATEMENTS 140-149)*****************************************
C
      IF(J.EQ.1)WRITE(6,2000) IGO,NXSEC
      IF(MOD(J,IOUT).EQ.0) GO TO 140
      GO TO 2
  140 IC=J/IOUT
      IF(MOD(IC,50).EQ.0) WRITE(6,2000) IGO,NXSEC
 2000 FORMAT(6X,'TIME',7X,'TEMP AT   TRAVEL  PARCEL     CHANGE  IN  PARC
     1EL  TEMP',6X,'TEMP AT   TRAVEL  PARCEL     CHANGE  IN  PARCEL  TEM
     2P',/,5X,'DAY HOUR',6X,'GRID     TIME   TEMP AT',12X,'DUE  TO',17X,
     3'GRID     TIME   TEMP AT',12X,'DUE  TO',/,17X,I5,6X,'HOUR     ENTRY
     4      DISP     TRIB     DECAY',7X,I5,6X,'HOUR     ENTRY      DISP',
     55X,'TRIB     DECAY')
      IDAY= (TIME/24.0)+1
      HR= TIME-FLOAT(IDAY-1)*24.0
      TT= TIME-PH(NS)
      WRITE(6,2001)IDAY,HR,CIGO,TTIGO,CIIGO,CDIGO,CTIGO,DCIGO,PT(NS),TT,
     #PTI(NS),PDF(NS),PTR(NS),PDC(NS)
 2001 FORMAT(5X,I2,1X,F5.2,4X,F7.2,2X,F7.2,2X,F7.2,3X,F7.2,2X,F7.2,F9.2,
     $5X,F7.2,2X,F7.2,2X,F7.2,3X,F7.2,2X,2F9.2)
 3000 FORMAT(' ',10E12.5)
    2 CONTINUE
      END
```

```
                  SUBROUTINE DECAY (DT,K,MX,J,JRS)
                  COMMON   H,PDC(500),PT(500)
                  RDT=DT
                1 DTM= RDT
                  CALL FINK (K,MX,JRS)
      C           FIND MAXIMUM DECAY TIME STEP
                  SUM= H
                  DTL= RDT
                  REF= PT(K)
                  IF(SUM.NE.0.0.AND.ABS(REF).GT.0.3) DTL=ABS(0.1*REF/SUM)
                  IF(DTL.LT.DTM) DTM=DTL
                  COM= 0.999*RDT
                  IF(DTM.GT.COM) DTM= RDT
      C           UPDATE TEMPERATURE
                  PT1= PT(K)
                  PT(K)= PT(K)+SUM*DTM
      C           IF(J.LT.3) WRITE(6,1000) PT1,PT(K),H   ,SUM,DTM,REF
             1000 FORMAT(' DECAY OUTPUT',8E12.5)
                  CALL FINK (K,MX,JRS)
                  SUM2= H
                  PT(K)= PT1+0.5*DTM*(SUM+SUM2)
                  PDC(K)=PDC(K)+0.5*(SUM+SUM2)*DTM
      C           IF(J.LT.3) WRITE(6,1000) XK,SUM2,PT(K),PDC(K)
                  IF(DTM.EQ.RDT) GO TO 5
                  RDT= RDT-DTM
                  GO TO 1
                5 RETURN
                  END
```

```
      SUBROUTINE FINK(K,MX,JT)
      DIMENSION RS(97,50),BED(50)
      COMMON   H,PDC(500),PT(500)
      COMMON/A/TA,V,A(50),W(50),A1,B1,HS,HL,EA,FLOW(4,50)
      COMMON/C/ RS
      COMMON/D/ BED
      CPR= 100.0
      SIG= 1.171E-7/24.0
      AL= 595.9-0.545*PT(K)
      TAB=PT(K)+273.16
      PSI= (A1+B1*V)/(24.0*10.0)
      SP= EXP(52.418-6788.6/TAB-5.0016*ALOG(TAB))
      H1=(HS*RS(JT,MX)+HL*0.97)/24.0
      H2=H1-0.97*SIG*((PT(K)+273.16)**4)
      H3=H2-PSI*AL*((SP-EA)+0.06*(PT(K)-TA))+BED(MX)
      H=H3*W(MX)/(A(MX)*CPR)
      IF(K.GT.5) GO TO 1
C     WRITE(6,3001) K,MX,JT
 3001 FORMAT(1H,'FINK SAYS',3I10)
C     WRITE(6,3000) TA,V,A(MX),HS,AL,TAB,PSI,SP,H
C     WRITE(6,3000)W(MX),H1,H2,H3,EA,HL,BED(MX)
 3000 FORMAT(1H,9E12.4)
    1 RETURN
      END
```

```
0001                 SUBROUTINE CRS(NXSEC)
               C     SUBROUTINE FOR COMPUTING ABSORPTION COEFFICIENTS ON A RIVER
               C     VARIABLE DEFINITIONS
               C     J= 1,96 TIME STEP AT 15 MINUTE INCREMENTS
               C     I= 1,50 GRID NUMBERS
               C     RS(J,I)=ABSOPRTION COEFFICIENT FOR TIME J, GRID I
               C     EBH(I)=TREE HEIGHT OR EFFECTIVE BARRIER HEIGHT FOR EACH SUBREACH,M
               C     AZ(I)=AZIMUTH OF RIVER SUBREACH, DEGREES
               C     AZS=AZIMUTH OF SUN, DEGREES
               C     BW(I)=BANK WIDTH, DISTANCE FROM TREES TO WATERS EDGE, METERS
               C     THE= ANGLE BETWEEN SUN AND STREAM AXIS, DEGREES
               C     BET= ANGLE BETWEEN SUN AND A NORMAL TO THE STREAM AXIS, DEGREES
               C     ELEV= ELEVATION OF THE SUN, DEGREES
               C     XN= NORMAL DISTANCE FROM TREES TO EDGE OF SHADOW, METERS
               C     X=  DISTANCE FROM TREES TO SHADOW ALONG A BEAM OF LIGHT, METERS
               C     DEL= DECLINATION OF THE SUN, DEGREES
               C     HA=  HOUR ANGLE FROM ZENITH TO SUN, DEGREES
               C     DHA= CHANGE IN HOUR ANGLE PER TIME STEP, DEGREES
               C     HAO= HOUR ANGLE AT MIDNIGHT, DEGREES
               C     PHI= LATITUDE OF RIVER, DEGREES
               C     ALON= LONGITUDE OF RIVER, DEGREES
               C     TZM= TIME ZONE MERIDIAN
               C     JDAT= JULIAN DATE FOR WHICH SHADING COMPUTATIONS ARE MADE
               C     DR=  DEGREE TO RADIAN CONVERSION
               C
0002                 DIMENSION EBH(50),AZ(50),BW(50),T(50)
0003                 COMMON/A/TA,V,A(50),W(50),A1,B1,HS,HL,EA,FLOW(4,50)
0004                 COMMON/C/ RS(97,50)
0005                 READ(5,1000) JDAT,PHI,ALON,TZM
0006            1000 FORMAT(10X,I7,3F7.1)
0007                 READ(5,1001) (AZ(I),I=1,NXSEC)
0008                 READ(5,1001) (BW(I),I=1,NXSEC)
0009                 READ(5,1001) (EBH(I),I=1,NXSEC)
0010            1001 FORMAT(10X,10F7.1)
0011                 DR= 3.14159/180.0
0012                 DHA= 3.75*DR
0013                 PHI= PHI*DR
0014                 DEL= DR*23.45*COS(6.2832*(172.0-FLOAT(JDAT))/365.0)
0015                 HAO= (180.0+ALON-TZM)*DR
0016                 SDSP= SIN(DEL)*SIN(PHI)
0017                 CDCP= COS(DEL)*COS(PHI)
0018                 DO 10 J=1,96
0019                 M= J-1
0020                 AJ=FLOAT(J-1)
0021                 HA=HAO-DHA*AJ
0022                 S= SDSP+CDCP*COS(HA)
0023                 ELEV= ARSIN(S)/DR
0024                 AZS= 0.0
0025                 IF(ELEV.GT.1.5) RSM=1.0-1.18*(1.0/ELEV**0.77)
0026                 IF(ELEV.GT.1.5) AZS=ARCOS((SIN(DEL)-SIN(ELEV*DR)*SIN(PHI))/(COS
                    *(ELEV*DR)*COS(PHI)))
0027                 IF(HA.LT.0.0) AZS= 360.0*DR-AZS
               C     WRITE(6,3001) J,HA,S,ELEV,RSM,AZS,DEL,HAD,SDSP,CDCP
0028            3001 FORMAT(5H STEP,I5,9E12.4)
               C
0029                 DO 10 I=1,NXSEC
0030                 IF(ELEV.GT.1.5) GO TO 1
0031                 RS(J,I)= 0.2
```

```
          GO TO 10
        1 THE= ABS(AZS-AZ(I)*DR)
          IF(THE.GT.(180.0*DR))  THE=THE-180.0*DR
          BET= ABS(THE-90.0*DR)
          X= EBH(I)/TAN(ELEV*DR)
          IF(COS(BET).GE.0.01) GO TO 2
          RS(J,I)= RSM
          GO TO 10
        2 XN= X*COS(BET)
          IF(XN.GE.BW(I)) GO TO 3
          RS(J,I)= RSM
          GO TO 10
        3 IF(XN.LE.(BW(I)+FLOW(3,I))) GO TO 4
          RS(J,I)= 0.2
          GO TO 10
        4 RS(J,I)= RSM*(FLOW(3,I)+BW(I)-XN)/FLOW(3,I)+0.2*(XN-BW(I))/
         #FLOW(3,I)
C         WRITE(6,3002) I,THE,BET,X,XN,FLOW(3,I),RS(J,I)
     3002 FORMAT(5H GRID,I5,9E12.4)
       10 CONTINUE
          DO 60 L=1,NXSEC
       60 RS(97,L)= RS(96,L)
          PHI=PHI/DR
          WRITE(6,5050) JDAT,TZM,PHI,ALON
     5050 FORMAT(1H0,39X,'ABSORPTION COEFFICIENTS FOR SOLAR RADIATION',38X,
         1//,53X,'JULIAN DAY ',I3,2X,'TIME ZONE  ',1F4.1,' DEGREES',29X,/,
         253X,'LATITUDE=',1F5.1,' LONGITUDE= ',F5.1,' DEGREES',27X,//,
         3' GRID    EBH     BW  AZIMUTH  ***********************************',
         4'****HOUR*****************************************************',/,
         58X,'METER  METER  DEGREE',4X,'5',5X,'6',5X,'7',5X,'8',5X,'9',4X,
         6'10',4X,'11',4X,'12',4X,'13',4X,'14',4X,'15',4X,'16',4X,'17',4X,
         7'18',4X,'19',3X)
          DO 11 I=1,NXSEC
          WRITE(6,3000) I,EBH(I),BW(I),AZ(I),(RS(J,I),J=20,76,4)
     3000 FORMAT(' ',I4,F9.1,F7.1,F8.1,1X,15F6.3)
       11 CONTINUE
          RETURN
          END
```

```
      SUBROUTINE BEDFX(NXSEC,DT)
C
C     DEFINE VARIABLES
C
C     RFO(J)= RESPONSE FUNCTION ORDINATE FOR FLOW OF HEAT TO THE WATER
C          TO THE BED DUE TO A UNIT CHANGE IN TEMPERATURE
C     DBT(J,I)= CHANGE IN WATER TEMPERATURE AT GRID I AND TIME T-JDT
C     TO(I)= OLD TEMPERATURE AT GRID I
C     CV= HEAT STORAGE CAPACITY OF THE BED MATERIAL IN CAL/(CU CM DEG C)
C     DIF= THERMAL DIFFUSIVITY OF THE BED MATERIAL SQ CM/HR
C     NRFO= NUMBER OF RESPONSE FUNCTION ORDINATES
C     XL= DEPTH IN BED AT WHICH IT IS ASSUMED THAT NO HEAT TRANSFER OCCU
C     TN(I)= NEW TEMPERATURE AT GRID I
C
      DIMENSION RFO(96),DBT(96,50),TO(50),TN(50)
      DOUBLE PRECISION X(51)
      COMMON/B/ X,DX(50),PX(500)
      COMMON H,PDC(500),PT(500)
      COMMON/D/ BED(50)
      READ(5,2000) DIF,CV
 2000 FORMAT(10X,2F7.3)
C
C     SET DBT'S EQUAL TO ZERO
C
      DO 1 I=1,NXSEC
      DO 1 J=1,96
      BED(J)= 0.0
    1 DBT(J,I)= 0.0
C
C     COMPUTE RESPONSE FUNCTION ORDINATES
C
      XL= 300.0
      DTB= DT
      IF(DTB.LT.0.25) DTB=0.25
      NRFO= 24/DTB
      HO= 1.0
      A= -DIF*9.86959*DTB/(4.0*XL*XL)
      DO 2 J=1,NRFO
      B= 0.0
      H= 0.0
      CA= 1.0
    3 CONTINUE
C
C     UPDATE SUMS
C
      TNP1= 2.0*B+1
      DH=(SIN(TNP1*1.5708))*(EXP(A*TNP1*TNP1*FLOAT(J)))*CA/(TNP1*TNP1)
      H= H+DH
      B= B+1
      CA= -CA
C     CHECK CONVERGENCE
      IF(ABS(DH).GT.1.0E-6) GO TO 3
C     FINAL COMPUTATIONS
      H= H*0.810569
      RFO(J)= (HO-H)*CV*XL
      HO= H
    2 CONTINUE
C
```

