US Army Corps
of Engineers
Hydrologic Engineering Center

Generalized Computer Program

WQRRS
Water Quality for River-Reservoir Systems

User's Manual

October 1978
Revised: December 1986

CPD-8

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
October 1978 revised: December 1986	Computer Program Documentation	

4. TITLE AND SUBTITLE	**5a. CONTRACT NUMBER**
WQRRS Water Quality for River-Reservoir Systems User's Manual	
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	**5d. PROJECT NUMBER**
CEIWR-HEC	**5e. TASK NUMBER**
	5F. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	**8. PERFORMING ORGANIZATION REPORT NUMBER**
US Army Corps of Engineers Institute for Water Resources Hydrologic Engineering Center (HEC) 609 Second Street Davis, CA 95616-4687	CPD-8
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	**10. SPONSOR/ MONITOR'S ACRONYM(S)**
	11. SPONSOR/ MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
User's manual for a computer program that provides a comprehensive water quality simulation model for rivers and reservoirs, WQRRS. The WQRRS computer program consists of three separate modules – the reservoir module, the stream hydraulic module, and the stream quality module. These three modules can be integrated for a complete river basin water quality analysis through automatic storage of results for input to downstream simulations.

15. SUBJECT TERMS
water quality, river, reservoir, ecological, simulation, estuaries, module, stream hydraulic, stream quality, downstream, basin, physical, chemical, biological, parameters, dynamic, flow, hydraulic, conditions, streamflow routing, St. Venant, kinematic wave, Muskingum, modified Puls, routing, branched, looped, biological, constituents, environments, input, output, inflow, tributary, geometric, meteorological, aerobic, impoundments, one-dimensional, isotherms, contours, long residence times, shallow impoundments, rapid flow-through time, mixed, gradually varied, steady, unsteady, peak flows, storm, runoff

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			
U	U	U	UU	380	**19b. TELEPHONE NUMBER**

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CPD-8

10 December 1984

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I. INTRODUCTION

BACKGROUND

A comprehensive ecological simulation model for reservoirs and estuaries was originally developed by Chen and Orlob under a Title II contract with the Office of Water Resources Research [1]. During this same period, the U.S. Army Corps of Engineers' Hydrologic Engineering Center (HEC) contracted with Water Resources Engineers (WRE) to combine the reservoir simulation model mentioned above and a river simulation model developed by Norton [2] to form a model capable of simulating the water quality within an entire basin and to apply the model to the Trinity River system in Texas [3]. This model was capable of analyzing 18 different physical, chemical, and biological water quality parameters in a river or reservoir or a river-reservoir system. A preprocessor was developed by the HEC to simplify preparation of input data and these two programs together were then called the "Water Quality for River-Reservoir Systems" (WQRRS) model [4].

The original river routines analyzed dynamic water quality conditions but were developed to handle only steady flow hydraulic conditions. In September 1974, the HEC contracted with Resource Management Associates to add streamflow routing capability to the WQRRS model [5]. This provided the model with a capability to dynamically route streamflows using either the St. Venant equations, Kinematic Wave, Muskingum, or Modified Puls routing methods. The capability of the model to analyze steady flow conditions was expanded to include both a backwater analysis and a stage-flow relationship specified by input data.

In 1976, the HEC contracted with the joint venture of Resource Management Associates and Tetra Tech, Inc. to add to WQRRS the capability of analyzing branched and looped stream systems and to add additional water quality and biological constituents to more adequately represent stream and reservoir environments [6,7].

With these latter modifications came new data requirements which were incompatible with the WQRRS preprocessor. In January 1978, the HEC contracted with Resources Management Associates to integrate the advantageous elements of the preprocessors into the simulation modules and expand and document their capabilities.

All of the above work was done under the direction of Mr. R. G. Willey of the HEC.

The basic structure and capabilities of the later versions of the WQRRS model is described below.

MODEL STRUCTURE

The WQRRS model consists of three separate but integrable modules; the reservoir module, the stream hydraulic module, and the stream quality module. The reservoir and stream hydraulics modules are stand-alone programs and may be executed, analyzed and interpreted independently. The stream quality module, however, has no hydraulic computation capability and requires a hydraulic data file which is generated by the stream hydraulics module. The three computer programs may also be integrated for a complete river basin water quality analysis through automatic storage of results for input to downstream simulations. The subsequent analysis may be a part of the same simulation or an entirely separate model execution. Input/output compatibility for downstream analysis is consistent among modules. Many subroutines are similar if not identical among the reservoir and stream modules.

An example of the downstream data saving technique would be to run the reservoir module and write an output discharge tape and an associated water quality tape. The reservoir discharge then serves as inflow tributary data to the stream hydraulics module which, along with additional tributary and geometric information, provide the necessary hydrologic data for the hydraulic computation program. The stream flow results are then saved for the stream quality module. The tape of reservoir discharge quality, the stream flow routing tape, the tributary inflow hydrographs and associated water quality, and other meteorological, biological and chemical data serve as input to the stream quality module.

The above procedure may also be executed in reverse order where the stream flow hydrograph and water quality information from the stream module are prepared and saved for input to the reservoir module.

The basin model has the flexibility to run one element at a time (i.e., individual reservoirs or stream reaches) during testing and calibration phases but to run entire stream or basin systems during later production phases.

An output plot tape may be generated upon demand by the specification and system definition of an auxiliary storage device. This tape has the potential for being used as an automatic input data set for an online pen plotting system such as CALCOMP or ZETA. This procedure has been successfully implemented and tested at HEC, but is not included as a part of this document except for the capability to generate the required tape. Information regarding this capability is available from the HEC.

GENERAL MODEL CAPABILITIES

Reservoir Module

The methodology in the reservoir section of the program is applicable to aerobic impoundments that can be represented as one-dimensional systems in which the isotherms, or indeed the contours of any parameter, are horizontal. This approximation is generally satisfactory in small to moderately large lakes or reservoirs with long residence times. The approximation may be less satisfactory in shallow impoundments or those that have a rapid flow-through time. Systems that have a rapid flow-through time are often fully mixed and can be treated as slowly moving streams using the stream section of the model. The reservoir is capable of simulating an unlimited number of days or years (the chief constraint is computer and data preparation time).

Stream Hydraulic Module

The methodology in this section of the basin model includes six hydraulic computation options. The stream flow module is capable of handling hydraulic behavior within both the "gradually varied" steady and unsteady flow regimes. Peak flows from storm water runoff or irregular hydropower releases can be represented in the stream hydraulic module. Capability also exists to simulate steady state hydraulics.

Stream Quality Module

In the stream quality module the rate of transport of quality parameters can be represented for aerobic streams, and peak pollutant loads into the steady or unsteady hydraulic environment can be simulated. A steady state stream water quality analysis can be simulated only through specification of inputs to be held constant over a long period of time.

Computer Requirements

The computer programs described in this manual are operational on the CDC 7600 and the UNIVAC 1108. Maximum storage required with the CDC 7600 is 50,000 words per module. The programs are written in FORTRAN IV and should require only minor modification, if any, to run on most high speed computers.