```
C      WRITE RESULTS
C
       WRITE(6,3000) CV,DIF
  3000 FORMAT(1H0,33X,'RESPONSE FUNCTION ORDINATES FOR BED CONDUCTION ',
      1'TERM (RFO IN CAL/(SQ CM HR))',/,36X,'HEAT STORAGE CAPACITY OF ',
      2'THE BED = ',F6.3,' CAL/(CU CM DEG).',/,36X,'THERMAL DIFFUSIVITY',
      3'=',F7.4,' SQ CM/HR.',//,' LAG',4X,'RFO  LAG    RFO  LAG    RFO',
      42X,'LAG    RFO  LAG    RFO  LAG    RFO  LAG    RFO  LAG    RFO',
      52X,'LAG    RFO  LAG    RFO')
       WRITE(6,3004) (K,RFO(K),K=1,NRFO)
  3004 FORMAT(1H ,10(I4,F8.2),/)
       RETURN
       ENTRY BEDC(NS)
C
C      UPDATE OLD TEMPERATURES
C
       DO 4 I=1,NXSEC
       IF(DT.LT.0.25) TO(I)=TO(I)+DT*4.0*(TN(I)-TO(I))
     4 IF(DT.GE.0.25) TO(I)= TN(I)
C      COMPUTE NEW TEMPERATURES
       TN(1)= PT(1)
       K=0
       INX= NXSEC-1
       DO 6 I=2,INX
     5 K=K+1
       IF(PX(K).LE.FLOAT(I)) GO TO 5
       IX= IFIX(PX(K))
       XR= X(IX)+DX(IX)*(PX(K)-FLOAT(IX))-X(I)
       K=K-1
       IX= IFIX(PX(K))
       XL= X(I)-X(IX)-DX(IX)*(PX(K)-FLOAT(IX))
       COF= XL/(XL+XR)
     6 TN(I)= PT(K)+COF*(PT(K+1)-PT(K))
       TN(NXSEC)= PT(NS)
       DO 7 I=1,NXSEC
C      UPDATE DBT'S
       IE= NRFO-1
       DO 8 K=1,IE
     8 DBT(NRFO+1-K,I)= DBT(NRFO-K,I)
       DBT(1,I)= TN(I)-TO(I)
C      COMPUTE BED FLUX
       BED(I)= 0.0
       DO 7 K=1,NRFO
       BED(I)= BED(I)-RFO(K)*DBT(K,I)
     7 CONTINUE
       RETURN
       END
```

Input Data for

Complete Temperature Model in Steady Flow

MODEL DOCUMENTATION FOR THE COMPLETE TEMPERATURE MODEL

8 40 1.00 12.00 5 2 1 8 3.01 1.13 00006720

RIVER MILE	360.00	357.18	355.15	353.41	351.61	348.76	347.86	345.21
AREA 1	8.0	17.6	30.4	10.2	42.0	29.4	36.8	48.2
WIDTH 1	17.1	39.5	61.9	81.8	89.1	82.5	115.4	123.2
TREB 1	5	0.65						
DQQ VALUES	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
INIT CONC1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
REFLECTION	194	40.0	77.0	75.0				
AZIMUTH	260.0	195.0	165.0	90.0	50.0	20.0	60.0	90.0
BANK WIDTH	2.0	2.0	5.0	5.0	5.0	5.0	5.0	5.0
EFF BR HGT	5.0	5.0	10.0	10.0	15.0	15.0	20.0	20.0
BEDFX CD1	27.720	0.680						
BC T1 CD1	1.30	20.0	1.40	526.4	535.0	1.52		
BC T1 CD2	20.0							
BC T2 CD1	4.80	21.0	1.50	738.5	535.0	1.50		
BC T2 CD2	20.0							
BC T3 CD1	11.70	23.0	1.60	913.2	535.0	1.48		
BC T3 CD2	20.0							
BC T4 CD1	12.30	25.0	1.50	951.6	535.0	1.45		
BC T4 CD2	20.0							
BC T5 CD1	12.90	27.0	.40	989.0	535.0	1.47		
BC T5 CD2	20.0							
BC T6 CD1	13.40	29.0	1.50	286.8	535.0	1.42		
BC T6 CD2	20.0							
BC T7 CD1	14.00	30.0	1.60	253.8	535.0	1.35		
BC T7 CD2	20.0							
BC T8 CD1	14.50	30.0	1.70	611.0	535.0	1.40		
BC T8 CD2	20.0							
BC T9 CD1	14.80	30.0	1.80	415.4	535.0	1.25		
BC T9 CD2	20.0							
BC T10 CD1	15.00	29.0	1.70	255.0	535.0	1.18		
BC T10 CD2	20.0							
BC T11 CD1	15.00	29.0	1.80	83.5	535.0	1.20		
BC T11 CD2	20.0							
BC T12 CD1	14.90	28.0	1.90	0.0	535.0	1.30		
BC T12 CD2	20.0							
BC T13 CD1	14.70	27.0	1.80	0.0	535.0	1.40		
BC T13 CD2	20.0							
BC T14 CD1	14.50	26.0	1.90	0.0	535.0	1.50		
BC T14 CD2	20.0							
BC T15 CD1	14.20	24.0	2.00	0.0	535.0	1.60		
BC T15 CD2	20.0							
BC T16 CD1	13.80	22.0	2.10	0.0	535.0	1.70		
BC T16 CD2	20.0							
BC T17 CD1	13.40	21.0	2.20	0.0	535.0	1.80		
BC T17 CD2	20.0							
BC T18 CD1	12.90	19.0	2.30	0.0	505.0	1.90		
BC T18 CD2	20.0							
BC T19 CD1	12.50	18.0	2.50	0.0	505.0	2.00		
BC T19 CD2	20.0							
BC T20 CD1	12.00	16.0	2.40	0.0	505.0	2.10		
BC T20 CD2	20.0							
BC T21 CD1	11.50	15.0	2.40	0.0	505.0	2.20		
BC T21 CD2	20.0							
BC T22 CD1	11.00	14.0	2.30	9.9	505.0	2.30		
BC T22 CD2	20.0							
BC T23 CD1	10.60	13.0	2.50	201.1	505.0	2.40		
BC T23 CD2	20.0							
BC T24 CD1	8.90	12.0	1.30	301.1	505.0	2.5		
BC T24 CD2	20.0							
BC T25 CD1	9.10	13.0	1.30	558.2	505.0	2.5		
BC T25 CD2	20.0							

BC	T26	CD1	9.30	15.0	1.20	693.4	505.0	2.5
BC	T26	CD2	20.0					
BC	T27	CD1	9.80	16.0	1.20	853.8	505.0	2.4
BC	T27	CD2	20.0					
BC	T28	CD1	10.10	18.0	1.30	934.1	505.0	2.3
BC	T28	CD2	20.0					
BC	T29	CD1	10.60	20.0	1.40	964.1	505.0	2.2
BC	T29	CD2	20.0					
BC	T30	CD1	11.20	21.0	1.50	925.3	505.0	2.0
BC	T30	CD2	20.0					
BC	T31	CD1	11.70	23.0	1.60	786.8	505.0	1.9
BC	T31	CD2	20.0					
BC	T32	CD1	12.30	25.0	1.50	650.0	505.0	1.8
BC	T32	CD2	20.0					
BC	T33	CD1	12.90	27.0	1.40	453.8	505.0	1.7
BC	T33	CD2	20.0					
BC	T34	CD1	13.40	29.0	1.50	258.2	505.0	1.5
BC	T34	CD2	20.0					
BC	T35	CD1	14.00	30.0	1.60	70.3	505.0	1.4
BC	T35	CD2	20.0					
BC	T36	CD1	1.30	28.0	1.90	0.0	505.0	1.3
BC	T36	CD2	20.0					
BC	T37	CD1	4.80	26.0	1.90	0.0	505.0	1.2
BC	T37	CD2	20.0					
BC	T38	CD1	8.00	24.0	2.00	0.0	505.0	1.1
BC	T38	CD2	20.0					
BC	T39	CD1	11.00	22.0	1.80	0.0	505.0	1.0
BC	T39	CD2	20.0					
BC	T40	CD1	12.10	19.0	1.70	0.0	505.0	0.9
BC	T40	CD2	20.0					

Output of

Complete Temperature Model in Steady Flow

MODEL DOCUMENTATION FOR THE COMPLETE TEMPERATURE MODEL

MODEL IS TO RUN 40 TIME STEPS EACH 1.00 HOURS LONG. THE RIVER IS DISCRETIZED BY 8 GRID POINTS.
THE INITIAL UPSTREAM DISCHARGE IS CONSTANT AT 12.00 CUBIC METERS PER SECOND.
THE PRINTOUT WILL BE GIVEN FOR GRIDS 5 AND 8 FOR EACH 2 TIME STEPS.
THE WIND FUNCTION IS 3.01+ 1.13*V IN MM/DAY KPA.

ABSORPTION COEFFICIENTS FOR SOLAR RADIATION

JULIAN DAY 194 ,TIME ZONE 75.0 DEGREES
LATITUDE= 40.0 LONGITUDE= 77.0 DEGREES

GRID	EBH	BW	AZIMUTH	************************************						HOUR	************************************							
	METER	METER	DEGREE	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	5.0	2.0	260.0	0.200	0.545	0.885	0.918	0.935	0.946	0.952	0.956	0.955	0.951	0.944	0.932	0.889	0.523	0.200
2	5.0	2.0	195.0	0.200	0.200	0.502	0.689	0.801	0.881	0.946	0.956	0.955	0.951	0.889	0.789	0.640	0.363	0.200
3	10.0	5.0	165.0	0.200	0.200	0.401	0.668	0.821	0.926	0.952	0.956	0.955	0.951	0.876	0.778	0.638	0.388	0.200
4	10.0	5.0	90.0	0.200	0.200	0.863	0.918	0.935	0.946	0.952	0.956	0.955	0.951	0.944	0.932	0.913	0.725	0.200
5	15.0	5.0	50.0	0.200	0.446	0.559	0.755	0.819	0.871	0.917	0.956	0.955	0.951	0.944	0.845	0.679	0.359	0.200
6	15.0	5.0	20.0	0.200	0.200	0.212	0.500	0.675	0.803	0.909	0.956	0.955	0.951	0.834	0.665	0.411	0.200	0.200
7	20.0	5.0	60.0	0.200	0.558	0.667	0.729	0.780	0.826	0.873	0.922	0.955	0.951	0.944	0.836	0.617	0.200	0.200
8	20.0	5.0	90.0	0.200	0.349	0.805	0.918	0.935	0.946	0.936	0.932	0.932	0.938	0.944	0.932	0.913	0.740	0.200

RESPONSE FUNCTION ORDINATES FOR BED CONDUCTION TERM (RFO IN CAL/(SQ CM HR))
HEAT STORAGE CAPACITY OF THE BED = 0.680 CAL/(CU CM DEG).
THERMAL DIFFUSIVITY=27.7200 SQ CM/HR.

LAG	RFO	LAG	RFO	LAG	RFO	LAG	RFO	LAG	RFO	LAG	RFO	LAG	RFO	LAG	RFO	LAG	RFO	LAG	RFO
1	4.04	2	1.57	3	1.28	4	1.08	5	0.95	6	0.86	7	0.79	8	0.74	9	0.69	10	0.66
11	0.62	12	0.60	13	0.57	14	0.55	15	0.53	16	0.51	17	0.50	18	0.48	19	0.47	20	0.46
21	0.45	22	0.44	23	0.43	24	0.42												

INITIAL CONDITIONS

GRID	RIVER MILE	VELOCITY M/HR	AREA SQ METERS	TOP WIDTH METERS	TRIB. FLOW CU M/SEC	DISP FACT DWQ	INITIAL TEMP
1	360.000	5400.	8.0	17.10	0.0		0.0
						0.05	
2	357.180	2455.	17.6	39.50	0.0		0.0
						0.05	
3	355.150	1421.	30.4	61.90	0.0		0.0
						0.05	
4	353.410	4235.	10.2	81.80	0.0		0.0
						0.05	
5	351.610	1029.	42.0	89.10	0.65		0.0
						0.05	
6	348.780	1549.	29.4	82.50	0.0		0.0
						0.05	
7	347.860	1237.	36.8	115.40	0.0		0.0
						0.05	
8	345.210	945.	48.2	123.20	0.0		0.0

TIME DAY	HOUR	TEMP AT GRID 6	TRAVEL TIME HOUR	PARCEL TEMP AT ENTRY	CHANGE IN PARCEL TEMP DUE TO DISP	TRIB	DECAY	TEMP AT GRID 8	TRAVEL TIME HOUR	PARCEL TEMP AT ENTRY	CHANGE IN PARCEL TEMP DUE TO DISP	TRIB	DECAY
1	10.00	1.89	2.00	0.0	-0.00	0.0	1.89	2.10	2.00	0.0	-0.00	0.0	2.10
1	12.00	5.04	4.00	0.0	-0.21	1.13	4.12	4.62	4.00	0.0	-0.00	0.0	4.62
1	14.00	6.58	6.00	0.0	0.05	0.42	6.10	6.02	6.00	0.0	0.01	0.0	6.00
1	16.00	7.62	8.00	0.0	0.07	0.68	6.86	7.04	8.00	0.0	0.15	0.0	6.89
1	18.00	8.17	8.45	3.24	0.78	0.68	3.47	8.15	10.00	0.0	-0.69	1.70	7.15
1	20.00	10.94	8.45	12.03	-0.74	0.43	-0.79	8.21	12.00	0.0	-0.01	0.48	7.73
1	22.00	11.85	8.45	13.18	0.00	0.39	-1.72	8.01	13.44	0.73	0.48	0.76	6.04
2	0.0	12.28	8.45	14.28	-0.06	0.37	-2.31	9.18	13.44	8.68	-0.16	0.55	0.11
2	2.00	12.60	8.45	14.91	-0.03	0.36	-2.64	10.67	13.44	12.64	-0.25	0.40	-2.11
2	4.00	12.83	8.45	14.94	-0.05	0.35	-2.42	11.25	13.44	13.74	-0.03	0.38	-2.84
2	6.00	12.91	8.45	14.59	-0.04	0.35	-2.00	11.65	13.44	14.67	-0.02	0.36	-3.37
2	8.00	13.13	8.45	13.98	-0.03	0.36	-1.17	12.31	13.44	15.00	-0.05	0.35	-3.00
2	10.00	13.89	8.45	13.12	-0.02	0.37	0.41	13.46	13.44	14.79	-0.05	0.35	-1.62
2	12.00	15.04	8.45	12.22	-0.02	0.37	2.47	14.96	13.44	14.33	-0.05	0.35	0.32
2	14.00	16.05	8.45	11.22	-0.04	0.34	4.53	16.39	13.44	13.57	-0.03	0.37	2.48
2	16.00	15.85	8.45	9.65	0.03	0.33	5.84	17.00	13.44	12.67	-0.03	0.38	3.98
2	18.00	14.79	8.45	9.21	0.16	0.33	5.09	16.45	13.44	11.72	-0.05	0.36	4.43
2	20.00	14.12	8.45	9.97	-0.07	0.31	3.91	15.48	13.44	10.77	-0.22	0.33	4.59
2	22.00	13.15	8.45	10.93	0.07	0.35	1.80	14.21	13.44	9.01	0.19	0.33	4.67
3	0.0	12.33	8.45	12.03	0.07	0.38	-0.15	13.15	13.44	9.58	0.01	0.32	3.24

ATTACHMENT D

10-Parameter Model in Steady Flow

```
C****************************I-D TRANSPORT MODEL*******************************C
C*********************10 PARAMETER MODEL IN STEADY FLOW***********************C
C                                         ********
C      DEFINITIONS
C
C      PXU,PXD,PX(K)= POSITION OF LAGRANGIAN PARTICLE (U/S,D/S,
C           PARCEL(K) IN EULERIAN GRID UNITS
C      PVU,PVD,PV(K)= VOLUME OF LAGRANGIAN PARCEL
C      PHU,PHD,PH(K)= TIME THE PARCEL ENTERED THE SYSTEM
C      PTU,PTD,PT(L,K)= CONCENTRATION OF CONSTITUENT L IN PARCEL K
C      PTRU,PTRD,PTR(L,K)= CHANGE IN CONC. OF CONSTITUENT L DUE TO TRIB.
C      INFLOW
C      PTIU,PTID,PTI(L,K)=  CONC. OF CONSTITUENT L IN PARCEL K AS IT
C      ENTERED SYSTEM
C      PDFU,PDFD,PDF(L,K)=CHANGE OF CONC. OF CONSTITUENT L DUE TO
C      DISPERSION
C      PDCU,PDCD,PDC(L,K)= CONCENTRATION CHANGE OF CONSTITUENT L DUE TO A
C      SPECIFIED REACTION
C      FLOW(L,I)= FLOW FIELD INFORMATION L AT GRID I
C              L=1 FOR FLOW VELOCITY IN METERS PER HR.
C              L=2 FOR FLOW AREA IN SQUARE METERS
C              L=3 FOR TOP WIDTH IN METERS
C              L=4 FOR TRIBUTARY INFLOW IN CU METERS/SECOND
C      U(I)= AVERAGE VELOCITY IN SUBREACH I IN METERS / HOUR
C      A(I)=AVERAGE AREA IN SUBREACH  IN SQUARE METERS
C      W(I)= AVERAGE TOP WIDTH IN SUBREACH I  IN METERS
C      X(I)= RIVER MILE OF GRID I
C      DX(I)= DISTANCE BETWEEN GRID I AND I+1
C      DQQ(I)= DISPERSION FACTOR (DISP/(U*U*DT))
C      DQ(K)= FLOWRATE BETWEEN PARCEL K AND K+1 DUE TO VELOCITY GRADIENTS
C      DF(L,K)=  CONC. CHANGE OF CONSTITUENT L IN PARCEL K DUE TO DISPERSION
C      TUP(L)= OBSERVED CONCENTRATION  OF CONSTITUENT L AT UPSTREAM END OF REACH
C      XK(L,M)= EXCHANGE COEFF. FOR CONSTITUENT L DUE TO CONC. OF CONSTITUENT M
C      S(L)= SOURCE FOR CONSTITUENT L IN CONC./HR
C      CR(L,N)= REFERENCE(EQUILIBRIUM) CONC. IN EQUATION L FOR CONSTITUENT N
C      TRIB(L,I)= OBSERVED CONC. OF CONSTITUENT L IN TRIB AT GRID I
C      QT(I)= TRIBUTARY INFLOW IN CUBIC METERS PER SECOND AT GRID I
C      Q= DISCHARGE AT UPSTREAM END IN CUBIC METERS PER SECOND
C      DT= TIME STEP SIZE (IN HOURS)
C      PDX= PART OF EULERIAN SUBREACH REMAINING TO BE TRAVERSED
C      PDT= TIME REQUIRED TO TRAVERSE THE REMAINING PART OF THE SUBREACH
C      RDT= TIME REMAINING FOR MOVEMENT
C      A1= CONSTANT IN WIND FUNCTION (MM/DAY KPA)
C      B1= MASS TRANSFER COEFFICIENT (MM/DAY KPA(M/S))
C      V= WIND SPEED IN M/S
C      TA= AIR TEMPERATURE IN DEGREES C
C      CPR= HEAT CAPACITY (100 CAL PER SQ CM M)
C      NXSEC= NUMBER OF EULERIAN GRIDS
C      INX= NXSEC-1
C      NS= NUMBER OF PARCLES IN THE SYSTEM
C      LNS= NS-1
C      LP= LAST PARCLE TO STAY IN THE SYSTEM AT D/S END
C      MX= GRID U/S OF PARCLE
C      IGT(N)= GRID NUMBER FOR TRIBUTARY INFLOW
C      NPT(I)= NUMBER OF PARCELS TO PASS GRID IGT(N) DURING DT
C      KPG(N,M)= PARCEL NUMBER OF PARCEL TO PASS GRID IGT(N) DURING DT
C      NEQ= NUMBER OF EQUATIONS
C      NHR= NUMBER OF TIME STEPS
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            C      NTRIB= NUMBER OF ACTUAL TRIBUTARIES
            C      IGO= GRID NUMBER WHERE OUTPUT IS DESIRED
            C      IOUT= NUMBER OF TIME STEPS BETWEEN OUTPUT LISTINGS
            C      JTS= NUMBER OF TIME STEPS FROM MIDNIGHT TO TIME ZERO IN MODEL
            C      LR(L)= INDEX DENOTING THAT THE DECAY OF CONSTITUENT L DUE TO CONSTITUENT
            C           LR(L) WILL BE TRACKED
            C      LABEL(10)= NAMES OF CONSTITUENTS MODELED, MAX OF FIVE LETTERS
            C       TITLE(20)= TITLE OF PROGRAM,  80 CHARACTERS MAX
            C
            C   PRELIMINARIES (STATEMENTS 0001-0038,LABEL STATEMENTS 20-39)********
            C
0001               DIMENSION PX(500),PV(500),PT(10,500),PH(500),PTR(10,500),
                  aPDC(10,500),PTI(10,500)
0002               DIMENSION  DX(50),U(50),A(50),FLOW(4,50),W(50),LR(10)
0003               DIMENSION DQQ(50),QT(50),TRIB(10,50),IGT(50),KPG(20,50),NPT(50)
0004               DIMENSION PDF(10,500),DQ(500),DF(10,500),TITLE(20)
0005               DIMENSION TUP(10),XK(10,10),S(10),CR(10,10),PTU(10),PTRU(10),
                  &  PTIU(10),PDFU(10),LABEL(10),PDCU(20)
0006               DIMENSION CIGO(10),CIIGO(10),CDIGO(10),CTIGO(10),DCIGO(10)
0007               DOUBLE PRECISION X(51)
0008               COMMON XK,PDC,PT,TA,V,A,W,A1,B1,S,CR,LR,U
            C
            C      MAXIMUM VALUE OF NXSEC IS 50
            C
            C      STEP 9 TO 37 ARE TO ZERO ARRAYS.
0009               DO 4 K=1,500
0010               PX(K)= 0.0
0011               DQ(K)= 0.0
0012               PV(K)= 0.0
0013               PV(K)=0.0
0014               PH(K)=0.0
0015               DO 4 L=1,10
0016               PT(L,K)= 0.0
0017               PTR(L,K)= 0.0
0018               PDF(L,K)= 0.0
0019               PTI(L,K)= 0.0
0020               PDC(L,K)= 0.0
0021             4 DF(L,K)= 0.0
0022               DO 5 I=1,50
0023               X(I)= 0.0
0024               DQQ(I)= 0.0
0025               QT(I)= 0.0
0026               FLOW(4,I)=0.0
0027               IGT(I)= 0
0028               DX(I)= 0.0
0029               U(I)= 0.0
0030               W(I)= 0.0
0031               A(I)=0.0
0032               DO 5 L=1,10
0033             5 TRIB(L,I)=0.0
0034               DO 6 L=1,10
0035               S(L)=0.0
0036               DO 6 M=1,10
0037               XK(L,M)=0.0
0038             6 CR(L,M)=0.0
            C
            C      READ INPUT (STATEMENTS 0039-0066)********************************
            C
```

```
0039              READ(5,1000)(TITLE(K),K=1,20)
0040         1000 FORMAT(20A4)
0041              WRITE(6,3003) (TITLE(K),K=1,20)
0042         3003 FORMAT(1H1,20X,20A4)
0043              WRITE(6,3002)
0044         3002 FORMAT (//)
0045              READ(5,1005) NXSEC,NHR,DT,Q,IGO,IOUT,NTRIB,JTS,A1,B1,NEQ
0046         1005 FORMAT(2I5,2F10.2,4I5,2F10.2,I5)
0047              DO 9 M=1,NEQ
0048            9 READ(5,1014) L,LABEL(M),LR(M)
0049         1014 FORMAT(10X,I7,A7,I7)
0050              READ(5,1006) (X(I),I=1,NXSEC)
0051         1006 FORMAT(10X,10F7.3)
0052              READ(5,1006)(FLOW(2,I),I=1,NXSEC)
0053              READ(5,1006)(FLOW(3,I),I=1,NXSEC)
0054              IF (NTRIB.EQ.0) GO TO 8
0055              DO 7 N=1,NTRIB
0056              READ(5,1010) IGT(N),QTT
0057         1010 FORMAT(10X,I7,F7.2)
0058              I= IGT(N)
0059            7 FLOW(4,I)=QTT
0060            8 READ(5,1006) (DQQ(I),I=1,NXSEC)
0061              DO 10 L=1,NEQ
0062           10 READ(5,1006) (PT(L,I),I=1,NXSEC)
0063              WRITE(6,3005) NHR,DT,NXSEC,Q,IGO,NXSEC,IOUT
0064         3005 FORMAT(' MODEL IS TO RUN',I5,' TIME STEPS EACH',F10.2,' HOURS LONG
                 1. THE RIVER IS DISCRETIZED BY',I5,' GRID POINTS.',/,' THE INITIAL
                 2UPSTREAM DISCHARGE IS CONSTANT AT',F10.2,' CUBIC METERS PER SECOND
                 3.',/,' THE PRINTOUT WILL BE GIVEN FOR GRIDS',I5,' AND',I5,' FOR
                 4EACH',I5,' TIME STEPS.')
0065              WRITE(6,1007) A1,B1
0066         1007 FORMAT(1H ,'THE WIND FUNCTION IS',F10.2,'+',F10.2,'*V IN MM/DAY KP
                 $A.')
            C
            C     PROCESS INPUT DATA (STATEMENTS 0067-0104)************************
            C
0067              X(NXSEC+1)=X(NXSEC)
0068              XUP=X(1)
0069              DO 1 I=1,NXSEC
0070              DX(I)=(X(I)-X(I+1))*1609.34
0071              X(I)=(XUP-X(I))*1609.34
0072              PX(I)=FLOAT(I)
0073              PH(I)=FLOAT(JTS)*DT
0074              FLOW(1,I)=3600.0*Q/FLOW(2,I)
0075              Q= Q+FLOW(4,I)
0076              DO 1 L=1,NEQ
0077              PTI(L,I)=PT(L,I)
0078              PDF(L,I)= 0.0
0079              PTR(L,I)= 0.0
0080              PDC(L,I)= 0.0
0081            1 CONTINUE
0082              INX=NXSEC-1
0083              PV(1)= FLOW(2,1)*(DX(1)+DT*FLOW(1,1))/2.0
0084              DO 3 I=1,INX
0085              U(I)=(FLOW(1,I)+FLOW(1,I+1))/2.0
0086              A(I)=(FLOW(2,I)+FLOW(2,I+1))/2.0
0087              W(I)=(FLOW(3,I)+FLOW(3,I+1))/2.0
0088              QT(I)=FLOW(4,I)
```

```
0089            3 PV(I+1)= FLOW(2,I+1)*(DX(I)+DX(I+1))/2.0
0090              PV(NXSEC)= FLOW(2,NXSEC)*(DX(INX))/2.0
0091              NS=NXSEC
0092              WRITE(6,3002)
0093              WRITE (6,3004)
0094         3004 FORMAT(1H0,50X,'INITIAL  CONDITIONS')
0095              WRITE(6,3002)
0096              WRITE(6,3010)
0097         3010 FORMAT(1H0,3X,'GRID  RIVER  VELOCITY    AREA    TOP WIDTH   TRIB.
             *FLOW',1X,
             1' DISP FACT',22X,'INITIAL TEMP OR CONC',/,10X,'MILE       M/HR',
             2  '    SQ METERS    METERS',5X,'CU M/SEC       DQQ      1      2      '
             3 ,'3       4       5       6       7       8       9     10')
0098              DO 11 I=1,NS
0099              RM= XJP-X(I)/1609.34
0100              WRITE(6,3011) I,RM,FLOW(1,I),FLOW(2,I),FLOW(3,I),QT(I),(PT(L,I)
             $   ,L=1,NEQ)
0101         3011 FORMAT(4X,I2,1X,F7.2,3X,F7.0,1X,F8.1,2X,F9.2,5X,F7.2,12X,10F6.2)
0102              IF(I.LT.NS) WRITE(6,3007) DQQ(I)
0103         3007 FORMAT(63X,F5.2)
0104           11 CONTINUE
0105              WRITE(6,3002)
            C
            C     START TIME LOOP ************************************************
            C
0106              DO 2 J=1,NHR
            C
            C     COMPUTE DISPERSION FLUXES (STATEMENTS 0107-0132,LABEL
            C             STATEMENTS 80-99)*****************************************
            C
            C    COMPUTE DISPERSIVE Q'S
0107              LNS=NS-1
0108              DO 80 K=1,LNS
0109              IX=(PX(K)+PX(K+1))/2.0
0110           80 DQ(K)=ABS(DQQ(IX)*U(IX)*A(IX))
            C     SET DQ=0 AT TRIBUTARY
0111              K=0
0112              DO 85 N=1,NTRIB
0113              XR=IGT(N)
0114           81 K=K+1
0115              IF(PX(K).LT.XR) GO TO 81
0116              K= K-1
0117           85 DQ(K)= 0.0
            C    LIMIT DQ TO FORCE STABILITY
0118              DO 82 K=1,NS
0119              IF(K.EQ.1) GO TO 83
0120              RATIO=DQ(K-1)*DT/PV(K)
0121              IF(RATIO.GT.0.35) DQ(K-1)=0.35*PV(K)/DT
0122              IF(K.EQ.NS) GO TO 82
0123           83 RATIO=DQ(K)*DT/PV(K)
0124              IF(RATIO.GT.0.35) DQ(K)=0.35*PV(K)/DT
0125           82 CONTINUE
            C     IF(J.GT.35)WRITE(6,3000) (DQ(K),K=1,LNS)
            C    DISPERSE HEAT
0126             DO 86 L=1,NEQ
0127             DF(L,1)=DQ(1)*(PT(L,2)-PT(L,1))*DT/PV(1)
0128             DO 84 K=2,LNS
0129             DF(L,K)=(DQ(K-1)*(PT(L,K-1)-PT(L,K))+DQ(K)*(PT(L,K+1)-PT(L,K)))*
```

```
                   @    DT/PV(K)
0130             84 IF(ABS(DF(L,K)).LT.1.0E-6) DF(L,K)=0.0
0131                DF(L,NS)=DQ(NS-1)*(PT(L,NS-1)-PT(L,NS))*DT/PV(NS)
              C     IF(J.GT.35) WRITE(6,3000) (DF(L,K),K=1,NS)
0132             86 CONTINUE
              C
              C     SET UPSTREAM BOUNDRY (STATEMENTS 0133-0146,LABEL STATEMENTS
              C            40-59)*****************************************************
              C
              C    READ BOUNDARY CONDITIONS
0133                DO 40 L=1,NEQ
0134                IF(L.EQ.1) READ(5,1006) TUP(1),TA,V,(TRIB(1,IGT(N)),N=1,NTRIB)
0135                IF(L.GT.1) READ(5,1006) TUP(L),(TRIB(L,IGT(N)),N=1,NTRIB)
0136             40 CONTINUE
0137                PXU=1.0
0138                PVU= FLOW(1,1)*FLOW(2,1)*DT
0139                PHU= DT*FLOAT(J+JTS)
0140                DO 41 L=1,NEQ
0141                PTU(L)=TUP(L)
0142                PTRU(L)=0.0
0143                PTIU(L)=TUP(L)
0144                PDFU(L)=0.0
0145                PDCU(L)=0.0
              C     IF(J.GT.30) WRITE(6,3000) PXU,PTU(L),PVU,PHU,PTRU(L)
0146             41 CONTINUE
              C
              C     SET D/S BOUNDRY (STATEMENTS 0147-0178, LABEL STATEMENTS 60-69)
              C
0147                MX=NXSEC-1
0148                RDT=DT
0149             60 PDT=DX(MX)/U(MX)
0150                IF(PDT.GE.RDT)GO TO 61
0151                RDT=RDT-PDT
0152                MX=MX-1
0153                GO TO 60
0154             61 XP=FLOAT(MX)+1.0-RDT/PDT
              C     FIND PARCEL U/S OF XP
0155                LP=NS-1
0156             62 IF(PX(LP).LT.XP)GO TO 63
0157                LP=LP-1
0158                GO TO 62
0159             63 NS=LP+2
0160                PX(NS)=FLOAT(NXSEC)
              C     FIND OLD CONCENTRATION OF PARCEL WHICH WILL FALL OUT
0161                MX=IFIX(XP)
0162                XP=X(MX)+DX(MX)*(XP-FLOAT(MX))
0163                MX=IFIX(PX(LP))
0164                XL=X(MX)+DX(MX)*(PX(LP)-FLOAT(MX))
0165                MX=IFIX(PX(LP+1))
0166                XR=X(MX)+DX(MX)*(PX(LP+1)-FLOAT(MX))
0167                COF=(XP-XL)/(XR-XL)
0168                PV(NS)= PV(LP+1)
0169                PH(NS)= PH(LP)*(1.0-COF)+PH(LP+1)*COF
0170                DO 64 L=1,NEQ
0171                PT(L,NS)=(PT(L,LP)+DF(L,LP))*(1.0-COF)+(PT(L,LP+1)+DF(L,LP+1))*COF
0172                PTR(L,NS)= PTR(L,LP)*(1.0-COF)+PTR(L,LP+1)*COF
0173                PTI(L,NS)=PTI(L,LP)*(1.0-COF)+PTI(L,LP+1)*COF
0174                PDF(L,NS)=(PDF(L,LP)+DF(L,LP))*(1.0-COF)+(PDF(L,LP+1)+DF(L,LP+1))
```

```
                   #      *COF
0175                PDC(L,NS)=PDC(L,LP)*(1.0-COF)+PDC(L,LP+1)*COF
              C     IF(J.LT.7)WRITE(6,3000) RDT,PDT,XP,XL,XR,COF,PT(L,NS),PH(NS),
              C    $PTR(L,NS),PDF(L,NS),PDC(L,NS)
0176             54 CONTINUE
0177                MX= (IFIX(PX(LP))+NXSEC)/2
              C     IF(J.LT.7)WRITE(6,3001) LP,NS,MX
0178                CALL DECAY(DT,NS,MX,J,NEQ)
              C
              C     MOVE INTERIOR PARCELS (STATEMENTS 0179-0212, LABEL STATEMENTS
              C              100-119)**********************************************
              C
              C
0179                LNS=NS-1
0180                DO 103 I=1,NXSEC
0181            103 NPT(I)= 0
0182                DO 100 KK=2,LNS
0183                K=LNS+2-KK
0184                KO=K-1
0185                XOLD=PX(KO)
0186                MX=IFIX(XOLD)
0187                RDT=DT
0188                PDX=FLOAT(MX+1)-PX(KO)
0189            102 PDT=PDX*DX(MX)/U(MX)
0190                IF(PDT.GE.RDT) GO TO 101
              C    PASSED GRID
0191                CALL DECAY(PDT,KO,MX,J,NEQ)
0192                RDT=RDT-PDT
0193                MX=MX+1
0194                XOLD=FLOAT(MX)
0195                PDX=1.0
0196                NPT(MX)= NPT(MX)+1
0197                KPG(NPT(MX),MX)=K
0198                GO TO 102
0199            101 CONTINUE
              C    STOPPED IN SUBREACH
0200                CALL DECAY(RDT,KO,MX,J,NEQ)
0201                PX(K)=XOLD+RDT*U(MX)/DX(MX)
0202                PV(K)= PV(KO)
0203                PH(K)=PH(KO)
0204                DO 104 L=1,NEQ
0205                PT(L,K)=PT(L,KO)+DF(L,KO)
0206                PTR(L,K)=PTR(L,KO)
0207                PTI(L,K)=PTI(L,KO)
0208                PDF(L,K)=PDF(L,KO)+DF(L,KO)
0209                PDC(L,K)= PDC(L,KO)
              C     IF(J.GT.35) WRITE(6,3000) PT(L,K),PTR(L,K),PTI(L,K),PDF(L,K),
              C    $  PDC(L,K)
0210            104 CONTINUE
0211           3001 FORMAT(' ',12I10)
              C     IF(J.GT.35)WRITE(6,3000) XOLD,RDT,PDT,PDX,PX(K),PV(K),PH(K)
0212            100 CONTINUE
              C
              C     TRANSFER BOUNDRY CONDITIONS TO PARCEL CHARACTERISTICS
              C              (STATEMENTS 0213-0221)*********************************
              C
0213                PX(1)=PXU
0214                PV(1)=PVU
```

```
0215            PH(1)=PHU
0216            DO 105 L=1,NEQ
0217            PT(L,1)=PTU(L)
0218            PTR(L,1)=PTRU(L)
0219            PTI(L,1)=PTIU(L)
0220            PDF(L,1)=PDFU(L)
0221        105 PDC(L,1)=PDCU(L)
          C
          C     DILUTE FOR TRIBUTARY  INFLOW (STATEMENTS 0222-0262, LABEL
          C            STATEMENTS 120-129)****************************************
          C
0222            IF(NTRIB.EQ.0) GO TO 123
0223            K=0
0224            DO 123 N=1,NTRIB
0225            I= IGT(N)
          C     IF(J.LT.7) WRITE(6,3001)K,N,NTRIB,IGT(N),I,NPT(I)
0226            IF(NPT(I).EQ.0)GO TO 120
0227            VOL=0.0
0228            M=NPT(I)
0229            DO 121 NN=1,M
0230            KK=KPG(NN,I)
0231        121 VOL=VOL+PV(KK)
0232            DO 122 NN=1,M
0233            KK=KPG(NN,I)
0234            COF=PV(KK)/VOL
0235            DO 125 L=1,NEQ
0236            DEL=(TRIB(L,I)*COF*QT(I)*3600.0*DT+PT(L,KK)*PV(KK))/(PV(KK)+QT(I)
               $*3600.0*COF*DT)-PT(L,KK)
0237            IF(QT(I).LE.0.0)DEL=0.0
0238            PT(L,KK)=PT(L,KK)+DEL
0239            PTR(L,KK)=PTR(L,KK)+DEL
          C     IF(J.GT.30)WRITE(6,3000)VOL,COF,PT(L,KK),PTR(L,KK),PV(KK),DEL
0240        125 CONTINUE
0241            PV(KK)=PV(KK)+COF*QT(I)*DT*3600.0
          C     IF(J.GT.30) WRITE(6,3001)K,KK,NN
0242        122 CONTINUE
0243            GO TO 123
0244        120 CONTINUE
          C
          C     FIND NEAREST PARCEL
          C
0245        124 K=K+1
0246            IF(PX(K).LT.FLOAT(I))GO TO 124
0247            MX=IFIX(PX(K))
0248            XR=X(MX)+(PX(K)-FLOAT(MX))*DX(MX)-X(I)
0249            K=K-1
0250            MX=IFIX(PX(K))
0251            XL=X(I)-X(MX)-(PX(K)-FLOAT(MX))*DX(MX)
0252            IF(XR.LT.XL)K=K+1
0253            DO 126 L=1,NEQ
0254            DEL=(TRIB(L,I)*QT(I)*3600.0*DT+PT(L,K)*PV(K))/(PV(K)+QT(I)*3600.0*
               #   DT)-PT(L,K)
0255            IF(QT(I).LE.0.0)DEL=0.0
0256            PT(L,K)=PT(L,K)+DEL
0257            PTR(L,K)=PTR(L,K)+DEL
          C     IF(J.GT.30) WRITE(6,3000)XR,XL,PT(L,K),PV(K),PTR(L,K),DEL,TRIB(L,I
          C    # ),PV(K),QT(I),DT
0258        126 CONTINUE
```

```
0259                PV(K)=PV(K)+QT(I)*DT*3600.0
0260                IF(J.GT.30) WRITE(6,3001)K,MX,I
0261                K= K-1
0262            123 CONTINUE
             C
             C      FIND CONCENTRATIONS AT IGO (STATEMENTS 0263-0279, LABEL
             C              STATEMENTS 130-139)****************************************
             C
0263                TIME=FLOAT(J+JTS)*DT
0264                K= 0
0265            130 K= K+1
0266                IF(PX(K).LE.FLOAT(IGO)) GO TO 130
0267                IX= IFIX(PX(K))
0268                XR= X(IX)+DX(IX)*(PX(K)-FLOAT(IX))-X(IGO)
0269                IX= IFIX(PX(K-1))
0270                XL= X(IGO)-X(IX)-DX(IX)*(PX(K-1)-FLOAT(IX))
0271                COF= XL/(XL+XR)
0272                DO 131 L=1,NEQ
0273                CIGO(L)=PT(L,K-1)+COF*(PT(L,K)-PT(L,K-1))
0274                CIIGO(L)= PTI(L,K-1)+COF*(PTI(L,K)-PTI(L,K-1))
0275                CDIGO(L)= PDF(L,K-1)+COF*(PDF(L,K)-PDF(L,K-1))
0276                CTIGO(L)= PTR(L,K-1)+COF*(PTR(L,K)-PTR(L,K-1))
0277                DCIGO(L)= PDC(L,K-1)+COF*(PDC(L,K)-PDC(L,K-1))
0278            131 CONTINUE
0279                TTIGO= TIME- PH(K-1)-COF*(PH(K)-PH(K-1))
             C
             C      WRITE RESULTS (STATEMENTS 0280-0305, LABEL STATEMENTS 140-149)
             C
0280                IF(J.EQ.1)WRITE(6,2000) IGO,NXSEC
0281                IF(MOD(J,IOUT).EQ.0) GO TO 140
0282                GO TO 2
0283            140 IC=J/IOUT
0284                IF(MOD(IC,50).EQ.0) WRITE(6,2000) IGO,NXSEC
0285           2000 FORMAT(5X,'TIME    CONC. AT    PARCEL    CHANGE  IN  CONCENTRATION
               1',13X,'CONC. AT    PARCEL    CHANGE  IN  CONCENTRATION',/,'  DAY H
               2OUR      GRID      ENTRY       OF  PARCEL  DUE  TO',20X,'GRID     E
               3NTRY        OF  PARCEL  DUE  TO',/,15X,I5,5X,'CONC.      DISP     '
               4,' TRIB     DECAY FROM',10X,I5,5X,'CONC.      DISP      TRIB     '
               5,'DECAY FROM')
0286           2001 FORMAT(1H0,I4,F6.2,5X,'TRAVEL  TIME TO GRID',I4,' IS',F6.2,' HOURS
               1',22X,'TRAVEL TIME TO GRID',I4,' IS',F6.2,' HOURS')
0287           2002 FORMAT(1H,3X,A7,5F10.2,1X,A7,2X,5F10.2,1X,A7)
0288                IDAY= (TIME/24.0)+1
0289                HR= TIME-FLOAT(IDAY-1)*24.0
0290                TT= TIME-PH(NS)
0291                WRITE(6,2001) IDAY,HR,IGO,TTIGO,NXSEC,TT
0292                DO 141 L=1,NEQ
0293            141 WRITE(6,2002) LABEL(L),CIGO(L),CIIGO(L),CDIGO(L),CTIGO(L),DCIGO(L)
               ?,LABEL(LR(L)),PT(L,NS),PTI(L,NS),PDF(L,NS),PTR(L,NS),PDC(L,NS),
               & LABEL(LR(L))
0294           3000 FORMAT(' ',10E12.5)
0295              2 CONTINUE
0296                DO 150 K=1,NS
0297                MX=IFIX(PX(K))
0298                XP=X(MX)+(PX(K)-FLOAT(MX))*DX(MX)
0299                RM=XUP-XP/1609.34
0300                WRITE(6,5000) RM,PV(K),PH(K)
0301           5000 FORMAT(1H0,'RIVER MILE=',F10.2,'PARCEL VOLUME=',F10.0,
```

```
                  * 'CUBIC METERS AND PARCEL ENTERED SYSTEM AT HOUR',F10.2)
0302                WRITE(6,5001)
0303           5001 FORMAT(1H0,' PARAMETER      CONC.  INT CONC  DEL DISP  DEL TRIB',
                  $ '      DECAY    DUE TO')
0304                DO 150 L=1,NEQ
0305            150 WRITE(6,2002) LABEL(L),PT(L,K),PTI(L,K),PDF(L,K),PTR(L,K),PDC(L,K)
                  @ ,LABEL(LR(L))
0306                END
```