The computer time requirements are quite varied and are a function of the length of simulation, computational time steps per day, size and complexity of the modeled system, number of water quality constituents (quality modules) and the hydraulics computation method (stream hydraulics module).

Program input options allow the user to specify input-output unit numbers as described in Chapter VIII. In addition to these units, numbers 5, 6 and 7 are reserved for the card reader, line printer and card punch respectively.

II. REPRESENTATION OF PHYSICAL MASS TRANSPORT

RESERVOIR MODULE

The reservoir or lake is represented conceptually by a series of one dimensional horizontal slices such as those shown in Figure II-1. Each horizontal slice or layered volume element is characterized by an area, thickness and volume. In the aggregate the assemblage of layered volume elements is a geometric representation in discretized form of the prototype lake or reservoir.

Within each element, the water is assumed to be fully mixed. This implies that only the vertical dimension is retained during the computation. Each horizontal layer is assumed to be completely homogeneous with all isotherms parallel to the water surface both laterally and longitudinally. External inflows and withdrawals occur as sources or sinks within each layer and are instantaneously dispersed and homogeneously mixed throughout each element from the headwaters of the impoundment to the dam. It is not possible, therefore, to look at longitudinal variations in water quality constituents.

Internal transport of heat and mass occur only in the vertical direction. The internal transport is assumed to occur by advection and through an effective diffusion mechanism that combines the effects of molecular and turbulent diffusion and convective mixing. Although the diffusion gradient among layers is based on the concentration differences of the individual constituents, the effective diffusion coefficient is always based on temperature. This is important to remember since mass diffusion may not be equivalent to dispersion of thermal energy.

Model results are most representative of conditions in the main reservoir body. It may be difficult to draw conclusions expected to occur in

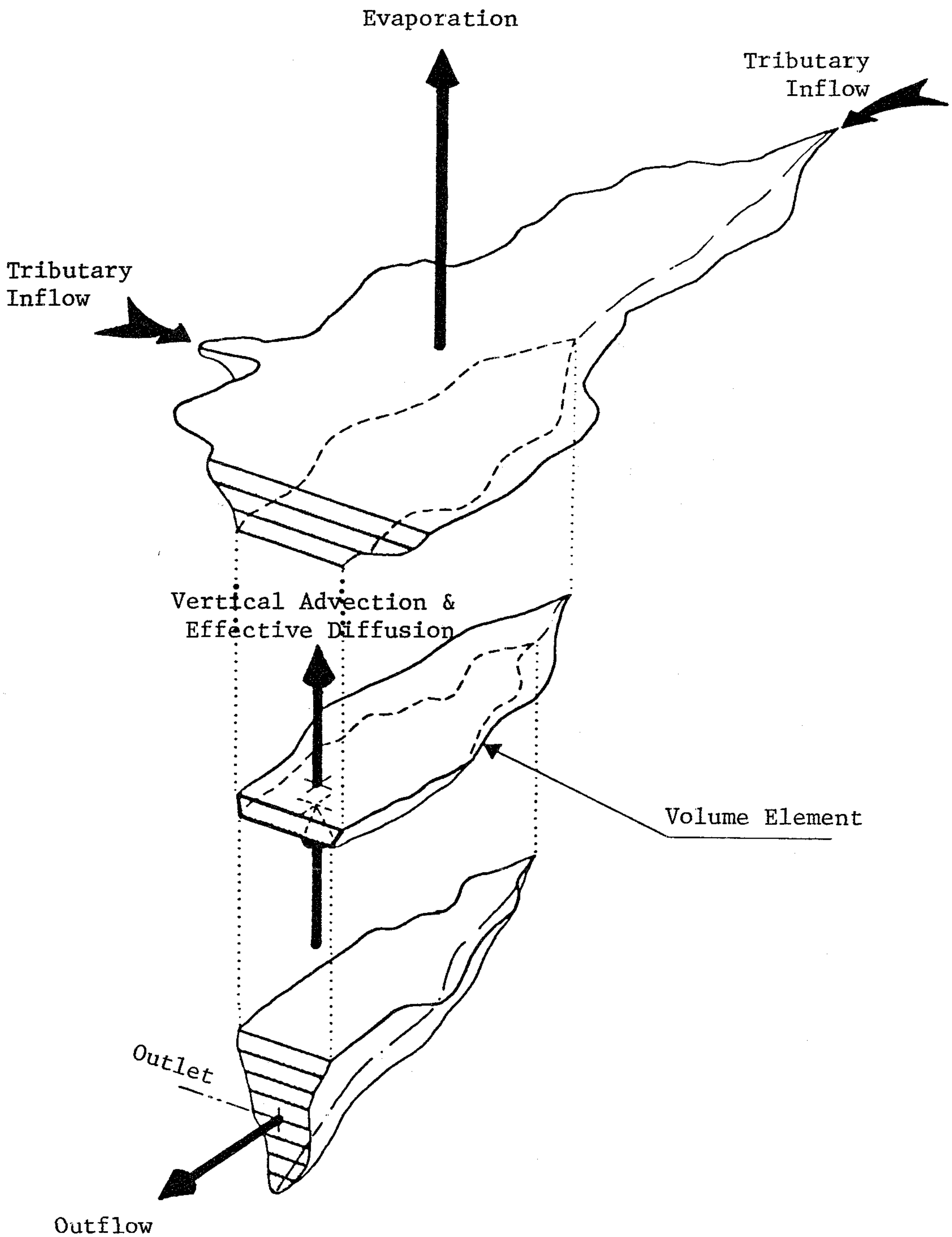


FIGURE II-1

Geometric Representation of a Stratified Reservoir
and Mass Transport Mechanisms

coves or the headwater area because of the one-dimensional horizontal considerations.

Representation of Flow (See pages 7A-7D)

The movement of water and hence advective effects is governed by the location of inflow to, and outflow from, the reservoir. Thus the computation of the zones of distribution and withdrawal for inflows and outflows are of considerable significance in operation of the model. Two options are available for determination of the allocation of outflow; the Debler-Craya method and the WES method. A modified Debler-Craya method is used exclusively for the placement of inflows.

Debler-Craya Withdrawal Allocation Method

The Debler-Craya withdrawal method employs two techniques for allocating the withdrawals through an outlet gate to the individual elements. When water is withdrawn from a level at which a negative density gradient exists (i.e., stratified zone), Debler's criteria [8] is used to determine the thickness of the flow field. The thickness of the flow field is defined by:

$$D = 2.88 \left(\frac{Q}{W}\sqrt{\frac{\rho}{g\beta}}\right)^{1/2} \qquad \text{II-1}$$

where
- D = thickness of the flow field in meters
- Q = withdrawal rate in m^3/sec
- W = effective width of reservoir at the withdrawal level in meters
- β = density gradient at the withdrawal location in kg/m^4
- g = acceleration due to gravity in m/sec^2
- ρ = water density at the outlet location in kg/m^3

Representation of Flow

The movement of water and hence advective effects is governed by the location of inflow to, and ouflow from, the reservoir. Therefore, the computation of the zones of distribution and withdrawal for inflows and ouflows are of considerable significance in operation of the model. Associated with the allocation of flow is the operation of the reservoir outlet structure.