```
      SUBROUTINE DECAY (DT,K,MX,J,NEQ)
      DIMENSION SUM(10),PT1(10),SUM2(10),DC(10),DC2(10)
      COMMON XK(10,10),PDC(10,500),PT(10,500),TA,V,A(50),W(50),A1,B1,
     2 S(10),CR(10,10),LR(10),U(50)
      RDT=DT
    1 DTM= RDT
      CALL FINK (K,MX,J,NEQ)
C     FIND MAXIMUM DECAY TIME STEP
      DO 2 L=1,NEQ
      SUM(L)=S(L)
      DO 3 LL=1,NEQ
    3 SUM(L)=SUM(L)+XK(L,LL)*(PT(LL,K)-CR(L,LL))
      DTL= RDT
      REF=PT(L,K)-CR(L,L)
      IF(SUM(L).NE.0.0.AND.ABS(REF).GT.0.3) DTL=ABS(0.1*REF/SUM(L))
      IF(DTL.LT.DTM) DTM=DTL
    2 CONTINUE
      COM= 0.999*RDT
      IF(DTM.GT.COM) DTM= RDT
C     UPDATE CONCENTRATION
      DO 4 L=1,NEQ
      LL=LR(L)
      DC(L)=XK(L,LL)*(PT(LL,K)-CR(L,LL))
      PT1(L)=PT(L,K)
      PT(L,K)=PT(L,K)+SUM(L)*DTM
C     IF(J.LT.6) WRITE(6,1000) PT1(L),PT(L,K),SUM(L),DTM,DC(L)
    4 CONTINUE
 1000 FORMAT(' DECAY OUTPUT',8E12.5)
      CALL FINK (K,MX,J,NEQ)
      DO 6 L=1,NEQ
      SUM2(L)=S(L)
      DO 7 LL=1,NEQ
    7 SUM2(L)=SUM2(L)+XK(L,LL)*(PT(LL,K)-CR(L,LL))
      LL=LR(L)
      DC2(L)=XK(L,LL)*(PT(LL,K)-CR(L,LL))
      PDC(L,K)=PDC(L,K)+(DC(L)+DC2(L))*0.5*DTM
      PT(L,K)=PT1(L)+0.5*(SUM(L)+SUM2(L))*DTM
C     IF(J.LT.6) WRITE(6,1000) SUM2(L),PT(L,K),PDC(L,K),DC2(L)
    6 CONTINUE
      IF(DTM.EQ.RDT) GO TO 5
      RDT= RDT-DTM
      GO TO 1
    5 RETURN
      END
```

```
      SUBROUTINE FINK(K,MX,J,NEQ)
      COMMON XK(10,10),PDC(10,500),PT(10,500),TA,V,A(50),W(50),A1,B1,
     2 S(10),CR(10,10),LR(10),U(50)
      CPR= 100.0
      SIG= 1.171E-7/24.0
      AL= 595.9-0.545*PT(1,K)
      PSI= (A1+B1*V)/(24.0*10.0)
      TAB=PT(1,K)+273.16
      DFT=1.1532E11*EXP(-4271.1/(PT(1,K)+242.63))/((PT(1,K)+242.63)**2)
      XKX=4.0*0.97*SIG*(TAB**3)+AL*PSI*(DFT+0.06)
      XK(1,1)=-XKX*W(MX)/(A(MX)*CPR)
      CR(1,1)=TA
      XK(2,2)=-0.00161*(U(MX)**0.607)/((A(MX)/W(MX))*1.689)
      CORT=1.047**(PT(1,K)-20.0)
      XK(2,3)=-0.1*CORT
      IF(PT(2,K).LT.1.0) XK(2,3)=0.0
      CR(2,2)=468.0/(PT(1,K)+31.6)
      XK(3,3)=XK(2,3)
      RETURN
      END
```

Input Data for

10-Parameter Model in Steady Flow

```
MODEL DOCUMENTATION FOR THE 10 PARAMETER MODEL
    8   40        1.00        6.00     6     2     1     8       3.01        1.13    3
TEMP CARD          1    TEMP        1
DO CARD            2    DO          2
BOD CARD           3    BOD         3
RIVER MILE 360.00 357.18 355.15 353.41 351.61 348.78 347.86 345.21
AREA   1       8.0    17.6    30.4    10.2    42.0    29.4    36.8    48.2
WIDTH  1      17.1    39.5    61.9    81.8    89.1    82.5   115.4   123.2
TREB   1         2    0.65
DQQ VALUES    0.20    0.20    0.20    0.20    0.20    0.20    0.20    0.20
INIT CONC1     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
INIT CONC2     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
INIT CONC3     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
T   T 1CD1    1.30   28.00    1.90   20.00
DO  T 1CD1   10.00    3.00
BOD T 1CD1    2.00  100.00
T   T 2CD1    4.80   26.00    1.90   20.00
DO  T 2CD1   10.00    3.00
BOD T 2CD1    2.00  100.00
T   T 3CD1    8.00   24.00    2.00   20.00
DO  T 3CD1   10.00    3.00
BOD T 3CD1    2.00  100.00
T   T 4CD1   11.00   22.00    1.80   20.00
DO  T 4CD1   10.00    3.00
BOD T 4CD1    2.00  100.00
T   T 5CD1   12.10   19.00    1.70   20.00
DO  T 5CD1   10.00    3.00
BOD T 5CD1    2.00  100.00
T   T 6CD1   11.80   16.00    1.60   20.00
DO  T 6CD1   10.00    3.00
BOD T 6CD1    2.00  100.00
T   T 7CD1   11.00   13.00    1.50   20.00
DO  T 7CD1   10.00    3.00
BOD T 7CD1    2.00  100.00
T   T 8CD1   10.20   12.00    1.60   20.00
DO  T 8CD1   10.00    3.00
BOD T 8CD1    2.00  100.00
T   T 9CD1    9.60   10.00    1.70   20.00
DO  T 9CD1   10.00    3.00
BOD T 9CD1    2.00  100.00
T   T10CD1    9.10   10.00    1.60   20.00
DO  T10CD1   10.00    3.00
BOD T10CD1    2.00  100.00
T   T11CD1    8.90   10.00    1.50   20.00
DO  T11CD1   10.00    3.00
    T11CD1    2.00  100.00
T   T12CD1    8.80   11.00    1.40   20.00
DO  T12CD1   10.00    3.00
BOD T12CD1    2.00  100.00
T   T13CD1    8.90   12.00    1.30   20.00
DO  T13CD1   10.00    3.00
BOD T13CD1    2.00  100.00
T   T14CD1    9.10   13.00    1.30   20.00
DO  T14CD1   10.00    3.00
BOD T14CD1    2.00  100.00
T   T15CD1    9.30   15.00    1.20   20.00
DO  T15CD1   10.00    3.00
BOD T15CD1    2.00  100.00
T   T16CD1    9.80   16.00    1.20   20.00
DO  T16CD1   10.00    3.00
BOD T16CD1    2.00  100.00
    T17CD1   10.10   18.00    1.30   20.00
    T17CD1   10.00    3.00
```

BOD	T17CD1	2.00	100.00		
T	T18CD1	10.60	20.00	1.40	20.00
DO	T18CD1	10.00	3.00		
BOD	T18CD1	2.00	100.00		
T	T19CD1	11.20	21.00	1.50	20.00
DO	T19CD1	10.00	3.00		
BOD	T19CD1	2.00	100.00		
T	T20CD1	11.70	23.00	1.60	20.00
DO	T20CD1	10.00	3.00		
BOD	T20CD1	2.00	100.00		
T	T21CD1	12.30	25.00	1.50	20.00
DO	T21CD1	10.00	3.00		
BOD	T21CD1	2.00	100.00		
T	T22CD1	12.90	27.00	1.40	20.00
DO	T22CD1	10.00	3.00		
BOD	T22CD1	2.00	100.00		
T	T23CD1	13.40	29.00	1.50	20.00
DO	T23CD1	10.00	3.00		
BOD	T23CD1	2.00	100.00		
T	T24CD1	14.00	30.00	1.60	20.00
DO	T24CD1	10.00	3.00		
BOD	T24CD1	2.00	100.00		
T	T25CD1	14.50	30.00	1.70	20.00
DO	T25CD1	10.00	3.00		
BOD	T25CD1	2.00	100.00		
T	T26CD1	14.80	30.00	1.80	20.00
DO	T26CD1	10.00	3.00		
BOD	T26CD1	2.00	100.00		
T	T27CD1	15.00	29.00	1.70	20.00
DO	T27CD1	10.00	3.00		
BOD	T27CD1	2.00	100.00		
T	T28CD1	15.00	29.00	1.80	20.00
DO	T28CD1	10.00	3.00		
BOD	T28CD1	2.00	100.00		
T	T29CD1	14.90	28.00	1.90	20.00
DO	T29CD1	10.00	3.00		
BOD	T29CD1	2.00	100.00		
T	T30CD1	14.70	27.00	1.80	20.00
DO	T30CD1	10.00	3.00		
BOD	T30CD1	2.00	100.00		
T	T31CD1	14.50	26.00	1.90	20.00
DO	T31CD1	10.00	3.00		
BOD	T31CD1	2.00	100.00		
T	T32CD1	14.20	24.00	2.00	20.00
DO	T32CD1	10.00	3.00		
BOD	T32CD1	2.00	100.00		
T	T33CD1	13.80	22.00	2.10	20.00
DO	T33CD1	10.00	3.00		
BOD	T33CD1	2.00	100.00		
T	T34CD1	13.40	21.00	2.20	20.00
DO	T34CD1	10.00	3.00		
BOD	T34CD1	2.00	100.00		
T	T35CD1	12.90	19.00	2.30	20.00
DO	T35CD1	10.00	3.00		
BOD	T35CD1	2.00	100.00		
T	T36CD1	12.50	18.00	2.50	20.00
DO	T36CD1	10.00	3.00		
BOD	T36CD1	2.00	100.0		
T	T37CD1	12.00	16.00	2.40	20.00
DO	T37CD1	10.00	3.00		
BOD	T37CD1	2.00	100.00		
T	T38CD1	11.50	15.00	2.40	20.00
DO	T38CD1	10.00	3.00		
BOD	T38CD1	2.00	100.00		
T	T39CD1	11.00	14.00	2.30	20.00
DO	T39CD1	10.00	3.00		

BOD	T39CD1	2.00	100.00		
T	T40CD1	10.60	13.00	2.50	20.00
DO	T40CD1	10.00	3.00		
BOD	T40CD1	2.00	100.00		

Output of

10-Parameter Model in Steady Flow

DOCUMENTATION FOR 10 PARAMETER MODEL

MODEL IS TO RUN 40 TIME STEPS EACH 1.00 HOURS LONG. THE RIVER IS DISCRETIZED BY 8 GRID POINTS.
THE INITIAL UPSTREAM DISCHARGE IS CONSTANT AT 6.00 CUBIC METERS PER SECOND.
THE PRINTOUT WILL BE GIVEN FOR GRIDS 5 AND 8 FOR EACH 2 TIME STEPS.
THE WIND FUNCTION IS 3.01+ 1.13*V IN MM/DAY KPA.

INITIAL CONDITIONS

GRID	RIVER MILE	VELOCITY M/HR	AREA SQ METERS	TOP WIDTH METERS	TRIB. FLOW CU M/SEC	DISP FACT DQQ	INITIAL TEMP OR CONC 1	2	3	4	5	6	7	8	9	10
1	360.00	2700.	8.0	17.10	0.0		0.0	0.0	0.0							
						0.20										
2	357.18	1227.	17.6	39.50	0.65		0.0	0.0	0.0							
						0.20										
3	355.15	788.	30.4	61.90	0.0		0.0	0.0	0.0							
						0.20										
4	353.41	2347.	10.2	81.80	0.0		0.0	0.0	0.0							
						0.20										
5	351.61	570.	42.0	89.10	0.0		0.0	0.0	0.0							
						0.20										
6	348.78	814.	29.4	82.50	0.0		0.0	0.0	0.0							
						0.20										
7	347.86	651.	36.8	115.40	0.0		0.0	0.0	0.0							
						0.20										
8	345.21	497.	48.2	123.20	0.0		0.0	0.0	0.0							

TIME DAY HOUR		CONC. AT GRID 6	PARCEL ENTRY CONC.	CHANGE IN CONCENTRATION OF PARCEL DUE TO DISP	TRIB	DECAY FROM		CONC. AT GRID 8	PARCEL ENTRY CONC.	CHANGE IN CONCENTRATION OF PARCEL DUE TO DISP	TRIB	DECAY FROM	
1 10.00		TRAVEL TIME TO GRID 6 IS 2.00 HOURS						TRAVEL TIME TO GRID 8 IS 2.00 HOURS					
	TEMP	2.55	0.0	-0.00	0.0	2.56	TEMP	2.56	0.0	0.00	0.0	2.56	TEMP
	DO	3.57	0.0	-0.00	0.0	3.57	DO	3.17	0.0	0.00	0.0	3.17	DO
	BOD	0.0	0.0	0.0	0.0	0.0	BOD	0.0	0.0	0.0	0.0	0.0	BOD
1 12.00		TRAVEL TIME TO GRID 6 IS 4.00 HOURS						TRAVEL TIME TO GRID 8 IS 4.00 HOURS					
	TEMP	4.31	0.0	0.02	0.0	4.29	TEMP	4.61	0.0	0.01	0.0	4.60	TEMP
	DO	5.62	0.0	0.08	0.0	5.54	DO	5.44	0.0	0.02	0.0	5.42	DO
	BOD	0.00	0.0	0.00	0.0	0.0	BOD	0.0	0.0	0.0	0.0	0.0	BOD
1 14.00		TRAVEL TIME TO GRID 6 IS 6.00 HOURS						TRAVEL TIME TO GRID 8 IS 6.00 HOURS					
	TEMP	5.34	0.0	0.14	0.0	5.20	TEMP	5.90	0.0	0.01	0.0	5.89	TEMP
	DO	7.20	0.0	0.29	0.0	6.91	DO	7.08	0.0	0.06	0.0	7.02	DO
	BOD	0.01	0.0	0.01	0.0	-0.00	BOD	0.00	0.0	0.00	0.0	-0.00	BOD
1 16.00		TRAVEL TIME TO GRID 6 IS 8.00 HOURS						TRAVEL TIME TO GRID 8 IS 8.00 HOURS					
	TEMP	6.27	0.0	0.03	0.0	6.24	TEMP	6.54	0.0	-0.05	0.0	6.59	TEMP
	DO	8.88	0.0	-0.29	0.0	9.20	DO	8.31	0.0	0.01	0.0	8.31	DO
	BOD	0.23	0.0	0.26	0.0	-0.03	BOD	0.00	0.0	0.00	0.0	-0.00	BOD

1 18.00		TRAVEL TIME TO GRID 6 IS 10.00 HOURS						TRAVEL TIME TO GRID 8 IS 10.00 HOURS					
	TEMP	6.99	0.0	-0.27	0.0	7.25	TEMP	6.79	0.0	-0.21	0.0	7.00	TEMP
	DO	9.91	0.0	-0.89	0.0	11.04	DO	9.28	0.0	-0.15	0.0	9.43	DO
	BOD	0.89	0.0	1.12	0.0	-0.23	BOD	0.01	0.0	0.01	0.0	-0.00	BOD
1 20.00		TRAVEL TIME TO GRID 6 IS 12.00 HOURS						TRAVEL TIME TO GRID 8 IS 12.00 HOURS					
	TEMP	7.54	0.0	0.10	0.33	7.11	TEMP	7.07	0.0	-0.06	0.0	7.13	TEMP
	DO	10.16	0.0	-0.18	0.02	11.40	DO	9.99	0.0	0.05	0.0	9.94	DO
	BOD	1.96	0.0	1.31	1.72	-1.08	BOD	0.02	0.0	0.03	0.0	-0.00	BOD
1 22.00		TRAVEL TIME TO GRID 6 IS 14.00 HOURS						TRAVEL TIME TO GRID 8 IS 14.00 HOURS					
	TEMP	8.22	0.0	0.42	0.96	6.84	TEMP	7.55	0.0	0.12	0.0	7.43	TEMP
	DO	10.05	0.0	0.92	-0.06	11.68	DO	10.49	0.0	0.23	0.0	10.27	DO
	BOD	2.79	0.0	0.03	5.25	-2.49	BOD	0.04	0.0	0.05	0.0	-0.01	BOD
2 0.0		TRAVEL TIME TO GRID 6 IS 15.90 HOURS						TRAVEL TIME TO GRID 8 IS 16.00 HOURS					
	TEMP	9.30	0.13	0.16	2.36	6.66	TEMP	8.31	0.0	0.34	0.0	7.97	TEMP
	DO	9.65	0.98	2.01	-0.54	12.30	DO	10.82	0.0	0.40	0.0	10.44	DO
	BOD	3.57	0.20	-5.05	13.53	-5.10	BOD	0.08	0.0	0.10	0.0	-0.02	BOD
2 2.00		TRAVEL TIME TO GRID 6 IS 15.90 HOURS						TRAVEL TIME TO GRID 8 IS 18.00 HOURS					
	TEMP	11.23	5.11	0.41	1.24	4.47	TEMP	9.60	0.0	0.04	0.0	9.56	TEMP
	DO	8.78	10.00	-0.60	-0.73	6.39	DO	10.87	0.0	-0.65	0.0	11.79	DO
	BOD	4.52	2.00	-0.80	9.59	-6.27	BOD	0.49	0.0	0.76	0.0	-0.27	BOD
2 4.00		TRAVEL TIME TO GRID 6 IS 15.90 HOURS						TRAVEL TIME TO GRID 8 IS 20.00 HOURS					
	TEMP	13.15	11.11	-1.58	0.86	2.76	TEMP	11.17	0.0	-0.25	0.04	11.39	TEMP
	DO	8.19	10.00	0.34	-0.70	5.45	DO	10.65	0.0	-1.07	0.00	12.68	DO
	BOD	4.65	2.00	-0.06	9.61	-6.90	BOD	0.96	0.0	1.73	0.19	-0.97	BOD
2 6.00		TRAVEL TIME TO GRID 6 IS 15.90 HOURS						TRAVEL TIME TO GRID 8 IS 22.00 HOURS					
	TEMP	14.86	11.72	-1.00	0.84	3.30	TEMP	13.03	0.0	0.31	0.42	12.30	TEMP
	DO	7.84	10.00	0.22	-0.59	5.38	DO	10.25	0.0	-0.04	0.03	12.63	DO
	BOD	4.56	2.00	0.02	9.61	-7.08	BOD	1.31	0.0	1.45	2.23	-2.36	BOD
2 8.00		TRAVEL TIME TO GRID 6 IS 15.90 HOURS						TRAVEL TIME TO GRID 8 IS 24.00 HOURS					
	TEMP	16.53	10.14	-0.05	0.96	5.48	TEMP	15.29	0.0	0.41	1.37	13.51	TEMP
	DO	7.58	10.00	0.01	-0.71	5.38	DO	9.72	0.0	1.30	-0.19	13.19	DO
	BOD	4.44	2.00	-0.06	9.61	-7.11	BOD	1.58	0.0	-1.51	7.67	-4.57	BOD
2 10.00		TRAVEL TIME TO GRID 6 IS 15.90 HOURS						TRAVEL TIME TO GRID 8 IS 25.36 HOURS					
	TEMP	18.10	9.08	0.23	1.03	7.76	TEMP	17.67	0.83	1.13	1.83	13.88	TEMP
	DO	7.29	10.00	-0.06	-0.72	5.29	DO	8.99	6.36	-0.47	-0.62	11.12	DO
	BOD	4.30	2.00	-0.09	9.61	-7.22	BOD	1.84	1.27	-3.17	11.14	-7.40	BOD
2 12.00		TRAVEL TIME TO GRID 6 IS 15.90 HOURS						TRAVEL TIME TO GRID 8 IS 25.36 HOURS					
	TEMP	19.48	8.81	0.18	1.03	9.46	TEMP	19.81	6.84	-0.15	1.11	12.01	TEMP
	DO	6.96	10.00	-0.04	-0.72	5.14	DO	8.15	10.00	-0.11	-0.73	7.89	DO
	BOD	4.10	2.00	-0.08	9.61	-7.43	BOD	2.03	2.00	-0.66	9.60	-8.91	BOD
2 14.00		TRAVEL TIME TO GRID 6 IS 15.90 HOURS						TRAVEL TIME TO GRID 8 IS 25.36 HOURS					
	TEMP	20.62	9.12	0.02	0.98	10.50	TEMP	21.29	11.70	-1.75	0.83	10.51	TEMP
	DO	6.61	10.00	0.01	-0.72	5.01	DO	7.58	10.00	0.45	-0.70	7.47	DO
	BOD	3.86	2.00	-0.06	9.61	-7.70	BOD	1.96	2.00	-0.01	9.61	-9.64	BOD
2 16.00		TRAVEL TIME TO GRID 6 IS 15.90 HOURS						TRAVEL TIME TO GRID 8 IS 25.36 HOURS					
	TEMP	21.26	9.83	-0.15	0.87	10.71	TEMP	21.93	11.29	-0.81	0.87	10.57	TEMP
	DO	6.31	10.00	0.05	-0.71	4.93	DO	7.25	10.00	0.21	-0.70	7.55	DO
	BOD	3.61	2.00	-0.04	9.61	-7.97	BOD	1.83	2.00	0.04	9.61	-9.82	BOD
2 18.00		TRAVEL TIME TO GRID 6 IS 15.90 HOURS						TRAVEL TIME TO GRID 8 IS 25.36 HOURS					
	TEMP	21.23	10.66	-0.08	0.75	9.90	TEMP	21.75	9.82	0.01	0.99	10.94	TEMP
	DO	6.12	10.00	0.06	-0.59	4.93	DO	7.07	10.00	-0.00	-0.71	7.64	DO
	BOD	3.41	2.00	-0.02	9.61	-8.18	BOD	1.71	2.00	-0.04	9.61	-9.86	BOD
2 20.00		TRAVEL TIME TO GRID 6 IS 15.90 HOURS						TRAVEL TIME TO GRID 8 IS 25.36 HOURS					

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     TEMP     20.64     11.76    -0.09     0.60     8.37    TEMP      21.05     8.97     0.24     1.04    10.80    TEMP
     DO        6.05     10.00     0.07    -0.58     4.98    DO         6.98    10.00    -0.06    -0.72     7.70    DO
     BOD       3.29      2.00    -0.02     9.62    -8.31    BOD        1.61     2.00    -0.06     9.61    -9.94    BOD

 2 22.00      TRAVEL   TIME TO GRID   6 IS 15.90 HOURS                 TRAVEL TIME TO GRID   8 IS 25.36 HOURS
     TEMP     19.59     12.95    -0.15     0.46     6.33    TEMP      20.00     8.86     0.18     1.02     9.94    TEMP
     DO        6.11     10.00     0.07    -0.56     5.06    DO         6.98    10.00    -0.03    -0.72     7.77    DO
     BOD       3.25      2.00    -0.02     9.62    -8.36    BOD        1.52     2.00    -0.05     9.61   -10.04    BOD

 3  0.0       TRAVEL   TIME TO GRID   6 IS 15.90 HOURS                 TRAVEL TIME TO GRID   8 IS 25.36 HOURS
     TEMP     18.33     14.05    -0.10     0.35     4.03    TEMP      18.85     9.23     0.06     0.95     8.62    TEMP
     DO        6.26     10.00     0.06    -0.56     5.16    DO         7.05    10.00     0.02    -0.71     7.89    DO
     BOD       3.29      2.00    -0.02     9.52    -8.31    BOD        1.45     2.00    -0.02     9.61   -10.14    BOD

RIVER MILE=   360.00PARCEL VOLUME=    21600.CUBIC METERS AND PARCEL ENTERED SYSTEM AT HOUR      48.00

 PARAMETER    CONC.   INT CONC  DEL DISP  DEL TRIB     DECAY     DUE TO
     TEMP     10.60     10.60     0.0       0.0        0.0       TEMP
     DO       10.00     10.00     0.0       0.0        0.0       DO
     BOD       2.00      2.00     0.0       0.0        0.0       BOD

RIVER MILE=   358.78PARCEL VOLUME=    21600.CUBIC METERS AND PARCEL ENTERED SYSTEM AT HOUR      47.00

 PARAMETER    CONC.   INT CONC  DEL DISP  DEL TRIB     DECAY     DUE TO
     TEMP     11.30     11.00     0.20      0.0        0.11      TEMP
     DO       10.08     10.00     0.01      0.0        0.20      DO
     BOD       1.83      2.00    -0.04      0.0       -0.13      BOD

RIVER MILE=   357.56PARCEL VOLUME=    21600.CUBIC METERS AND PARCEL ENTERED SYSTEM AT HOUR      46.00

 PARAMETER    CONC.   INT CONC  DEL DISP  DEL TRIB     DECAY     DUE TO
     TEMP     11.84     11.50     0.14      0.0        0.20      TEMP
     DO       10.05     10.00    -0.02      0.0        0.32      DO
     BOD       1.72      2.00    -0.03      0.0       -0.25      BOD

RIVER MILE=   356.75PARCEL VOLUME=    23940.CUBIC METERS AND PARCEL ENTERED SYSTEM AT HOUR      45.00

 PARAMETER    CONC.   INT CONC  DEL DISP  DEL TRIB     DECAY     DUE TO
     TEMP     13.06     12.00     0.01      0.75       0.29      TEMP
     DO        9.31     10.00    -0.01     -0.58       0.38      DO
     BOD      11.24      2.00    -0.00      9.52      -0.38      BOD

RIVER MILE=   356.12PARCEL VOLUME=    23940.CUBIC METERS AND PARCEL ENTERED SYSTEM AT HOUR      44.00

 PARAMETER    CONC.   INT CONC  DEL DISP  DEL TRIB     DECAY     DUE TO
     TEMP     13.68     12.50     0.15      0.70       0.34      TEMP
     DO        8.46     10.00    -0.19     -0.58       0.52      DO
     BOD      10.21      2.00    -0.21      9.52      -1.19      BOD

RIVER MILE=   355.50PARCEL VOLUME=    23940.CUBIC METERS AND PARCEL ENTERED SYSTEM AT HOUR      43.00

 PARAMETER    CONC.   INT CONC  DEL DISP  DEL TRIB     DECAY     DUE TO
     TEMP     14.14     12.90     0.15      0.54       0.45      TEMP
     DO        7.98     10.00    -0.12     -0.57       0.74      DO
     BOD       9.49      2.00    -0.16      9.52      -1.97      BOD

RIVER MILE=   354.72PARCEL VOLUME=    23940.CUBIC METERS AND PARCEL ENTERED SYSTEM AT HOUR      42.00

 PARAMETER    CONC.   INT CONC  DEL DISP  DEL TRIB     DECAY     DUE TO
     TEMP     14.65     13.40     0.16      0.58       0.51      TEMP
     DO        7.68     10.00    -0.10     -0.57       1.17      DO
     BOD       8.66      2.00    -0.24      9.52      -2.73      BOD

RIVER MILE=   353.74PARCEL VOLUME=    23940.CUBIC METERS AND PARCEL ENTERED SYSTEM AT HOUR      41.00

 PARAMETER    CONC.   INT CONC  DEL DISP  DEL TRIB     DECAY     DUE TO
```

PARAMETER	CONC.	INT CONC	DEL DISP	DEL TRIB	DECAY	DUE TO
TEMP	15.03	13.80	0.14	0.52	0.58	TEMP
DO	7.78	10.00	-0.02	-0.66	1.82	DO
BOD	7.97	2.00	-0.20	9.62	-3.45	BOD

RIVER MILE= 352.81PARCEL VOLUME= 23940.CUBIC METERS AND PARCEL ENTERED SYSTEM AT HOUR 40.00

PARAMETER	CONC.	INT CONC	DEL DISP	DEL TRIB	DECAY	DUE TO
TEMP	15.50	14.20	0.18	0.47	0.65	TEMP
DO	7.58	10.00	-0.08	-0.66	2.40	DO
BOD	7.22	2.00	-0.26	9.62	-4.14	BOD

RIVER MILE= 351.91PARCEL VOLUME= 23940.CUBIC METERS AND PARCEL ENTERED SYSTEM AT HOUR 39.00

PARAMETER	CONC.	INT CONC	DEL DISP	DEL TRIB	DECAY	DUE TO
TEMP	15.87	14.50	0.16	0.42	0.79	TEMP
DO	7.40	10.00	-0.03	-0.66	2.97	DO
BOD	6.61	2.00	-0.21	9.62	-4.80	BOD

RIVER MILE= 351.32PARCEL VOLUME= 23940.CUBIC METERS AND PARCEL ENTERED SYSTEM AT HOUR 38.00

PARAMETER	CONC.	INT CONC	DEL DISP	DEL TRIB	DECAY	DUE TO
TEMP	16.34	14.70	0.20	0.37	1.07	TEMP
DO	7.11	10.00	-0.13	-0.66	3.32	DO
BOD	5.98	2.00	-0.21	9.62	-5.43	BOD

RIVER MILE= 350.89PARCEL VOLUME= 23940.CUBIC METERS AND PARCEL ENTERED SYSTEM AT HOUR 37.00

PARAMETER	CONC.	INT CONC	DEL DISP	DEL TRIB	DECAY	DUE TO
TEMP	16.71	14.90	0.07	0.33	1.41	TEMP
DO	6.89	10.00	-0.05	-0.66	3.60	DO
BOD	5.50	2.00	-0.10	9.62	-6.02	BOD

RIVER MILE= 350.46PARCEL VOLUME= 23940.CUBIC METERS AND PARCEL ENTERED SYSTEM AT HOUR 36.00

PARAMETER	CONC.	INT CONC	DEL DISP	DEL TRIB	DECAY	DUE TO
TEMP	17.14	15.00	0.02	0.31	1.81	TEMP
DO	6.64	10.00	-0.03	-0.64	3.89	DO
BOD	4.94	2.00	-0.11	9.62	-6.58	BOD

RIVER MILE= 350.03PARCEL VOLUME= 23940.CUBIC METERS AND PARCEL ENTERED SYSTEM AT HOUR 35.00

PARAMETER	CONC.	INT CONC	DEL DISP	DEL TRIB	DECAY	DUE TO
TEMP	17.51	15.00	-0.07	0.29	2.29	TEMP
DO	6.47	10.00	0.00	-0.64	4.20	DO
BOD	4.46	2.00	-0.07	9.62	-7.09	BOD

RIVER MILE= 349.60PARCEL VOLUME= 23940.CUBIC METERS AND PARCEL ENTERED SYSTEM AT HOUR 34.00

PARAMETER	CONC.	INT CONC	DEL DISP	DEL TRIB	DECAY	DUE TO
TEMP	17.84	14.80	-0.04	0.30	2.79	TEMP
DO	6.35	10.00	0.02	-0.66	4.53	DO
BOD	4.01	2.00	-0.06	9.62	-7.55	BOD

RIVER MILE= 349.17PARCEL VOLUME= 23940.CUBIC METERS AND PARCEL ENTERED SYSTEM AT HOUR 33.00

PARAMETER	CONC.	INT CONC	DEL DISP	DEL TRIB	DECAY	DUE TO
TEMP	18.12	14.50	-0.12	0.32	3.42	TEMP
DO	6.28	10.00	0.04	-0.66	4.86	DO
BOD	3.61	2.00	-0.04	9.52	-7.97	BOD

RIVER MILE= 348.74PARCEL VOLUME= 23940.CUBIC METERS AND PARCEL ENTERED SYSTEM AT HOUR 32.00

PARAMETER	CONC.	INT CONC	DEL DISP	DEL TRIB	DECAY	DUE TO
TEMP	18.35	14.00	-0.10	0.36	4.10	TEMP
DO	6.26	10.00	0.06	-0.66	5.20	DO
BOD	3.26	2.00	-0.02	9.52	-8.34	BOD

RIVER MILE= 348.28PARCEL VOLUME= 23940.CUBIC METERS AND PARCEL ENTERED SYSTEM AT HOUR 31.00

PARAMETER	CONC.	INT CONC	DEL DISP	DEL TRIB	DECAY	DUE TO
TEMP	18.42	13.40	-0.10	0.40	4.72	TEMP
DO	6.39	10.00	0.09	-0.66	5.62	DO
BOD	2.95	2.00	-0.01	9.62	-8.66	BOD

RIVER MILE= 347.83PARCEL VOLUME= 23940.CUBIC METERS AND PARCEL ENTERED SYSTEM AT HOUR 30.00

PARAMETER	CONC.	INT CONC	DEL DISP	DEL TRIB	DECAY	DUE TO
TEMP	18.51	12.90	-0.19	0.46	5.33	TEMP
DO	6.48	10.00	0.09	-0.67	6.01	DO
BOD	2.67	2.00	0.00	9.62	-8.95	BOD

RIVER MILE= 347.48PARCEL VOLUME= 23940.CUBIC METERS AND PARCEL ENTERED SYSTEM AT HOUR 29.00

PARAMETER	CONC.	INT CONC	DEL DISP	DEL TRIB	DECAY	DUE TO
TEMP	18.60	12.30	-0.14	0.53	5.91	TEMP
DO	6.51	10.00	0.08	-0.67	6.30	DO
BOD	2.43	2.00	0.01	9.62	-9.20	BOD

RIVER MILE= 347.12PARCEL VOLUME= 23940.CUBIC METERS AND PARCEL ENTERED SYSTEM AT HOUR 28.00

PARAMETER	CONC.	INT CONC	DEL DISP	DEL TRIB	DECAY	DUE TO
TEMP	18.66	11.70	-0.10	0.61	6.46	TEMP
DO	6.58	10.00	0.08	-0.68	6.59	DO
BOD	2.22	2.00	0.01	9.62	-9.41	BOD

RIVER MILE= 346.77PARCEL VOLUME= 23940.CUBIC METERS AND PARCEL ENTERED SYSTEM AT HOUR 27.00

PARAMETER	CONC.	INT CONC	DEL DISP	DEL TRIB	DECAY	DUE TO
TEMP	18.72	11.20	-0.17	0.68	7.00	TEMP
DO	6.66	10.00	0.09	-0.69	6.85	DO
BOD	2.04	2.00	0.01	9.62	-9.59	BOD

RIVER MILE= 346.41PARCEL VOLUME= 23940.CUBIC METERS AND PARCEL ENTERED SYSTEM AT HOUR 26.00

PARAMETER	CONC.	INT CONC	DEL DISP	DEL TRIB	DECAY	DUE TO
TEMP	18.76	10.60	-0.08	0.75	7.48	TEMP
DO	6.75	10.00	0.08	-0.69	7.11	DO
BOD	1.87	2.00	0.01	9.61	-9.75	BOD

RIVER MILE= 346.05PARCEL VOLUME= 23940.CUBIC METERS AND PARCEL ENTERED SYSTEM AT HOUR 25.00

PARAMETER	CONC.	INT CONC	DEL DISP	DEL TRIB	DECAY	DUE TO
TEMP	18.79	10.10	-0.08	0.82	7.95	TEMP
DO	6.84	10.00	0.07	-0.70	7.36	DO
BOD	1.73	2.00	0.00	9.61	-9.89	BOD

RIVER MILE= 345.70PARCEL VOLUME= 23940.CUBIC METERS AND PARCEL ENTERED SYSTEM AT HOUR 24.00

PARAMETER	CONC.	INT CONC	DEL DISP	DEL TRIB	DECAY	DUE TO
TEMP	18.82	9.80	-0.15	0.88	8.29	TEMP
DO	6.93	10.00	0.06	-0.71	7.58	DO
BOD	1.60	2.00	-0.00	9.61	-10.01	BOD

RIVER MILE= 345.34PARCEL VOLUME= 23940.CUBIC METERS AND PARCEL ENTERED SYSTEM AT HOUR 23.00

PARAMETER	CONC.	INT CONC	DEL DISP	DEL TRIB	DECAY	DUE TO
TEMP	18.84	9.30	0.07	0.93	8.55	TEMP
DO	7.02	10.00	0.03	-0.71	7.81	DO
BOD	1.49	2.00	-0.02	9.61	-10.11	BOD

RIVER MILE= 345.21PARCEL VOLUME= 23940.CUBIC METERS AND PARCEL ENTERED SYSTEM AT HOUR 22.64

PARAMETER	CONC.	INT CONC	DEL DISP	DEL TRIB	DECAY	DUE TO
TEMP	18.85	9.23	0.06	0.95	8.62	TEMP
DO	7.05	10.00	0.02	-0.71	7.89	DO
BOD	1.45	2.00	-0.02	9.61	-10.14	BOD