Outlet Gate Selection

The withdrawal structure assumed in the model may include one or two wet wells, containing up to eight ports each, a flood control outlet, and an uncontrolled spillway which operates only when the total flow exceeds the combined capacity of the wet wells and flood control outlet. As an option, the gate of the outlet structure can be operated to meet downstream temperature and water quality objectives. With this selective withdrawal option only one port in each wet well and the flood control outlet is operated.

A port selection algorithm serves to determine which ports should be open and what flow rate should pass through each open port. Solution of this problem is accomplished by using mathematical optimization techniques developed by Poore and Loftis (7a). The optimization algorithm utilizes an objective function which is related to the departure from downstream target qualities subject to hydraulic constraints on the individual ports.

The algorithm proceeds by considering a sequence of problems representing all possible combinations of open ports. For each combination of open ports, a sequence of flow allocation strategies is generated using a gradient method, a gradient projection method, or a Newton projection method as appropriate. The value of any flow allocation strategy is determined by evaluation of a water quality index. The sequence converges to the optimal flow allocation strategy for the particular combination of open ports. The combination of open ports and flows with the highest water quality index (i.e., smallest departure from the objective) define the optimal operation strategy.

To evaluate the water quality index for a feasible flow allocation strategy, the release concentration for every water quality constituent is computed by:

7a. Poore, A. B. and B. Loftis, "Water Quality Optimization Through Selective Withdrawal," Technical Report E-83-9, Army Engineers Experiment Station, Corps of Engineers, Vicksburg, Mississippi, March, 1983.

$$R_c = \frac{\sum_{p=1}^{N_p} (\Phi_{cp}\ Q_p)}{\sum_{p=1}^{N_p} Q_p} \quad ; \qquad c = 1, N_c \qquad \text{II-a}$$

where R_c = release concentration for constituent c

c = index for constituents

p = index for open ports

N_p = number of open ports

Φ_{cp} = concentration of constituent c at port p

Q_p = flow rate through port p

N_c = number of constituents under consideration

The deviation of release qualities from downstream target qualities can be computed by:

$$D_c = R_c - T_c \quad ; \qquad c = 1, N_c \qquad \text{II-b}$$

where D_c = deviation of constituent c

T_c = downstream target quality for constituent c

The subindex S for each constituent can be determined by:

$$S_c = f(D_c) \quad ; \qquad c = 1, N_c \qquad \text{II-c}$$

Where the function f takes the form of the sixth order polynomial:

$$f(D_c) = a + bD_c + cD_c^{\,2} + dD_c^{\,3} + eD_c^{\,4} + fD_c^{\,5} \qquad \text{II-d}$$

In selecting these coefficients, the magnitude and importance of the water quality parameter should be considered. To aid in the coefficient selection process, Table 1, Figure 1a and the following discussion is provided.

Table 1. Typical Coefficients in Constituent Suboptimization Function

Curve Number	Coefficient					
	a*	b	c	d	e	f
1	100	0.0	- 0.1	0.0	0.000	0
2	100	0.0	- 2.0	0.0	0.000	0
3	100	0.0	-10.0	0.0	0.000	0
4	100	-3.2	- 0.7	-0.1	-0.005	0
5	100	3.2	- 0.7	0.1	-0.005	0

* a should always equal 100

Curves 1 through 3 are functions where equal weight is given to deviation on either side of the target concentration. Under normal conditions, this type of function should be used.

Curve number 1 would be used for a quality parameter such as TDS since wide variations from the target are normally allowable. For a parameter such as nitrate where the concentration is low, curve number 3 would be appropriate. Curve number 2 might be used for temperature or other parameters where the concentration range is 5 to 25.

Curves number 4 and 5 are functions where deviations about the target are not weighted equally. Curve number 4 could be used for a toxic parameter where the lowest discharge concentration would be desirable, conversely, curve 5 could be used for a parameter where a higher concentration is always desirable. Curve 5 might be appropriate for dissolved oxygen.

In summary, almost any shape of function can be developed (a curve fit routine will be very helpful) using the sixth order polynomial function. In developing these functions, the importance of the parameter and the normal anticipated concentration magnitude are the major considerations.

Only the water quality parameters that are of interest in the outflow need to be included and are usually a subset of the total number of parameters being modeled. Present program dimensions limit the number of parameters to 10.

Upon completion of the gate selection process, the flow must be allocated to the individual elements. Two options are available for allocation of outflow; the Debler-Craya method and the WES method. A modified Debler-Craya method is used exclusively for the placement of inflows.