ATTACHMENT E

Flow Routing Model of Dawdy and others

```
      C***********************************************************************
      C  FLOW ROUTING DAWDY ET AL
      C***********************************************************************
      C      X(I)= X COORDINATE IN RIVER MILES
      C      QO,Q(I)=OLD,NEW DISCHARGE AT GRID I,TRIBS ENTER JUST D/S OF GRID
      C      AO,A(I)=OLD,NEW AREA IN SUBREACH I
      C      W(I)= WIDTH AT SECTION I IN METERS
      C      QT(I)=TRIBUTARY INFLOW AT GRID I
      C      DT=TIME STEP IN SECONDS
      C      DX(I)=DISTANCE BETWEEN GRIDS IN METERS
      C      NXSEC=NUMBER OF CROSS SECTIONS(INX=NXSEC-1)
      C      FLOW(L,I)= FLOW FIELD AT GRID I
      C         L=1 FOR VELOCITY IN METERS/SEC
      C         L=2 FOR AREA IN SQ. METERS
      C         L=3 FO TOP WIDTH IN METERS
      C         L=4 FOR TRIBUTARY INFLOW IN CU. METERS/SEC
      C***********************************************************************
      C
            DIMENSION QO(50),Q(50),AO(50),A(50),QT(50),DX(50),X(50),W(50)
            DIMENSION FLOW(4,50)
            DATA FLOW/200*0.0/
            DATA QO,Q,AO,A,QT,DX/50*0.0,50*0.0,50*0.0,50*0.0,50*0.0,50*0.0/
            QO(1)=6.0
            QT(5)=0.65
            DT=3600.0
            NXSEC=8
            IT=0
            READ(5,4000) (X(I),I=1,NXSEC)
       4000 FORMAT(10X,10F7.2)
      C
      C*****CONVERT MILES TO METERS IN THE DX ARRAY
      C
            INX=NXSEC-1
            DO 100 I=1,INX
            DX(I)=(X(I)-X(I+1))*1609.34
            QO(I+1)=QO(I)+QT(I)
        100 CONTINUE
      C
      C*****INITIALIZE SUBROUTINE XSEC
      C
            CALL XSEC(NXSEC)
            DO 200 I=1,NXSEC
            CALL QTA(I,QO(I),AO(I))
            CALL ATW(I,AO(I),W(I))
            FLOW(1,I)=3600.0*QO(I)/AO(I)
            FLOW(2,I)=AO(I)
            FLOW(3,I)=W(I)
            FLOW(4,5)=0.65
        200 CONTINUE
      C
      C***** WRITE FLOW @ TIME ZERO
      C
            WRITE(6,9001)
       9001 FORMAT(' ','TIME=0.0 HOURS')
            WRITE(6,8001)
            DO 202 I=1,NXSEC
            WRITE(6,8000) IT,I,(FLOW(K,I),K=1,4)
        202 CONTINUE
```

```
                WRITE(65,6500) ((FLOW(K,I),K=1,4),I=1,NXSEC)
                WRITE(6,8002)
          8002 FORMAT(' ',//)
         C
         C*****BEGIN TIME LOOP
         C
                DO 2 J=1,40
                READ(5,3000) Q(1)
          3000 FORMAT(10X,F8.1,4(F6.1))
                CALL QTA(1,Q(1),A(1))
                DO 3 I=2,NXSEC
                II=I-1
                U=QO(I)/AO(I)
                THETA=U*DT/DX(II)
                IF(THETA.LT.1.0) GO TO 4
                CALL QTA(II,Q(II),A(II))
                Q(I)=Q(II)-DX(II)*(A(II)-AO(II))/DT+QT(I)
                CALL QTA(I,Q(I),A(I))
                GO TO 3
             4 VI=(QO(I-1)+QT(I-1))*DT
                VO=QO(I)*DT
                DELS=VI-VO
                A(I)=AO(I)+DELS/DX(II)
                CALL ATQ(I,A(I),Q(I))
             3 CONTINUE
                DO 7 I=1,NXSEC
                AO(I)=A(I)
                CALL ATW(I,A(I),W(I))
                FLOW(1,I)=3600.0*Q(I)/A(I)
                FLOW(2,I)=A(I)
                FLOW(3,I)=W(I)
                FLOW(4,5)=0.65
             7 QO(I)=Q(I)
                TIME=J*DT/3600.0
                WRITE(6,4001)TIME
          4001 FORMAT(' ','TIME=',F6.2,'HOURS')
         C
         C***** WRITE FLOW FOR EACH TIME STEP
         C
                WRITE(6,8001)
          8001 FORMAT(1X,'TIME',10X,'VELOCITY',7X,'AREA',8X,'WIDTH',6X,'TRIB.',/,
               *1X,'STEP',2X,'GRID',4X,'(M/HR.)',6X,'(SQ. M.)',4X,'(METERS)',5X,'(
               *CU.M./S.)')
                DO 77 I=1,NXSEC
                WRITE(6,8000) J,I,(FLOW(K,I),K=1,4)
          8000 FORMAT(1X,I3,3X,I3,1X,4F12.3)
            77 CONTINUE
                WRITE(65,6500)((FLOW(K,I),K=1,4),I=1,NXSEC)
          6500 FORMAT(8F10.3)
                WRITE(6,8002)
             2 CONTINUE
             5 STOP
                END
```

```
      SUBROUTINE XSEC(NXSEC)
C
C*****YP(N,I)= DEPTH OF CROSS SECTION AT BREAK POINT N
C*****QP(N,I)=DISCHARGE OF CROSS SECTION I AT BREAK POINT N
C*****AP(N,I)=AREA OF CROSS SECTION I BELOW BREAK POINT N
C*****WP(N,I)=WIDTH OF CROSS SECTION AT BREAK POINT N
C
      DIMENSION AP(24,50),QP(24,50),YP(24,50),WP(24,50)
      DO 1 I=1,NXSEC
      READ(5,1000) (YP(N,I),N=1,11)
      READ(5,1000) (QP(N,I),N=1,11)
      READ(5,1000) (AP(N,I),N=1,11)
      READ(5,1000) (WP(N,I),N=1,11)
 1000 FORMAT(12X,11F6.2)
    1 CONTINUE
      RETURN
C
      ENTRY QTA(I,Q,A)
C     QTA CONVERTS FROM DISCHARGES TO AREAS
      N=0
   20 N=N+1
      IF(Q.GT.QP(N,I)) GO TO 20
      A=AP(N-1,I)+(Q-QP(N-1,I))*(AP(N,I)-AP(N-1,I))/(QP(N,I)-QP(N-1,I))
      RETURN
C
      ENTRY ATQ(I,A,Q)
C     ATQ CONVERTS FROM AREAS TO DISCHARGE
      N=0
   22 N=N+1
      IF(A.GT.AP(N,I)) GO TO 22
      Q=QP(N-1,I)+(A-AP(N-1,I))*(QP(N,I)-QP(N-1,I))/(AP(N,I)-AP(N-1,I))
      RETURN
C
      ENTRY ATW(I,A,W)
C $$ ATW CONVERTS FROM AREA TO TOP WIDTH
      N=0
   23 N=N+1
      IF(A.GT.AP(N,I)) GO TO 23
      W=AP(N-1,I)+(A-AP(N-1,I))*(WP(N,I)-WP(N-1,I))/(AP(N,I)-AP(N-1,I))
      RETURN
      END
```

Input Data for

Flow Routing Model of Dawdy and others

RIVER MILE	360.00	357.18	355.15	353.41	351.61	349.78	347.86	345.21			
DEPTH SEC 1	0.151	0.227	0.281	0.335	0.424	0.519	0.660	0.825	1.037	1.176	1.559
DISCH SEC 1	1.34	3.43	5.26	7.37	11.31	16.30	24.82	36.32	54.20	69.42	116.41
AREA SEC 1	2.4	3.7	4.7	5.6	7.2	8.8	11.3	14.2	18.0	20.9	29.0
WIDTH SEC 1	15.8	16.1	16.3	16.5	16.9	17.3	17.8	18.5	19.3	19.9	21.4
DEPTH SEC 2	0.094	0.187	0.249	0.312	0.414	0.526	0.694	0.892	1.149	1.337	1.840
DISCH SEC 2	1.34	3.43	5.26	7.37	11.31	16.30	24.82	36.32	54.20	69.42	116.41
AREA SEC 2	3.6	7.2	9.7	12.2	16.3	20.8	27.5	35.4	46.2	54.4	76.4
WIDTH SEC 2	38.1	38.4	38.7	38.9	39.4	39.8	40.5	41.3	42.3	43.0	45.1
DEPTH SEC 3	0.163	0.248	0.308	0.368	0.463	0.563	0.705	0.861	1.057	1.192	1.523
DISCH SEC 3	1.34	3.43	5.26	7.37	11.31	16.30	24.82	36.32	54.20	69.42	116.41
AREA SEC 3	9.9	15.2	18.9	22.6	28.5	34.8	43.6	53.3	65.6	74.5	96.4
WIDTH SEC 3	60.6	60.9	61.1	61.4	61.8	62.2	62.7	63.3	64.1	64.7	66.0
DEPTH SEC 4	0.027	0.053	0.072	0.090	0.118	0.150	0.196	0.252	0.330	0.391	0.562
DISCH SEC 4	1.34	3.43	5.26	7.37	11.31	16.30	24.82	36.32	54.20	69.42	116.41
AREA SEC 4	2.2	4.4	5.8	7.3	9.7	12.3	16.2	20.9	27.4	32.4	46.7
WIDTH SEC 4	81.4	81.5	81.6	81.7	81.8	81.9	82.1	82.3	82.6	82.9	83.5
DEPTH SEC 5	0.150	0.231	0.289	0.348	0.444	0.547	0.697	0.867	1.088	1.247	1.656
DISCH SEC 5	1.99	4.08	5.91	8.02	11.96	16.95	25.47	36.97	54.85	70.07	117.06
AREA SEC 5	13.2	20.5	25.7	30.9	39.5	48.7	62.1	77.3	97.4	112.3	150.3
WIDTH SEC 5	87.8	88.1	88.4	88.6	89.0	89.4	90.0	90.7	91.6	92.2	93.8
DEPTH SEC 6	0.121	0.183	0.226	0.269	0.337	0.412	0.519	0.643	0.809	0.936	1.264
DISCH SEC 6	1.99	4.08	5.91	8.02	11.96	16.95	25.47	36.97	54.85	70.07	117.06
AREA SEC 6	9.9	15.1	18.7	22.2	27.9	34.1	43.1	53.4	67.2	77.7	106.1
WIDTH SEC 6	81.6	81.8	82.0	82.2	82.4	82.7	83.2	83.7	84.3	84.8	86.2
DEPTH SEC 7	0.100	0.155	0.194	0.234	0.300	0.373	0.483	0.613	0.791	0.925	1.284
DISCH SEC 7	1.99	4.08	5.91	8.02	11.96	16.95	25.47	36.97	54.85	70.07	117.06
AREA SEC 7	11.5	17.8	22.3	27.0	34.7	43.2	55.9	71.1	91.7	107.4	150.2
WIDTH SEC 7	114.5	114.7	114.9	115.0	115.3	115.6	116.0	116.6	117.3	117.8	119.2
DEPTH SEC 8	0.130	0.200	0.250	0.300	0.380	0.470	0.600	0.750	0.950	1.100	1.500
DISCH SEC 8	1.99	4.08	5.91	8.02	11.96	16.95	25.47	36.97	54.85	70.07	117.06
AREA SEC 8	15.9	24.6	30.7	36.9	46.8	58.0	74.1	92.6	117.4	136.4	187.4
WIDTH SEC 8	122.1	122.4	122.6	122.8	123.1	123.5	124.0	124.6	125.4	126.0	127.6

1	6.0
2	6.0
3	6.0
4	6.0
5	32.11
6	71.28
7	100.0
8	90.86
9	71.28
10	53.00
11	41.25
12	30.81
13	27.54
14	24.93
15	22.97
16	21.01
17	19.06
18	18.66
19	17.36
20	15.79
21	14.62
22	13.57
23	12.53
24	12.14
25	11.22
26	10.70
27	9.92
28	9.0
29	8.35
30	8.09

31	7.31
32	7.04
33	6.65
34	6.39
35	6.26
36	6.13
37	6.00
38	6.00
39	6.00
40	6.00

Output of

Flow Routing Model of Dawdy and others

TIME=0.0 HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
0	1	4306.527	5.016	4.770	0.0
0	2	2042.210	10.577	9.770	0.0
0	3	1069.433	20.198	19.005	0.0
0	4	3414.444	6.326	5.835	0.0
0	5	833.276	25.922	25.709	0.650
0	6	1201.356	19.927	18.770	0.0
0	7	999.652	23.948	22.335	0.0
0	8	728.226	32.874	30.770	0.0

TIME= 1.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
1	1	4306.527	5.016	4.770	0.0
1	2	2042.210	10.577	9.770	0.0
1	3	1069.432	20.198	19.005	0.0
1	4	3414.445	6.326	5.835	0.0
1	5	833.275	25.922	25.709	0.650
1	6	1201.355	19.927	18.770	0.0
1	7	999.651	23.948	22.335	0.0
1	8	728.226	32.874	30.770	0.0

TIME= 2.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
2	1	4306.527	5.016	4.770	0.0
2	2	2042.210	10.577	9.770	0.0
2	3	1069.432	20.198	19.005	0.0
2	4	3414.443	6.326	5.835	0.0
2	5	833.275	25.922	25.709	0.650
2	6	1201.355	19.927	18.770	0.0
2	7	999.651	23.948	22.335	0.0
2	8	728.226	32.874	30.770	0.0

TIME= 3.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
3	1	4306.527	5.016	4.770	0.0
3	2	2042.210	10.577	9.770	0.0
3	3	1069.432	20.198	19.005	0.0
3	4	3414.441	6.326	5.835	0.0
3	5	833.275	25.922	25.709	0.650
3	6	1201.355	19.927	18.770	0.0
3	7	999.651	23.948	22.335	0.0
3	8	728.226	32.874	30.770	0.0

TIME= 4.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
4	1	4306.527	5.016	4.770	0.0
4	2	2042.210	10.577	9.770	0.0
4	3	1069.432	20.198	19.005	0.0

4	4	3414.441	6.326	5.835	0.0
4	5	833.275	25.922	25.709	0.650
4	6	1201.355	19.927	18.770	0.0
4	7	999.651	23.948	22.335	0.0
4	8	728.226	32.874	30.770	0.0

TIME= 5.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
5	1	8798.367	13.138	11.744	0.0
5	2	2042.210	10.577	9.770	0.0
5	3	1069.432	20.198	19.005	0.0
5	4	3414.441	6.326	5.835	0.0
5	5	833.274	25.922	25.709	0.650
5	6	1201.354	19.927	18.770	0.0
5	7	999.651	23.948	22.335	0.0
5	8	728.226	32.874	30.770	0.0

TIME= 6.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
6	1	12092.391	21.221	20.959	0.0
6	2	3490.243	31.288	27.884	0.0
6	3	1069.432	20.198	19.005	0.0
6	4	3414.441	6.326	5.835	0.0
6	5	833.274	25.922	25.709	0.650
6	6	1201.354	19.927	18.770	0.0
6	7	999.650	23.948	22.335	0.0
6	8	728.226	32.874	30.770	0.0

TIME= 7.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
7	1	13755.535	26.171	21.876	0.0
7	2	5048.656	63.767	55.294	0.0
7	3	2210.372	47.012	43.811	0.0
7	4	3749.479	7.688	7.316	0.0
7	5	833.274	25.922	25.709	0.650
7	6	1201.354	19.927	18.770	0.0
7	7	999.650	23.948	22.335	0.0
7	8	728.225	32.874	30.770	0.0

TIME= 8.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
8	1	13298.883	24.596	21.584	0.0
8	2	5113.316	65.368	55.447	0.0
8	3	3420.212	75.637	74.567	0.0
8	4	6940.102	25.725	21.123	0.0
8	5	888.375	28.417	25.805	0.650
8	6	1201.354	19.927	18.770	0.0
8	7	999.650	23.948	22.335	0.0
8	8	728.225	32.874	30.770	0.0

TIME= 9.00HOURS

TIME	VELOCITY	AREA	WIDTH	TRIB.

STEP	GRID	(M/HR.)	(SQ. M.)	(METERS)	(CU.M./S.)
9	1	12092.391	21.221	20.959	0.0
9	2	4748.723	57.263	54.673	0.0
9	3	3694.138	80.778	74.873	0.0
9	4	8049.605	35.282	32.521	0.0
9	5	1795.303	81.340	77.481	0.650
9	6	1238.764	20.728	18.816	0.0
9	7	999.650	23.948	22.335	0.0
9	8	728.225	32.874	30.770	0.0

TIME= 10.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
10	1	10752.344	17.745	14.946	0.0
10	2	4311.332	47.914	46.346	0.0
10	3	3274.113	72.422	66.060	0.0
10	4	7824.152	33.296	32.438	0.0
10	5	2531.396	128.977	113.002	0.650
10	6	2308.675	47.666	43.322	0.0
10	7	1028.442	25.121	22.360	0.0
10	8	728.225	32.874	30.770	0.0

TIME= 11.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
11	1	9739.133	15.248	14.421	0.0
11	2	4154.539	44.438	36.237	0.0
11	3	2981.123	65.739	65.609	0.0
11	4	7355.953	29.186	27.507	0.0
11	5	2164.021	106.199	97.754	0.650
11	6	3756.267	95.703	78.587	0.0
11	7	2038.455	82.002	71.470	0.0
11	8	734.855	33.319	30.784	0.0

TIME= 12.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
12	1	8658.191	12.811	11.665	0.0
12	2	3760.626	36.479	35.500	0.0
12	3	2853.347	62.263	53.883	0.0
12	4	7039.617	26.620	21.164	0.0
12	5	2085.747	100.976	97.544	0.650
12	6	2956.787	67.747	67.226	0.0
12	7	2315.658	104.377	92.104	0.0
12	8	1164.122	66.771	58.272	0.0

TIME= 13.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
13	1	8271.707	11.986	11.466	0.0
13	2	3456.217	30.691	27.823	0.0
13	3	2328.495	49.875	43.988	0.0
13	4	6578.480	22.927	20.994	0.0
13	5	1971.184	92.960	78.001	0.650
13	6	3045.774	70.521	67.358	0.0
13	7	2206.366	95.489	91.821	0.0
13	8	1576.163	105.217	93.007	0.0

TIME= 14.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
14	1	7922.848	11.328	11.307	0.0
14	2	3362.775	29.164	27.668	0.0
14	3	2200.896	46.796	43.798	0.0
14	4	5959.965	18.727	16.308	0.0
14	5	1802.667	81.768	77.500	0.650
14	6	2855.143	64.108	53.866	0.0
14	7	2136.329	90.123	71.746	0.0
14	8	1668.772	115.732	93.346	0.0

TIME= 15.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
15	1	7687.160	10.757	9.191	0.0
15	2	3240.889	27.330	21.482	0.0
15	3	2132.131	45.290	43.705	0.0
15	4	5759.762	17.498	16.255	0.0
15	5	1607.918	69.413	62.437	0.650
15	6	2622.276	56.797	53.548	0.0
15	7	2006.166	79.635	71.390	0.0
15	8	1667.649	115.592	93.342	0.0

TIME= 16.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
16	1	7428.367	10.182	9.076	0.0
16	2	3174.341	26.034	21.347	0.0
16	3	2024.010	42.844	35.257	0.0
16	4	5609.988	16.678	16.220	0.0
16	5	1544.404	65.675	62.265	0.650
16	6	2359.146	49.115	43.392	0.0
16	7	1845.371	68.953	56.415	0.0
16	8	1601.075	107.853	93.092	0.0

TIME= 17.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
17	1	7140.160	9.610	8.962	0.0
17	2	3085.883	24.491	21.186	0.0
17	3	1980.182	41.596	35.186	0.0
17	4	5449.387	15.756	12.477	0.0
17	5	1493.556	62.960	62.140	0.650
17	6	2264.187	46.458	43.263	0.0
17	7	1751.584	62.300	56.153	0.0
17	8	1492.082	97.199	92.748	0.0

TIME= 18.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
18	1	7076.750	9.492	8.938	0.0
18	2	2986.225	22.957	21.025	0.0
18	3	1900.973	39.517	35.068	0.0
18	4	5349.566	15.131	12.445	0.0
18	5	1450.021	60.138	49.212	0.650

18	6	2187.877	44.523	43.169	0.0
18	7	1698.105	59.051	56.024	0.0
18	8	1402.837	88.781	74.576	0.0

TIME= 19.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
19	1	6859.375	9.111	8.862	0.0
19	2	2964.871	22.653	20.994	0.0
19	3	1816.079	37.507	34.954	0.0
19	4	5187.598	14.215	12.398	0.0
19	5	1418.754	57.978	49.115	0.650
19	6	2118.298	42.795	34.583	0.0
19	7	1650.983	56.457	55.922	0.0
19	8	1345.654	83.090	74.392	0.0

TIME= 20.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
20	1	6581.852	8.636	7.559	0.0
20	2	2888.150	21.625	20.886	0.0
20	3	1803.003	37.216	34.937	0.0
20	4	5040.391	13.474	12.360	0.0
20	5	1372.289	55.039	48.984	0.650
20	6	2076.936	41.465	34.509	0.0
20	7	1619.042	54.408	43.553	0.0
20	8	1296.230	78.729	74.250	0.0

TIME= 21.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
21	1	6370.891	8.261	7.465	0.0
21	2	2797.510	20.388	16.663	0.0
21	3	1736.176	35.794	34.856	0.0
21	4	4991.855	13.247	12.349	0.0
21	5	1326.321	52.411	48.866	0.650
21	6	2016.121	39.653	34.409	0.0
21	7	1584.525	52.147	43.482	0.0
21	8	1255.379	75.455	74.144	0.0

TIME= 22.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
22	1	6164.562	7.925	7.381	0.0
22	2	2737.810	19.418	16.577	0.0
22	3	1666.819	34.230	28.864	0.0
22	4	4856.387	12.650	12.318	0.0
22	5	1304.352	51.241	48.814	0.650
22	6	1950.823	37.877	34.310	0.0
22	7	1542.193	49.618	43.402	0.0
22	8	1223.793	72.619	58.454	0.0

TIME= 23.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
23	1	5942.156	7.591	7.298	0.0

23	2	2673.313	18.468	16.493	0.0
23	3	1624.086	33.039	28.788	0.0
23	4	4727.469	12.056	9.791	0.0
23	5	1267.162	49.376	48.730	0.650
23	6	1909.884	36.842	34.252	0.0
23	7	1507.144	47.703	43.342	0.0
23	8	1195.498	69.724	58.364	0.0

TIME= 24.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
24	1	5853.633	7.466	7.267	0.0
24	2	2602.650	17.529	16.409	0.0
24	3	1573.327	31.727	28.705	0.0
24	4	4634.496	11.563	9.772	0.0
24	5	1234.578	47.452	39.846	0.650
24	6	1859.539	35.644	34.186	0.0
24	7	1475.827	46.113	43.292	0.0
24	8	1167.058	67.037	58.281	0.0

TIME= 25.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
25	1	5638.621	7.163	5.991	0.0
25	2	2568.338	17.106	16.372	0.0
25	3	1518.077	30.412	28.621	0.0
25	4	4522.734	11.022	9.751	0.0
25	5	1207.511	45.728	39.771	0.650
25	6	1806.693	34.467	34.120	0.0
25	7	1450.777	44.915	43.254	0.0
25	8	1139.806	64.649	58.206	0.0

TIME= 26.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
26	1	5540.625	6.952	5.938	0.0
26	2	2500.264	16.326	16.302	0.0
26	3	1487.424	29.728	28.578	0.0
26	4	4400.297	10.484	9.730	0.0
26	5	1176.035	43.875	39.690	0.650
26	6	1767.312	33.432	28.168	0.0
26	7	1408.634	42.963	34.992	0.0
26	8	1115.384	62.650	58.144	0.0

TIME= 27.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
27	1	5381.934	6.636	5.859	0.0
27	2	2468.689	15.819	12.641	0.0
27	3	1437.937	28.688	28.512	0.0
27	4	4330.262	10.199	9.719	0.0
27	5	1141.134	41.988	39.608	0.650
27	6	1727.778	32.302	28.113	0.0
27	7	1392.378	41.994	34.957	0.0
27	8	1086.717	60.456	58.076	0.0

TIME= 28.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
28	1	5174.121	6.262	5.765	0.0
28	2	2420.334	15.083	12.552	0.0
28	3	1411.736	28.015	22.967	0.0
28	4	4226.254	9.804	9.704	0.0
28	5	1115.329	40.694	39.552	0.650
28	6	1681.861	31.082	28.054	0.0
28	7	1360.136	40.197	34.894	0.0
28	8	1063.121	58.761	58.024	0.0

TIME= 29.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
29	1	5011.695	5.998	5.699	0.0
29	2	2354.021	14.178	12.441	0.0
29	3	1377.605	27.083	22.904	0.0
29	4	4173.363	9.565	7.394	0.0
29	5	1087.592	39.329	31.292	0.650
29	6	1641.506	30.083	28.006	0.0
29	7	1328.512	38.577	34.837	0.0
29	8	1041.728	56.933	47.162	0.0

TIME= 30.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
30	1	4942.648	5.892	5.673	0.0
30	2	2293.954	13.448	12.352	0.0
30	3	1329.845	25.879	22.822	0.0
30	4	4105.316	9.204	7.379	0.0
30	5	1073.150	38.343	31.246	0.650
30	6	1601.126	29.146	27.960	0.0
30	7	1301.962	37.315	34.792	0.0
30	8	1022.430	55.044	47.094	0.0

TIME= 31.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
31	1	4720.859	5.574	4.894	0.0
31	2	2260.065	13.068	12.306	0.0
31	3	1282.529	24.787	22.748	0.0
31	4	4002.238	8.707	7.359	0.0
31	5	1055.171	37.183	31.192	0.650
31	6	1569.323	28.448	27.927	0.0
31	7	1272.803	36.021	34.747	0.0
31	8	1002.723	53.239	47.030	0.0

TIME= 32.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
32	1	4642.402	5.459	4.869	0.0
32	2	2191.251	12.359	12.219	0.0
32	3	1250.380	24.097	22.701	0.0
32	4	3893.135	8.236	7.339	0.0
32	5	1029.945	35.668	31.122	0.650
32	6	1538.942	27.774	22.396	0.0
32	7	1253.403	35.208	34.718	0.0

32	8	982.082	51.472	46.967	0.0

TIME= 33.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
33	1	4523.047	5.293	4.832	0.0
33	2	2158.597	11.976	9.882	0.0
33	3	1203.898	23.163	22.638	0.0
33	4	3826.159	7.971	7.328	0.0
33	5	1000.608	34.055	31.047	0.650
33	6	1510.601	26.969	22.367	0.0
33	7	1233.282	34.271	27.283	0.0
33	8	963.349	49.967	46.913	0.0

TIME= 34.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
34	1	4439.219	5.182	4.807	0.0
34	2	2126.532	11.555	9.848	0.0
34	3	1171.659	22.540	19.195	0.0
34	4	3716.967	7.574	7.311	0.0
34	5	976.204	32.821	30.989	0.650
34	6	1474.926	26.020	22.334	0.0
34	7	1214.399	33.240	27.243	0.0
34	8	945.205	48.591	46.864	0.0

TIME= 35.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
35	1	4395.945	5.127	4.795	0.0
35	2	2098.432	11.209	9.821	0.0
35	3	1149.098	21.978	19.150	0.0
35	4	3650.135	7.350	7.302	0.0
35	5	947.520	31.479	30.927	0.650
35	6	1439.543	25.142	22.303	0.0
35	7	1187.954	31.896	27.191	0.0
35	8	927.040	47.287	46.817	0.0

TIME= 36.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
36	1	4351.727	5.071	4.782	0.0
36	2	2079.850	10.992	9.803	0.0
36	3	1126.749	21.447	19.107	0.0
36	4	3599.619	7.126	5.888	0.0
36	5	926.490	30.444	25.882	0.650
36	6	1401.321	24.258	22.272	0.0
36	7	1163.552	30.749	27.146	0.0
36	8	909.864	45.893	37.173	0.0

TIME= 37.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
37	1	4306.527	5.016	4.770	0.0
37	2	2064.348	10.817	9.789	0.0
37	3	1109.184	21.048	19.074	0.0

37	4	3549.823	6.892	5.873	0.0
37	5	910.545	29.562	25.849	0.650
37	6	1366.313	23.501	22.246	0.0
37	7	1135.862	29.544	27.099	0.0
37	8	893.392	44.491	37.130	0.0

TIME= 38.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
38	1	4306.527	5.016	4.770	0.0
38	2	2049.637	10.656	9.776	0.0
38	3	1095.029	20.737	19.049	0.0
38	4	3510.413	6.717	5.861	0.0
38	5	894.315	28.715	25.816	0.650
38	6	1335.591	22.875	22.224	0.0
38	7	1111.693	28.566	27.061	0.0
38	8	875.203	43.040	37.086	0.0

TIME= 39.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
39	1	4306.527	5.016	4.770	0.0
39	2	2044.677	10.603	9.772	0.0
39	3	1082.617	20.472	19.027	0.0
39	4	3479.066	6.584	5.852	0.0
39	5	879.632	27.990	25.788	0.650
39	6	1306.884	22.319	22.204	0.0
39	7	1090.272	27.752	27.029	0.0
39	8	856.649	41.653	37.044	0.0

TIME= 40.00HOURS

TIME STEP	GRID	VELOCITY (M/HR.)	AREA (SQ. M.)	WIDTH (METERS)	TRIB. (CU.M./S.)
40	1	4306.527	5.016	4.770	0.0
40	2	2043.026	10.585	9.771	0.0
40	3	1075.549	20.324	19.015	0.0
40	4	3448.434	6.459	5.844	0.0
40	5	867.078	27.398	25.765	0.650
40	6	1285.976	21.834	18.879	0.0
40	7	1069.809	27.017	27.001	0.0
40	8	838.503	40.381	37.005	0.0