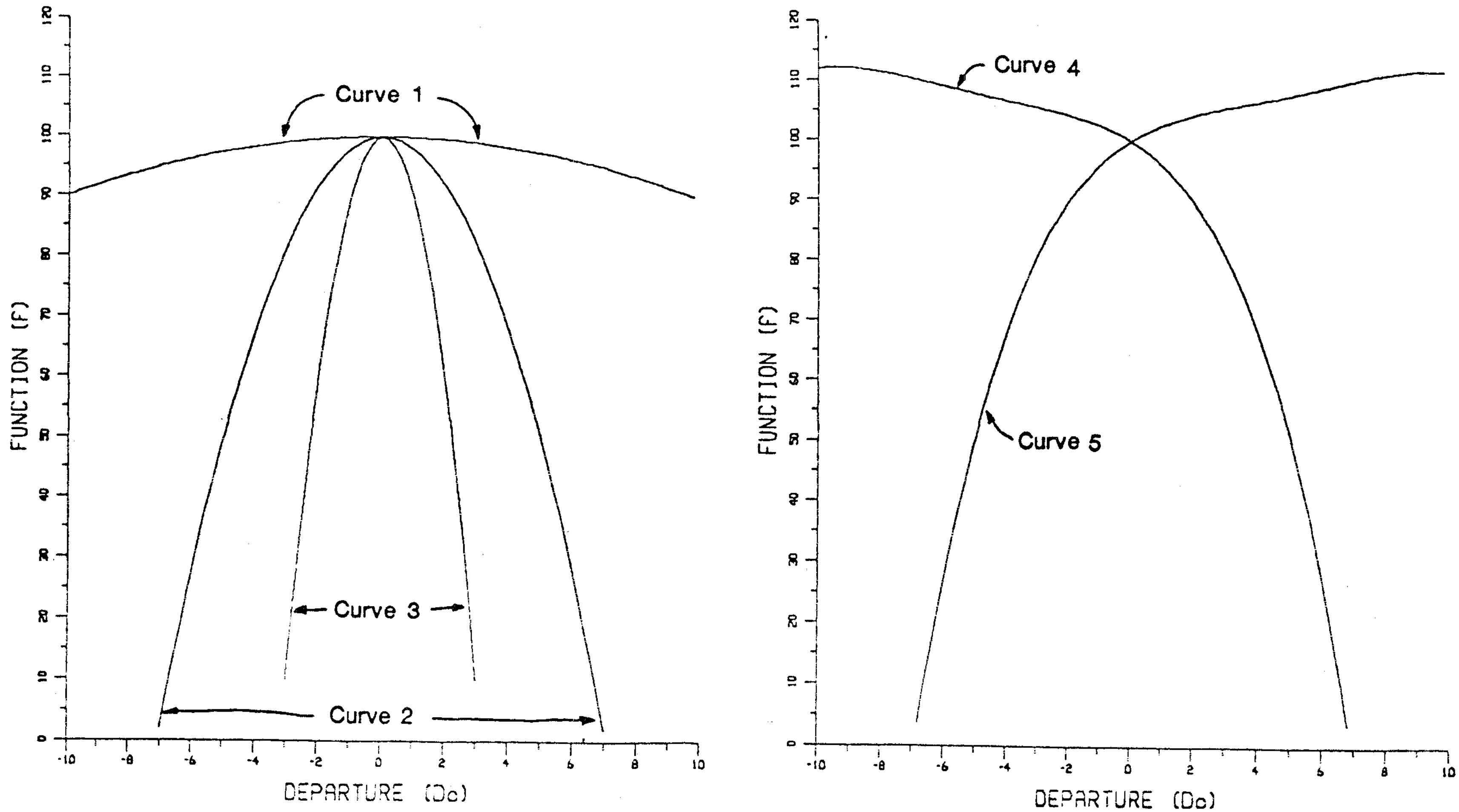


Figure 1a. Relationship Between the Deviation from the Release Target Quality and the Suboptimization Function for the Coefficients Presented in Table 1

The water density is calculated as a function of temperature and dissolved and inorganic suspended solids using the following empirical expression.

$$\rho = 1000 - [(T-3.98)^2 (T+283)/(503.57\ (T+67.26))] + .00062C_1 + .00124C_2 \qquad \text{II-2}$$

where T = water temperature in degrees celsius

C_1 = total dissolved solids concentration in mg/ℓ

C_2 = total suspended inorganic solids concentration in mg/ℓ

This expression was numerically derived from a curve fit of physical data.

The outflows are withdrawn from elements above and below the centerline of the outlet assuming a uniform velocity distribution within the flow field. If the zone of withdrawal extends above the water surface or below the reservoir bottom, the area above or below is ignored and the velocity increased proportionally.

When water is withdrawn from a level at which no density gradient exists (i.e., zone of convective mixing), the theory of Craya as reported by Yih [9] is used to determine the maximum amount of flow which will remain contained in the zone of convective mixing without encroaching into the stratified zone. This flow, referred to as Craya's critical flow, is defined by:

$$Q = C\ W\ D^{3/2}\ \Delta\rho^{1/2} \qquad \text{II-3}$$

where Q = Craya's critical flow or the maximum amount of flow which will remain contained in the zone of convective mixing in m^3/sec

C = empirical constant, $C = .074$ for withdrawal from the surface element and $C = .151$ for withdrawal from subsurface elements

W = effective width of the reservoir at the withdrawal level in meters

D = thickness of the zone of convective mixing in meters

$\Delta\rho$ = the maximum water density difference between the zone of convective mixing and the stratified zone in kg/m^3

If the rate of withdrawal is less than Craya's critical flow, the entire withdrawal is distributed throughout the zone of convective mixing, assuming a uniform velocity distribution. If the rate of withdrawal is greater than the maximum which can remain contained in the zone of convective mixing, the excess is withdrawn from the stratified zone using Debler's criteria.

WES Withdrawal Allocation Method

The outflow component of the model incorporates as an option the selective withdrawal techniques developed at the U.S. Army Engineer Waterways Experiment Station [10]. Laboratory investigations were conducted to determine the withdrawal zone characteristics created in a randomly density-stratified impoundment by releasing flow through a submerged orifice. From these investigations generalized relationships were developed for describing the vertical limits of the withdrawal zone and the vertical velocity distribution within the zone.

A definition sketch of variables for orifice flow is shown in Figure II-2. The following transcendental equation defines the zero velocity limits of the withdrawal zone.

$$V_o = \frac{Z^2}{A_o} \sqrt{\left(\frac{\Delta\rho'}{\rho_o}\right) g\, Z} \qquad \text{II-4}$$

where
- V_o = average velocity through the orifice in m/sec
- Z = vertical distance from the elevation of the orifice center line to the upper or lower limit of the zone of withdrawal in meters
- A_o = area of the orifice opening in m^2
- $\Delta\rho'$ = density difference of fluid between the elevations of the orifice center line and the upper or lower limit of the zone of withdrawal in kg/m^3
- ρ_o = fluid density of the elevation of the orifice center line in kg/m^3
- g = acceleration due to gravity in m/sec^2

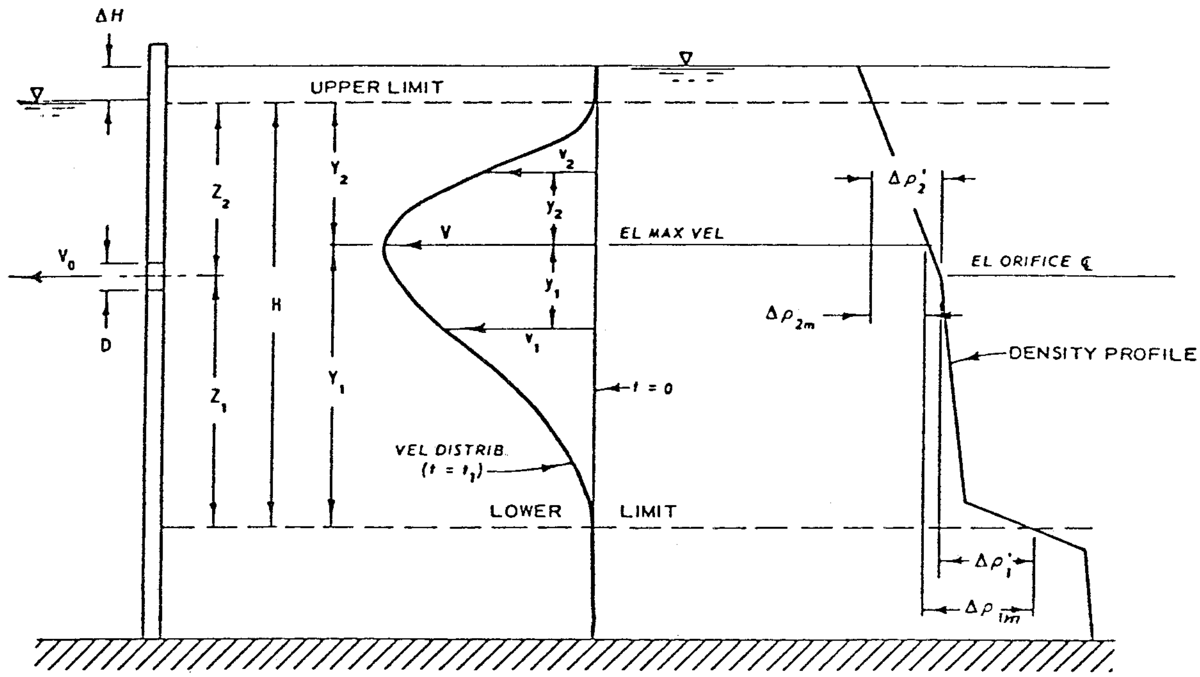


FIGURE II-2

Definition Sketch of Variables for Orifice Flow

With knowledge of the withdrawal limits, the velocity profile due to outflow can be determined. First, the location of the maximum velocity is determined by,

$$\frac{Y_1}{H} = [\sin (1.57 \frac{Z_1}{H})]^2 \qquad \text{II-5}$$

where Y_1 = vertical distance from the elevation of the maximum velocity V to the lower limit of the zone of withdrawal in meters

H = thickness of the withdrawal zone in meters

Z_1 = vertical distance from the elevation of the orifice center line to the lower limit of the zone of withdrawal in meters

The distribution of velocities within the withdrawal zone is then determined by,

$$\frac{v}{V} = (1 - \frac{y\Delta\rho}{Y\Delta\rho_m})^2 \qquad \text{II-6}$$

where v = local normalized velocity in the zone of withdrawal at a distance y from the elevation of the maximum velocity V

V = maximum velocity in the zone of withdrawal in m/sec

y = vertical distance from the elevation of the maximum velocity V to that of the corresponding local velocity v in meters

Y = vertical distance from the elevation of the maximum velocity V to the limit of the zone of withdrawal in meters

$\Delta\rho$ = density difference of fluid between the elevation of the maximum velocity V and the corresponding local velocity v in kg/m^3

$\Delta\rho_m$ = density difference of fluid between the elevation of the maximum velocity V and the limit of the zone of withdrawal in kg/m^3

This equation can be used to describe both the upper and lower sections of a velocity distribution using the elevation of the maximum velocity V as the reference elevation, except for conditions in which the withdrawal zone is limited by either the free surface or the bottom boundary. For conditions where the free surface and bottom boundary limit the withdrawal zone, the velocity distribution is computed by,

$$\frac{v}{V} = 1 - \left(\frac{y\Delta\rho}{Y\Delta\rho_m}\right)^2 \qquad \text{II-7}$$

For a situation in which only one limit (upper or lower) is affected by a boundary (free surface or bottom boundary), equation II-6 can be used to determine the velocity distribution from the elevation of maximum velocity V to the limit unaffected by a boundary, and equation II-7 can be used to determine the velocity distribution from the elevation of maximum velocity V to the limit affected by a boundary. The flow from each layer is then the product of the velocity in the layer, the width of the layer and the thickness of the layer. A flow-weighted average is applied to water quality profiles to determine the value of the release content of each constituent for each time step.

Allocation of Inflow

The allocation of inflows is based on the assumption that the inflow water will seek a level of like density within the lake. If the inflow water density is outside the range of densities found within the lake, the inflow is deposited at either the surface or the bottom depending on whether the inflow water density is less than the minimum or greater than the maximum water density found within the lake.

Once the entry level is established, allocation of the inflow to the individual elements may proceed. If the inflow enters a zone of convective mixing, the inflow is distributed throughout the convective mixed zone. If the inflow enters a stratified region of the lake, one of two user specified options is used to allocate the inflow.

The first option is analogous to the Debler-Craya withdrawal allocation method. Debler criterion is used to determine the thickness of the flow field resulting from the deposition of the inflow at the entry level. The water is deposited to the elements about the entry level assuming a uniform velocity distribution. With this application of Debler's criterion, the effective width of the flow field is defined as the reservoir area at the entry level divided by the effective reservoir length at the inflow location. This option should be used when the distance from the inflow location to the deepest part of the reservoir is not great.

The second option allows for flow entrainment into all elements down to the entry level as the inflow water travels along the reservoir bottom seeking the level of like density. The amount deposited to each element is proportional to the element size. This option should be used when several miles separate the inflow location from the deepest part of the reservoir.

Vertical Advection

Vertical advection is the net interelement flow and is one of two transport mechanisms used in the model to transport heat and dissolved or suspended materials between elements. The vertical advection is defined as the interelement flows which result in a continuity of flow in all elements. Beginning with the lowermost element, the vertical advection is calculated by algebraically summing the inflows and outflows. Any flow inbalance is made up by vertical advection into or out of the element above. This process is repeated for all remaining elements taking into account the vertical advection from or to the element below. Any resulting flow inbalance in the surface element is accounted for by an increase or decrease in the lake volume.

Effective Diffusion

Effective diffusion is the other transport mechanism used in the model to transport heat and mass between elements. The effective diffusion is composed of molecular and turbulent diffusion and convective mixing.

Wind and flow induced turbulent diffusion and convective mixing are the dominant components of effective diffusion in the epilimnion of most reservoirs. In quiescent well stratified reservoirs, molecular diffusion may be a significant component in the metalimnion and hypolimnion. For deep, well stratified reservoirs with significant inflows to or withdrawals from the hypolimnion, flow induced turbulance in the hypolimnion dominates. For weakly stratified reservoirs, wind induced or wind and flow induced turbulent diffusion will be the dominant component of the effective diffusion throughout the reservoir.

One of two methods may be selected by the user to calculate effective diffusion coefficients; the stability method and the wind method.

1. Stability Method

The stability method of computing the effective diffusion coefficients is appropriate for most deep, well stratified reservoirs and shallower reservoirs where wind mixing is not the dominant turbulent mixing force. This method is based on the assumption that mixing will be at a minimum when the density gradient or water column stability is at a maximum.