ATTACHMENT F

Conservative Transport in Unsteady Flow

```
      C****************************1-D  TRANSPORT MODEL****************
      C***************CONSERVATIVE TRANSPORT IN UNSTEADY FLOW*****************
      C                                            ********
      C     DEFINITIONS
      C
      C     PXU,PXD,PX(K)= POSITION OF LAGRANGIAN PARTICLE (U/S,D/S,
      C          PARCEL K) IN EULERIAN GRID UNITS
      C     PTU,PTD,PT(K)= CONCENTRATION OF LAGRANGIAN PARCEL
      C     PVU,PVD,PV(K)= VOLUME OF LAGRANGIAN PARCEL
      C     PHU,PHD,PH(K)= TIME THE PARCEL ENTERED THE SYSTEM
      C     PTRU,PTRD,PTR(K)= CHANGE IN CONCENTRATION DUE
      C          TO TRIBUTARY INFLOW
      C     PTIU,PTID,PTI(K)=CONCENTRATION OF PARCEL AS IT ENTERED THE SYSTEM
      C     PDFU,PDFD,PDF(K)=CHANGE IN PARCEL CONCENTRATION DUE TO DISPERSION
      C     FLOW(L,I)= FLOW FIELD INFORMATION L AT EULERIAN GRID I
      C              L=1 FOR FLOW VELOCITY IN METERS/HOUR
      C              L=2 FOR FLOW AREA IN SQUARE METERS
      C              L=3 FOR TOP WIDTH IN METERS
      C              L=4 FOR TRIBUTARY INFLOW IN CU METERS/SECOND
      C     U(I)= AVERAGE VELOCITY IN SUBREACH I IN METERS / HOUR
      C     A(I)=AVERAGE AREA IN SUBREACH , IN SQUARE METERS
      C     X(I)= X COORDINATE OF EULERIAN GRID I IN RIVER MILES
      C     DX(I)= DISTANCE BETWEEN GRID I AND I+1
      C     DQQ(I)= DISPERSION FACTOR (DISP/(U*U*DT))
      C     DQ(K)= FLOWRATE BETWEEN PARCEL K AND K+1 DUE TO VELOCITY GRADIENTS
      C     DF(K)=CONCENTRATION CHANGE OF PARCLE K DURING DT DUE TO DISPERSION
      C     TUP= OBSERVED CONCENTRATION AT UPSTREAM END OF REACH
      C     QT(I)= TRIBUTARY INFLOW IN CUBIC METERS PER SECOND AT GRID I
      C     TRIB(I)= OBSERVED CONCENTRATION OF TRIBUTARY INFLOW AT GRID I
      C     Q = DISCHARGE AT UPSTREAM END IN CUBIC METERS PER SECOND
      C     DT= TIME STEP SIZE (IN HOURS)
      C     PDX= PART OF EULERIAN SUBREACH REMAINING TO BE TRAVERSED
      C     PDT= TIME REQUIRED TO TRAVERSE THE REMAINING PART OF THE SUBREACH
      C     RDT= TIME REMAINING FOR MOVEMENT
      C     NXSEC= NUMBER OF EULERIAN GRIDS
      C     INX= NXSEC-1
      C     NS= NUMBER OF PARCLES IN THE SYSTEM
      C     LNS= NS-1
      C     LP= LAST PARCLE TO STAY IN THE SYSTEM AT D/S END
      C     MX= GRID U/S OF PARCLE
      C     IGT(N)= GRID NUMBER FOR TRIBUTARY INFLOW
      C     NPT(I)= NUMBER OF PARCELS TO PASS GRID IGT(N) DURING DT
      C     KPG(N,M)= PARCEL NUMBER OF PARCEL TO PASS GRID IGT(N) DURING DT
      C     NHR= NUMBER OF TIME STEPS
      C     NTRIB= NUMBER OF ACTUAL TRIBUTARIES
      C     IGO= GRID NUMBER WHERE OUTPUT IS DESIRED
      C     IOUT= NUMBER OF TIME STEPS BETWEEN OUTPUT LISTINGS
      C     JTS= NUMBER OF TIME STEPS FROM MIDNIGHT TO TIME ZERO IN MODEL
      C      TITLE(20)= TITLE OF PROGRAM,80 CHARACTERS MAX.
      C
      C  PRELIMINARIES (STATEMENTS 0001-0025, LABEL STATEMENTS 20-39)
      C
0001        DIMENSION PX(500),PV(500),PT(500),PH(500),PTR(500),PTI(500)
0002        DIMENSION  DX(50),U(50),A(50),FLOW(4,50),W(50)
0003        DIMENSION DQQ(50),QT(50),TRIB(50),IGT(50),KPG(20,50),NPT(50)
0004        DIMENSION PDF(500),DQ(500),DF(500),TITLE(20)
0005        DOUBLE PRECISION X(51)
      C
```

```
                  C      MAXIMUM VALUE OF NXSEC IS 50
                  C
                  C      STEP 5 TO 24 ARE TO ZERO ARRAYS.
0006                     DO 4 K=1,500
0007                     PX(K)= 0.0
0008                     PT(K)= 0.0
0009                     PV(K)= 0.0
0010                     PH(K)= 0.0
0011                     PTR(K)= 0.0
0012                     PDF(K)= 0.0
0013                     PTI(K)= 0.0
0014                     DQ(K)= 0.0
0015                   4 DF(K)= 0.0
0016                     DO 5 I=1,50
0017                     X(I)= 0.0
0018                     DQQ(I)= 0.0
0019                     QT(I)= 0.0
0020                     FLOW(4,I)=0.0
0021                     TRIB(I)= 0.0
0022                     IGT(I)= 0.0
0023                     DX(I)= 0.0
0024                     U(I)= 0.0
0025                   5 A(I)= 0.0
                  C
                  C      READ INPUT (STATEMENTS 0026-0046)********************************
                  C
0026                     READ(5,1000)(TITLE(K),K=1,20)
0027                1000 FORMAT(20A4)
0028                     WRITE(6,3003) (TITLE(K),K=1,20)
0029                3003 FORMAT(1H1,20X,20A4)
0030                     WRITE(6,3002)
0031                3002 FORMAT (//)
0032                     READ(5,1005) NXSEC,NHR,DT,Q,IGO,IOUT,NTRIB,JTS
0033                1005 FORMAT(2I5,2F10.2,4I5)
0034                     READ(5,1006) (X(I),I=1,NXSEC)
0035                1006 FORMAT(10X,10F7.3)
0036                     READ(5,1006)(FLOW(2,I),I=1,NXSEC)
0037                     IF (NTRIB.EQ.0) GO TO 8
0038                     DO 7 N=1,NTRIB
0039                     READ(5,1010) IGT(N),QTT
0040                1010 FORMAT(10X,I7,F7.2)
0041                     I= IGT(N)
0042                   7 FLOW(4,I)=QTT
0043                   8 READ(5,1006) (DQQ(I),I=1,NXSEC)
0044                     READ(5,1006) (PT(I),I=1,NXSEC)
0045                     WRITE(6,3005) NHR,DT,NXSEC,Q,IGO,NXSEC,IOUT
0046                3005 FORMAT(' MODEL IS TO RUN',I5,' TIME STEPS EACH',F10.2,' HOURS LONG
                        1. THE RIVER IS DISCRETIZED BY',I5,' GRID POINTS.',/,' THE INITIAL
                        2UPSTREAM DISCHARGE IS CONSTANT AT',F10.2,' CUBIC METERS PER SECOND
                        3.',/,' THE PRINTOUT WILL BE GIVEN FOR GRIDS',I5,' AND',I5,' FOR
                        4EACH',I5,' TIME STEPS.')
                  C
                  C      PROCESS INPUT DATA (STATEMENTS 0047-0082)***********************
                  C
0047                     XUP=X(1)
0048                     X(NXSEC+1)=X(NXSEC)
0049                     DO 1 I=1,NXSEC
0050                     DX(I)=(X(I)-X(I+1))*1609.34
```

```
0051              X(I)=(XUP-X(I))*1609.34
0052              PX(I)=FLOAT(I)
0053              PH(I)= FLOAT(JTS)*DT
0054              PTI(I)=PT(I)
0055              PDF(I)= 0.0
0056              PTR(I)= 0.0
0057              FLOW(1,I)=3500.0*Q/FLOW(2,I)
0058              Q= Q+FLOW(4,I)
0059            1 CONTINUE
0060              READ(55,6500)   ((FLOW(K,I),K=1,4),I=1,NXSEC)
0061         6500 FORMAT(8F10.3)
0062              INX=NXSEC-1
0063              PV(1)= FLOW(2,1)*(DX(1)+DT*FLOW(1,1))/2.0
0064              DO 3 I=1,INX
0065              U(I)=(FLOW(1,I)+FLOW(1,I+1))/2.0
0066              A(I)=(FLOW(2,I)+FLOW(2,I+1))/2.0
0067              QT(I)=FLOW(4,I)
0068            3 PV(I+1)= FLOW(2,I+1)*(DX(I)+DX(I+1))/2.0
0069              PV(NXSEC)= FLOW(2,NXSEC)*(DX(INX))/2.0
0070              NS=NXSEC
0071              WRITE(6,3002)
0072              WRITE (6,3004)
0073         3004 FORMAT(1H0,50X,'INITIAL  CONDITIONS')
0074              WRITE(6,3002)
0075              WRITE(6,3010)
0076         3010 FORMAT(3X,'GRID  RIVER  VELOCITY    AREA    TRIB. FLOW  DISP FACT
                 1   INITIAL',/,10X,'MILE      M/HR   SQ METERS  CU M/SEC',6X,'DQQ',
                 28X,'CONC')
0077              DO 9 I=1,NS
0078              RM=XUP-X(I)/1609.34
0079              WRITE(6,3011) I,RM,FLOW(1,I),FLOW(2,I),QT(I),PT(I)
0080         3011 FORMAT(4X,I2,1X,F7.3,3X,F7.0,3X,F8.1,2X,F9.2,14X,F7.2)
0081              IF(I.LT.NS) WRITE(6,3007) DQQ(I)
0082         3007 FORMAT(50X,F5.2)
0083            9 CONTINUE
0084              WRITE(6,3002)
            C
            C     START TIME LOOP ***************************************************
            C
0085              DO 2 J=1,NHR
            C
            C      COMPUTE REACH AVERAGE FLOW(STATEMENTS 0085-0095)
            C
0086              DO 14 I=1,INX
0087              U(I)=FLOW(1,I)+FLOW(1,I+1)
0088              A(I)=FLOW(2,I)+FLOW(2,I+1)
0089              QT(I)=FLOW(4,I)
0090           14 CONTINUE
0091              READ(55,6500)   ((FLOW(K,I),K=1,4),I=1,NXSEC)
0092              DO12 I=1,INX
0093               U(I)=(U(I)+FLOW(1,I)+FLOW(1,I+1))*0.25
0094              A(I)=(A(I)+FLOW(2,I)+FLOW(2,I+1))*0.25
0095              QT(I)=(QT(I)+FLOW(4,I))*0.5
0096           12 CONTINUE
            C
            C
            C     COMPUTE DISPERSION FLUXES (STATEMENTS 0097-0120, LABEL
            C           STATEMENTS 80-99)*******************************************
```

```
                C
                C     COMPUTE DISPERSIVE Q'S
0097                  LNS=NS-1
0098                  DO 80 K=1,LNS
0099                  IX=(PX(K)+PX(K+1))/2.0
0100               80 DQ(K)=ABS(DQQ(IX)*J(IX)*A(IX))
                C     SET DQ=0 AT TRIBUTARY
0101                  K=0
0102                  DO 85 N=1,NTRIB
0103                  XR=IGT(N)
0104               81 K=K+1
0105                  IF(PX(K).LT.XR) GO TO 81
0106                  K= K-1
0107               85 DQ(K)= 0.0
                C     LIMIT DQ TO FORCE STABILITY
0108                  DO 82 K=1,NS
0109                  IF(K.EQ.1) GO TO 83
0110                  RATIO=DQ(K-1)*DT/PV(K)
0111                  IF(RATIO.GT.0.35) DQ(K-1)=0.35*PV(K)/DT
0112                  IF(K.EQ.NS) GO TO 82
0113               83 RATIO=DQ(K)*DT/PV(K)
0114                  IF(RATIO.GT.0.35) DQ(K)=0.35*PV(K)/DT
0115               82 CONTINUE
                C     IF(J.LT.5)WRITE(6,3000) (DQ(K),K=1,LNS)
                C     DISPERSE HEAT
0116                  DF(1)=DQ(1)*(PT(2)-PT(1))*DT/PV(1)
0117                  DO 84 K=2,LNS
0118                  DF(K)=(DQ(K-1)*(PT(K-1)-PT(K))+DQ(K)*(PT(K+1)-PT(K)))*DT/PV(K)
0119               84 IF(ABS(DF(K)).LT.1.0E-6) DF(K)=0.0
0120                  DF(NS)=DQ(NS-1)*(PT(NS-1)-PT(NS))*DT/PV(NS)
                C     IF(J.LT.5) WRITE(6,3000) (DF(K),K=1,NS)
                C
                C     SET UPSTREAM BOUNDRY (STATEMENTS 0121-0128, LABEL STATEMENTS
                C             40-59)*******************************************************
                C
                C     READ BOUNDARY CONDITIONS
0121                  READ(5,1006) TUP,(TRIB(IGT(N)),N=1,NTRIB)
0122                  PXU=1.0
0123                  PTU=TUP
0124                  PVU= FLOW(1,1)*FLOW(2,1)*DT
0125                  PHU= DT*FLOAT(J+JTS)
0126                  PTRU= 0.0
0127                  PTIU=TUP
0128                  PDFU=0.0
                C     IF(J.LT.7) WRITE(6,3000) PXU,PTU,PVU,PHU,PTRU
                C
                C     SET D/S BOUNDARY (STATEMENTS 0129-0155, LABEL STATEMENTS 60-79)
                C
0129                  MX=NXSEC-1
0130                  RDT=DT
0131               60 PDT=DX(MX)/J(MX)
0132                  IF(PDT.GE.RDT)GO TO 61
0133                  RDT=RDT-PDT
0134                  MX=MX-1
0135                  GO TO 60
0136               61 XP=FLOAT(MX)+1.0-RDT/PDT
                C     FIND PARCEL U/S OF XP
0137                  LP=NS-1
```

```
0138            62 IF(PX(LP).LT.XP)GO TO 63
0139               LP=LP-1
0140               GO TO 62
0141            63 NS=LP+2
0142               PX(NS)=FLOAT(NXSEC)
           C       FIND OLD CONCENTRATION OF PARCEL WHICH WILL FALL OUT
0143               MX=IFIX(XP)
0144               XP=X(MX)+DX(MX)*(XP-FLOAT(MX))
0145               MX=IFIX(PX(LP))
0146               XL=X(MX)+DX(MX)*(PX(LP)-FLOAT(MX))
0147               MX=IFIX(PX(LP+1))
0148               XR=X(MX)+DX(MX)*(PX(LP+1)-FLOAT(MX))
0149               COF=(XP-XL)/(XR-XL)
0150               PT(NS)=(PT(LP)+DF(LP))*(1.0-COF)+(PT(LP+1)+DF(LP+1))*COF
0151               PV(NS)= 10.0
0152               PH(NS)= PH(LP)*(1.0-COF)+PH(LP+1)*COF
0153               PTR(NS)= PTR(LP)*(1.0-COF)+PTR(LP+1)*COF
0154               PTI(NS)=PTI(LP)*(1.0-COF)+PTI(LP+1)*COF
0155               PDF(NS)=(PDF(LP)+DF(LP))*(1.0-COF)+(PDF(LP+1)+DF(LP+1))*COF
           C       IF(J.LT.7)WRITE(6,3000) RDT,PDT,XP,XL,XR,COF,PT(NS),PH(NS),
           C      $PTR(NS),PDF(NS)
           C       IF(J.LT.7)WRITE(6,3001) LP,NS
           C
           C       MOVE INTERIOR PARCELS (STATEMENTS 0156-0183, LABEL STATEMENTS
           C               100-119)*************************************************
           C
           C
0156               LNS=NS-1
0157               DO 103 I=1,NXSEC
0158           103 NPT(I)= 0
0159               DO 100 KK=2,LNS
0160               K=LNS+2-KK
0161               KO=K-1
0162               XOLD=PX(KO)
0163               MX=IFIX(XOLD)
0164               RDT=DT
0165               PDX=FLOAT(MX+1)-PX(KO)
0166           102 PDT=PDX*DX(MX)/U(MX)
0167               IF(PDT.GE.RDT) GO TO 101
           C      PASSED GRID
0168               RDT=RDT-PDT
0169               MX=MX+1
0170               XOLD=FLOAT(MX)
0171               PDX=1.0
0172               NPT(MX)= NPT(MX)+1
0173               KPG(NPT(MX),MX)=K
0174               GO TO 102
0175           101 CONTINUE
           C      STOPPED IN SUBREACH
0176               PX(K)=XOLD+RDT*U(MX)/DX(MX)
0177               PT(K)=PT(KO)+DF(KO)
0178               PV(K)=PV(KO)
0179               PH(K)=PH(KO)
0180               PTR(K)=PTR(KO)
0181               PTI(K)=PTI(KO)
0182               PDF(K)=PDF(KO)+DF(KO)
           C       IF(J.LT.7) WRITE(6,3001) K,KO,MX,(NPT(I),I=1,NXSEC)
0183          3001 FORMAT(' ',12I10)
```

```
                C      IF(J.LT.7)WRITE(6,3000) XOLD,RDT,PDT,PDX,PX(K),PT(K),PV(K),PH(K),PTR(K)
0184              100 CONTINUE
                C
                C      TRANSFER BOUNDARY CONDITIONS TO PARCEL CHARACTERISTICS(STATEMENTS
                C              0185-0191
                C
0185                   PX(1)=PXU
0186                   PT(1)=PTU
0187                   PV(1)=PVU
0188                   PH(1)=PHU
0189                   PTR(1)=PTRU
0190                   PTI(1)=PTIU
0191                   PDF(1)=PDFU
                C
                C      DILUTE FOR TRIBUTARY INFLOW (STATEMENTS 0192-0227, LABEL
                C             STATEMENTS 120-129)*****************************************
                C
0192                   IF(NTRIB.EQ.0) GO TO 123
0193                   K=0
0194                   DO 123 N=1,NTRIB
0195                   I= IGT(N)
                C      IF(J.LT.7) WRITE(6,3001)K,N,NTRIB,IGT(N),I,NPT(I)
0196                   IF(NPT(I).EQ.0)GO TO 120
0197                   VOL=0.0
0198                   M=NPT(I)
0199                   DO 121 K=1,M
0200                   KK=KPG(K,I)
0201              121 VOL=VOL+PV(KK)
0202                   DO 122 K=1,M
0203                   KK=KPG(K,I)
0204                   COF=PV(KK)/VOL
0205                   DEL=(TRIB(I)*COF*QT(I)*3600.0*DT+PT(KK)*PV(KK))/(PV(KK)+QT(I)
                      $*3600.0*COF*DT)-PT(KK)
0206                   IF(QT(I).LE.0.0)DEL=0.0
0207                   PT(KK)=PT(KK)+DEL
0208                   PTR(KK)=PTR(KK)+DEL
0209                   PV(KK)=PV(KK)+COF*QT(I)*DT*3600.0
                C      IF(J.LT.10)WRITE(6,3000)VOL,COF,PT(KK),PTR(KK),PV(KK),DEL
                C      IF(J.LT.10) WRITE(6,3001)K,KK
0210              122 CONTINUE
0211                   GO TO 123
0212              120 CONTINUE
                C
                C      FIND NEAREST PARCEL
                C
0213              124 K=K+1
0214                   IF(PX(K).LT.FLOAT(I))GO TO 124
0215                   MX=IFIX(PX(K))
0216                   XR=X(MX)+(PX(K)-FLOAT(MX))*DX(MX)-X(I)
0217                   K=K-1
0218                   MX=IFIX(PX(K))
0219                   XL=X(I)-X(MX)-(PX(K)-FLOAT(MX))*DX(MX)
0220                   IF(XR.LT.XL)K=K+1
0221                   DEL=(TRIB(I)*QT(I)*3600.0*DT+PT(K)*PV(K))/(PV(K)+QT(I)*3600.0*DT)
                      $-PT(K)
0222                   IF(QT(I).LE.0.0)DEL=0.0
0223                   PT(K)=PT(K)+DEL
0224                   PTR(K)=PTR(K)+DEL
```

```
0225                PV(K)=PV(K)+QT(I)*DT*3600.0
             C      IF(J.LT.10) WRITE(6,3000)XR,XL,PT(K),PV(K),PTR(K),DEL
             C      IF(J.LT.10) WRITE(6,3001)K,MX,I
0226                K= K-1
0227            123 CONTINUE
             C
             C      FIND CONCENTRATIONS AT IGO (STATEMENTS 0228-0241, LABEL
             C              STATEMENTS 130-139)*****************************************
             C
0228                TIME= FLOAT(J+JTS)*DT
0229                K= 0
0230            130 K= K+1
0231                IF(PX(K).LE.FLOAT(IGO)) GO TO 130
0232                IX= IFIX(PX(K))
0233                XR= X(IX)+DX(IX)*(PX(K)-FLOAT(IX))-X(IGO)
0234                IX= IFIX(PX(K-1))
0235                XL= X(IGO)-X(IX)-DX(IX)*(PX(K-1)-FLOAT(IX))
0236                COF= XL/(XL+XR)
0237                CIGO= PT(K-1)+COF*(PT(K)-PT(K-1))
0238                CIIGO= PTI(K-1)+COF*(PTI(K)-PTI(K-1))
0239                CDIGO= PDF(K-1)+COF*(PDF(K)-PDF(K-1))
0240                CTIGO= PTR(K-1)+COF*(PTR(K)-PTR(K-1))
0241                TTIGO= TIME            -PH(K-1)-COF*(PH(K)-PH(K-1))
             C
             C      WRITE RESULTS (STATEMENTS 0242-0253, LABEL STATEMENTS 140-149)
             C
0242                IF(J.EQ.1)WRITE(6,2000) IGO,NXSEC
0243                IF(MOD(J,IOUT).EQ.0) GO TO 140
0244                GO TO 2
0245            140 IC=J/IOUT
0246                IF(MOD(IC,50).EQ.0) WRITE(6,2000) IGO,NXSEC
0247           2000 FORMAT(6X,'TIME',7X,'CONC AT',3X,'TRAVEL  PARCEL',3X,'CHANGE IN PA
               1RCEL',16X,'CONC AT',3X,'TRAVEL  PARCEL   CHANGE IN PARCEL',/,5X,'D
               2AY HOUR',6X,'GRID',5X,'TIME',3X,'CONC AT',4X,'CONC DUE TO',21X,'GR
               3ID',5X,'TIME   CONC AT',4X,'CONC DUE TO',/,16X,I5,7X,'HOUR',4X,
               4'ENTRY',6X,'DISP',5X,'TRIB',16X,I4,7X,'HOUR',4X,'ENTRY',6X,
               5'DISP',5X,'TRIB')
0248                IDAY= (TIME/24.0)+1
0249                HR= TIME-FLOAT(IDAY-1)*24.0
0250                TT= TIME-PH(NS)
0251                WRITE(6,2001)IDAY,HR,CIGO,TTIGO,CIIGO,CDIGO,CTIGO,PT(NS),TT,
               *PTI(NS),PDF(NS),PTR(NS)
0252           2001 FORMAT(5X,I2,1X,F5.2,4X,F7.2,F7.2,2X,F7.2,2X,F7.2,3X,F7.2,2X,F7.2,15X,
               $F7.2,2X,F7.2,2X,F7.2,3X,F7.2,2X,F7.2)
0253           3000 FORMAT(' ',10E12.5)
0254              2 CONTINUE
0255                END
```

Output of

Conservative Transport in Unsteady Flow

MODEL DOCUMENTATION FOR A CONSERVATIVE SUBSTANCE IN UNSTEADY FLOW

MODEL IS TO RUN 40 TIME STEPS EACH 1.00 HOURS LONG. THE RIVER IS DISCRETIZED BY 8 GRID POINTS.
THE INITIAL UPSTREAM DISCHARGE IS CONSTANT AT 12.00 CUBIC METERS PER SECOND.
THE PRINTOUT WILL BE GIVEN FOR GRIDS 5 AND 8 FOR EACH 1 TIME STEPS.

INITIAL CONDITIONS

GRID	RIVER MILE	VELOCITY M/HR	AREA SQ METERS	TRIB. FLOW CU M/SEC	DISP FACT DQN	INITIAL CONC
1	360.000	4307.	5.0	0.0		0.0
					0.05	
2	357.180	2042.	10.6	0.0		0.0
					0.05	
3	355.150	1059.	20.2	0.0		0.0
					0.05	
4	353.410	3414.	5.3	0.0		0.0
					0.05	
5	351.610	833.	25.9	0.55		0.0
					0.05	
6	349.780	1201.	19.9	0.0		0.0
					0.05	
7	347.360	1000.	23.9	0.0		0.0
					0.05	
8	345.210	726.	32.9	0.0		0.0

TIME DAY	TIME HOUR	CONC AT GRID 5	TRAVEL TIME HOUR	PARCEL CONC AT ENTRY	CHANGE IN PARCEL CONC DUE TO DISP	CHANGE IN PARCEL CONC DUE TO TRIB	CONC AT GRID 8	TRAVEL TIME HOUR	PARCEL CONC AT ENTRY	CHANGE IN PARCEL CONC DUE TO DISP	CHANGE IN PARCEL CONC DUE TO TRIB
1	5.00	0.0	1.00	0.0	0.0	0.0	0.0	1.00	0.0	0.0	0.0
1	6.00	0.0	2.00	0.0	0.0	0.0	0.0	2.00	0.0	0.0	0.0
1	7.00	0.0	3.00	0.0	0.0	0.0	0.0	3.00	0.0	0.0	0.0
1	8.00	0.0	4.00	0.0	0.0	0.0	0.0	4.00	0.0	0.0	0.0
1	9.00	0.0	5.00	0.0	0.0	0.0	0.0	5.00	0.0	0.0	0.0
1	10.00	0.01	6.00	0.0	0.01	0.0	0.0	6.00	0.0	0.0	0.0
1	11.00	0.07	7.00	0.0	0.07	0.0	0.0	7.00	0.0	0.0	0.0
1	12.00	1.10	8.00	0.0	0.25	0.85	0.00	8.00	0.0	0.00	0.0
1	13.00	3.25	9.00	0.0	1.23	2.01	0.00	9.00	0.0	0.00	0.0
1	14.00	17.55	9.45	16.57	-1.51	2.49	0.00	10.00	0.0	0.00	0.0
1	15.00	30.03	4.57	30.00	-0.00	0.03	0.02	11.00	0.0	0.02	0.0
1	16.00	30.04	4.06	30.00	-0.00	0.04	0.64	12.00	0.0	0.64	0.0
1	17.00	28.27	4.28	30.00	-1.79	0.05	9.18	13.00	0.0	5.92	3.2
1	18.00	15.52	4.49	14.63	0.55	0.23	30.03	7.37	30.00	-0.00	0.0
1	19.00	4.72	4.77	0.0	4.18	0.54	29.50	5.92	30.00	-0.54	0.04
1	20.00	2.14	5.13	0.0	1.17	0.97	26.21	7.19	30.00	-3.85	0.0
1	21.00	1.25	5.45	0.0	0.38	0.87	16.76	7.54	16.22	0.32	0.21
1	22.00	1.95	5.75	0.0	1.24	0.72	6.43	7.94	0.0	6.01	0.4
1	23.00	5.44	5.99	0.43	4.30	0.71	3.04	8.38	0.0	2.23	0.8
2	0.0	17.41	6.15	25.33	-8.37	0.40	1.74	8.82	0.0	0.74	1.0
2	1.00	9.67	6.30	9.12	-0.16	0.70	1.65	9.23	0.0	0.85	0.8
2	2.00	3.95	6.47	0.0	2.99	0.95	3.83	9.56	0.0	3.12	0.7
2	3.00	1.75	6.54	0.0	0.58	1.08	8.29	9.85	4.59	3.04	0.6
2	4.00	1.50	6.81	0.0	0.14	1.37	15.28	10.09	27.16	-12.26	0.38
2	5.00	2.17	6.97	0.0	-0.07	2.24	9.35	10.33	9.97	-0.81	0.59
2	6.00	2.42	7.13	0.0	1.06	1.36	5.04	10.58	0.0	4.10	0.94
2	7.00	5.08	7.30	3.51	0.37	1.20	2.34	10.82	0.0	1.29	1.06
2	8.00	8.59	7.47	7.64	-0.17	1.12	1.64	11.05	0.0	0.49	1.15
2	9.00	12.40	7.55	11.73	-0.34	1.02	1.98	11.29	0.0	0.02	1.96
2	10.00	16.27	7.84	15.78	-0.41	0.89	2.54	11.52	0.0	0.76	1.78
2	11.00	20.24	8.02	19.88	-0.39	0.75	3.82	11.77	1.13	1.47	1.22
2	12.00	24.25	8.18	24.12	-0.43	0.55	6.41	12.03	4.86	0.39	1.18
2	13.00	27.58	8.33	28.37	-1.18	0.39	9.62	12.28	8.59	-0.06	1.10
2	14.00	29.50	8.49	30.00	-0.95	0.45	13.08	12.53	12.33	-0.24	1.00
2	15.00	30.13	8.57	30.00	-0.35	0.48	16.67	12.79	16.07	-0.28	0.88
2	16.00	29.55	8.88	29.88	-0.34	0.34	20.37	13.03	19.84	-0.22	0.75
2	17.00	29.02	9.09	29.09	-0.49	0.42	23.71	13.27	23.64	-0.51	0.58
2	18.00	27.13	9.28	27.20	-0.56	0.60	26.61	13.51	27.43	-1.25	0.42
2	19.00	24.22	9.48	23.88	-0.51	0.85	28.74	13.75	30.00	-1.64	0.38
2	20.00	20.51	9.58	19.39	-0.10	1.23	29.87	14.02	30.00	-0.68	0.55