The relationship between stability and the effective diffusion is shown graphically in Figure II-3. This figure shows the range of effective diffusion coefficient reported by WRE [11] and were deduced from data collected in reservoirs of the Pacific Northwest. Effective diffusion coefficients for reservoirs in other regions may fall below the lower envelop of values shown on Figure II-3. The relationship between effective diffusion and stability is shown below.

$$D_c = A_1 \qquad \text{when } E \leq E_{crit} \qquad \text{II-8}$$

$$D_c = A_2 \, E^{A_3} \qquad \text{when } E > E_{crit} \qquad \text{II-9}$$

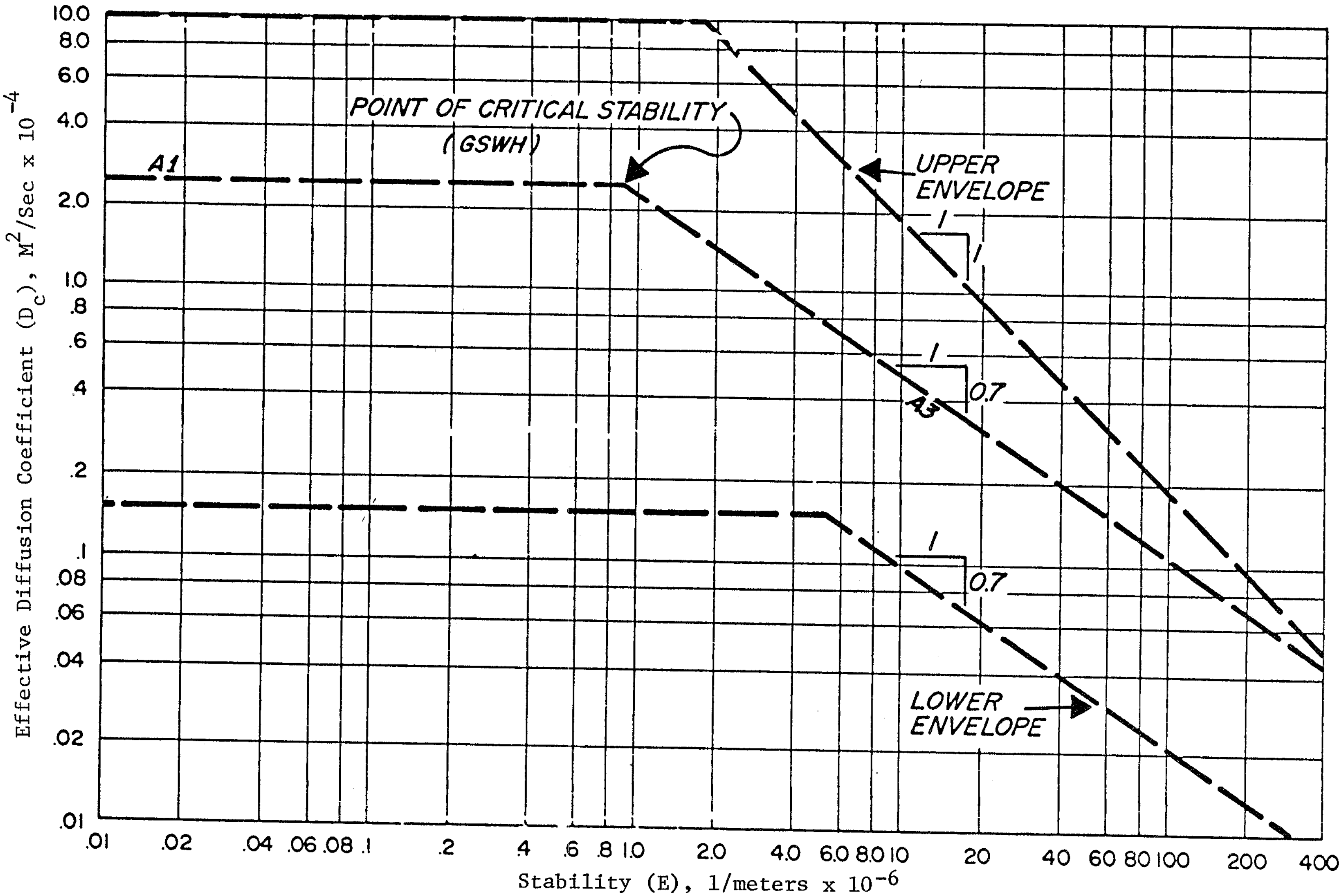


FIGURE II-3

Log of Effective Diffusion Versus Log of Density Gradient where D_c = effective diffusion coefficient in m^2/sec

A_1 = maximum effective diffusion coefficient in m^2/sec

$E = \frac{1}{\bar{\rho}} \cdot \frac{\partial \rho}{\partial z}$

E = water column stability or normalized density gradient in 1/meter

E_{crit} = water column critical stability in 1/meter

A_2, A_3 = empirical constants

A typical density profile one might find in a stratified reservoir along with the resulting effective diffusion coefficient distribution is shown in Figure II-4.

2. Wind Method

The wind method for computing effective diffusion coefficients is appropriate for reservoirs in which wind mixing appears to be the dominant component of turbulent diffusion. This method assumes that wind induced mixing is greater at the surface and diminishes exponentially with depth. The following empirical expression which is a combination of wind induced turbulent diffusion and a minimum diffusion term representing the combined effects of all other mixing phenomena is used to calculate the effective diffusion coefficient:

$$D_c = D_{min} + A_1 V_w e^{-kd} \qquad \text{II-10}$$

where D_{min} = minimum effective diffusion coefficient in m^2/sec

A_1 = empirical coefficient in meters

V_w = wind speed in m/sec

$k = A_2/d_t$

A_2 = empirical coefficient

d_t = depth of the thermocline in meters or six meters during unstratified conditions

d = depth of specific layer in meters

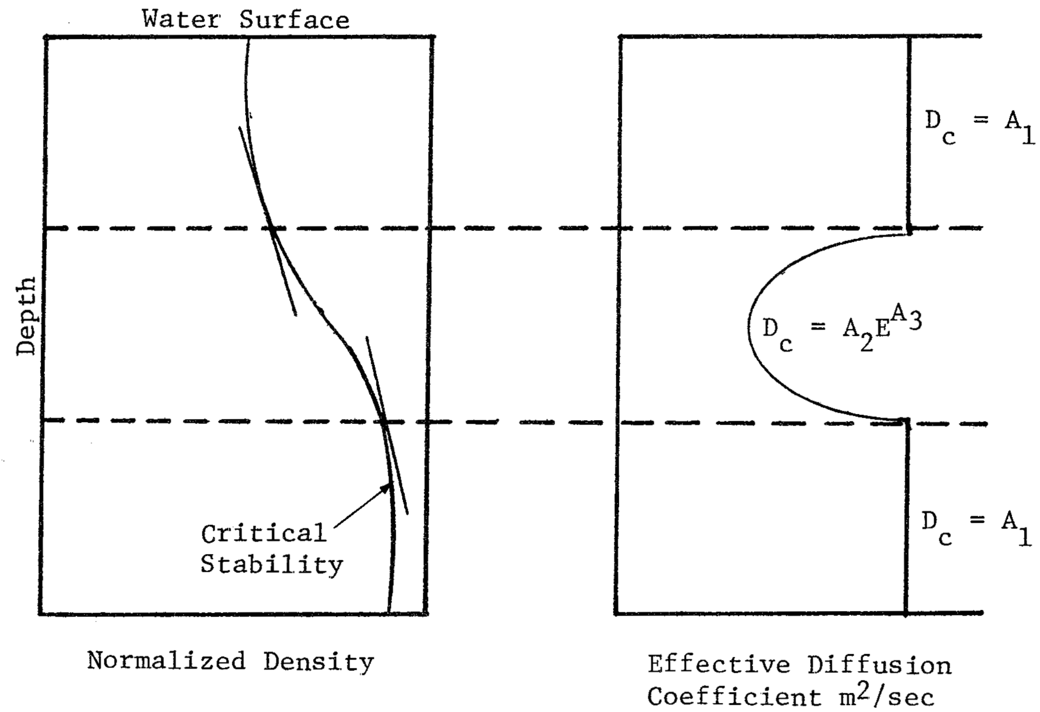


FIGURE II-4

Normalized Density and
Effective Diffusion Coefficients vs. Depth

Typical volumes reported by Baca [12] for the minimum effective dispersion coefficient and the empirical coefficients required by Equation II-10 are presented in Table II-1. Within the model the actual diffusion coefficient, D_c, is constrained by a maximum D_{max}, which is usually about 5×10^{-4}. The shape of the diffusion coefficient as a function of depth is shown in Figure II-5 for two different cases.

TABLE II-1

Minimum Effective Diffusion Coefficient and Empirical Coefficient for Wind Mixing Method

Coefficient	Well Mixed Reservoirs	Stratified Reservoirs
Minimum Effective Diffusion Coeff (D_{min})	1×10^{-5} to 5×10^{-5}	1×10^{-6} to 1×10^{-7}
Empirical Coeff (A_1)	1×10^{-4} to 2×10^{-4}	1×10^{-5} to 5×10^{-5}
Empirical Coeff (A_2)	4.6	4.6

A more detailed description of the procedure for distributing inflow and withdrawals and the development of the effective diffusion coefficients has been presented previously by WRE [11,13].

STREAM HYDRAULICS MODULE

The stream system is represented conceptually as a linear network of segments or volume elements. Each element is characterized by length, width, cross section, and certain other parameters that are identified with the particular stream sub-reach that the element represents (see Figure II-6).

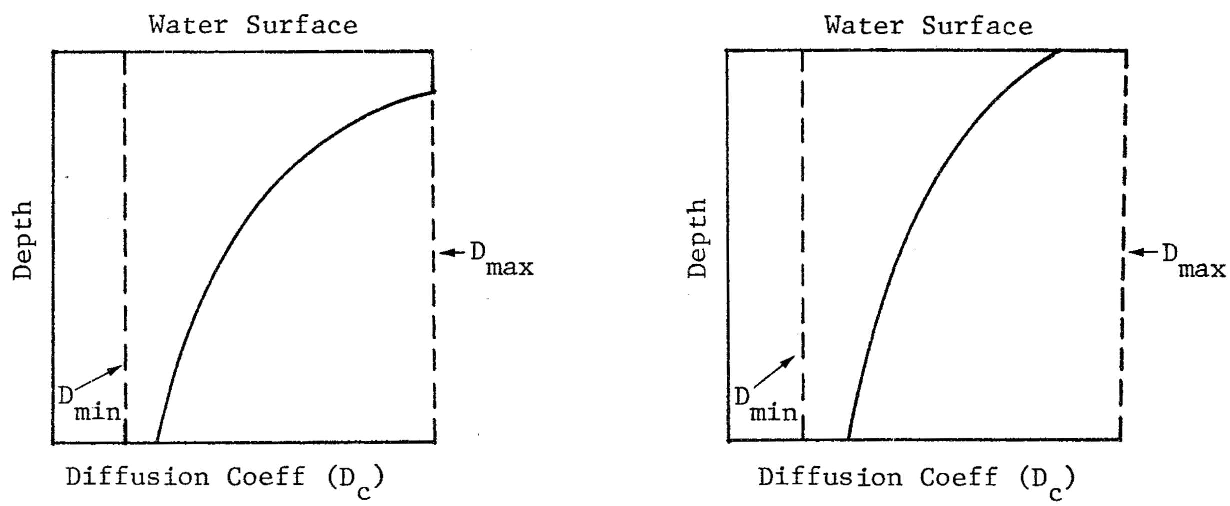


FIGURE II-5

Diffusion Coefficient vs. Depth

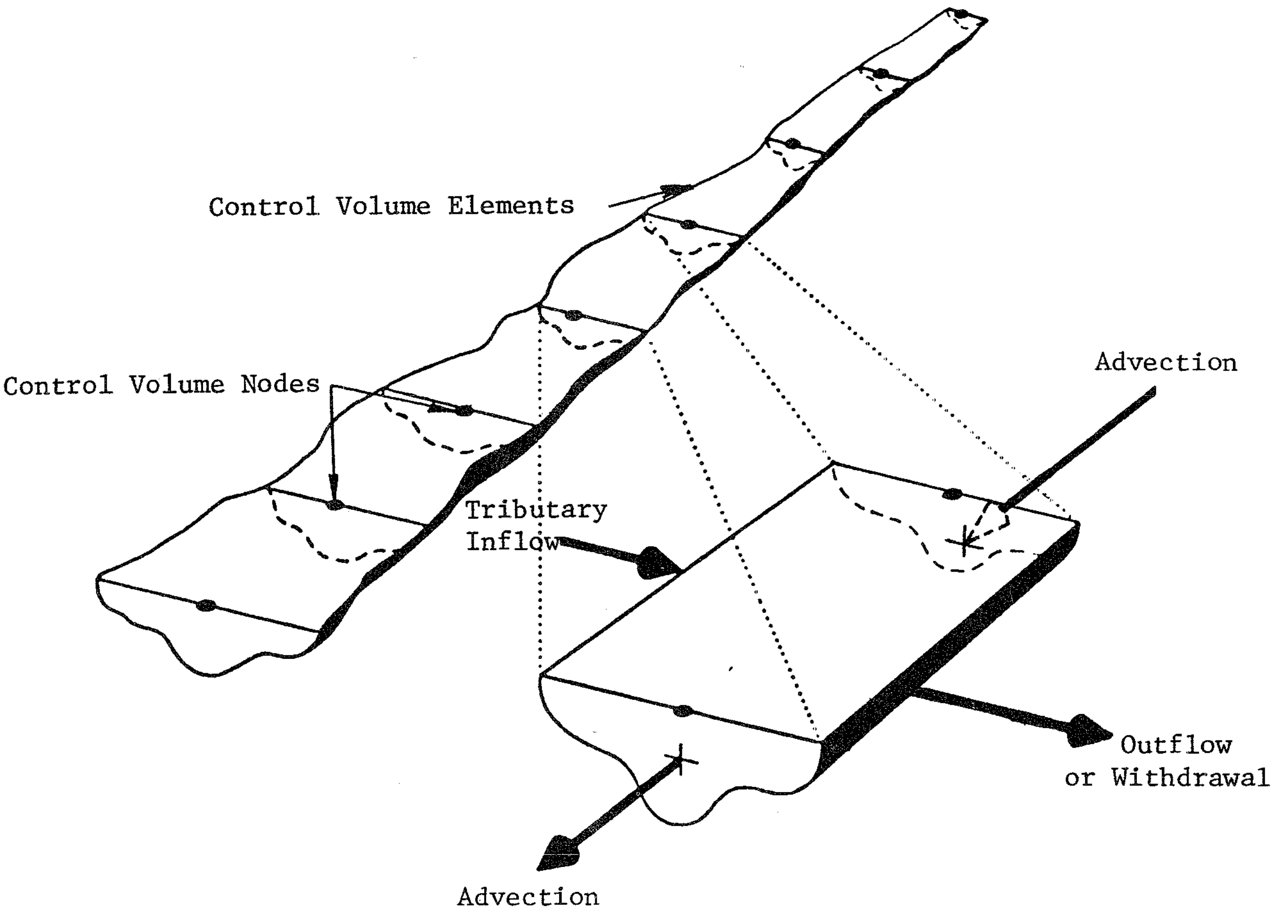


FIGURE II-6

Geometric Representation of Stream System and
Mass Transport Mechanisms

Hydraulic Computation Methods

Six methods of hydraulic computation are incorporated into the Stream Hydraulic Module. They include:

1. Backwater hydraulic solution (steady flow)
2. Solution of the full St. Venant equations
3. Solution of the kinematic wave equations
4. Direct input of a stage-flow relationship (steady flow)
5. Muskingum hydrologic routing
6. Modified Puls hydrologic routing

Of the six methods listed above, the first three represent hydraulic behavior of the prototype stream system under gradually varied flow. The basic definitions of hydraulic parameters used by these methods is shown on Figure II-7. With these three methods, the following assumptions are made for the stream system as a whole and for each element.

1. The system is one-dimensional in a mathematical sense (i.e., flow and velocity at any point is uniform both laterally and vertically with only variation in the longitudinal (x) direction).
2. The variation of cross-section over an element is such that linear interpolation gives an adequate definition of the system.
3. The rate of energy loss for gradually varied steady and unsteady flow is the same as that for uniform flow having the same velocity and hydraulic radius. This implies a uniform flow formula can be used to evaluate friction slope and that roughness coefficients developed for uniform flow are also applicable to gradually varied steady and unsteady flow.
4. The slope of the channel bottom is small (i.e., $\cos \theta = 1$).

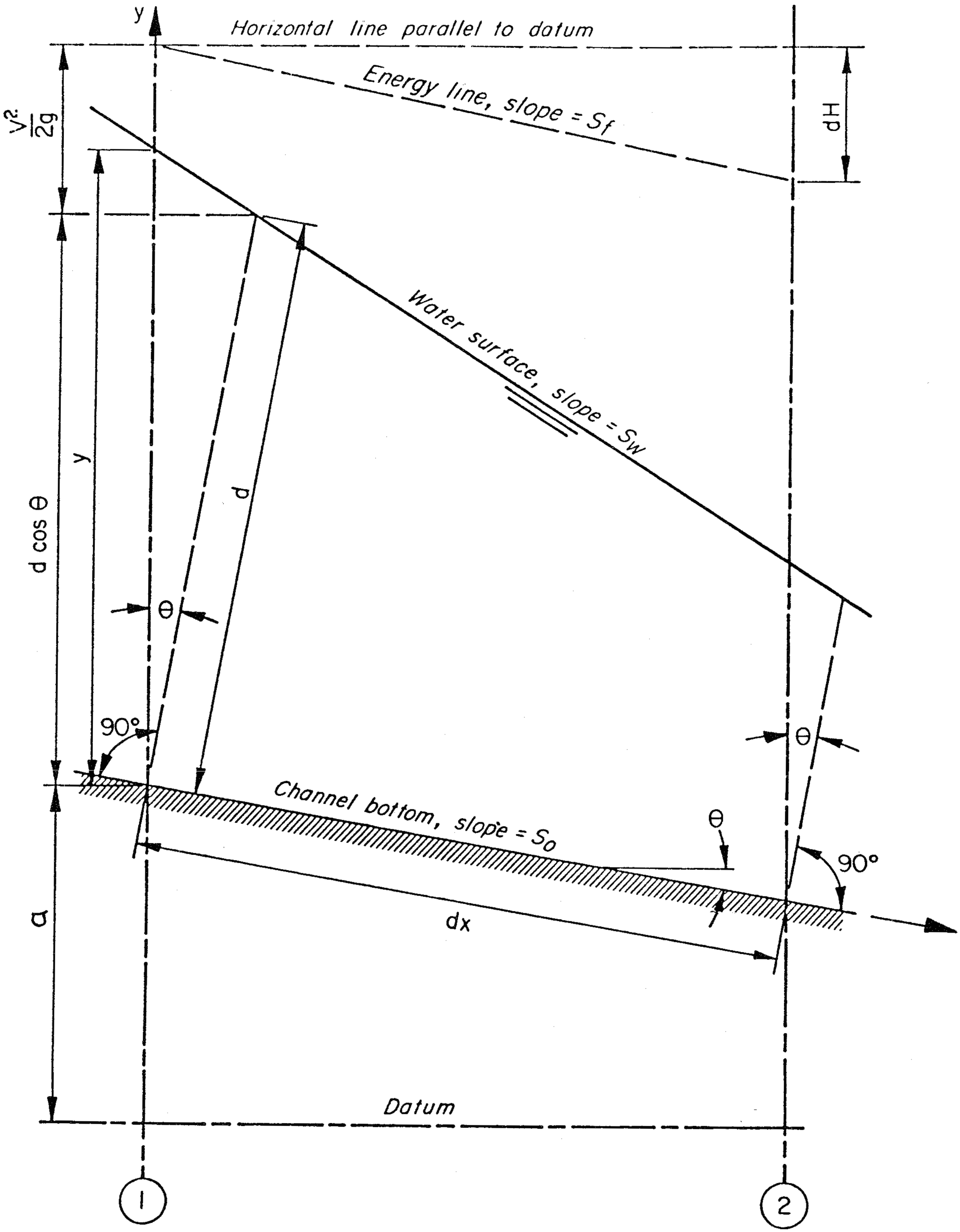


FIGURE II-7

Definition Sketch--Gradually Varied Flow Equation

Each of these three methods assumes that the hydraulic behavior of the prototype stream can be represented by the St. Venant equation of motion (i.e., gradually varied flow equation). In its usual form, the St. Venant equation may be written as

$$\frac{\partial v}{\partial t} + v \frac{\partial v}{\partial x} + g \left(\frac{\partial a}{\partial x} + \frac{\partial y}{\partial x} + p\right) + M = 0 \qquad \text{II-11}$$

where
- v = velocity in the channel in m/sec
- t = time coordinates (seconds)
- x = space coordinate (meters)
- g = acceleration due to gravity in m/sec^2
- a = invert elevation of the channel in meters
- y = depth of water in channel in meters measured from elevation a
- p = effect of bed friction, in Manning form $p = v^2 n^2 R^{-4/3}$
- M = momentum effect of inflow or withdrawal

By transforming velocities into flow by $Q = Av$ II-12

where A = effective area of flow (i.e., within conveyance limits) in m^2

$$\text{i.e.,} \quad \frac{\partial v}{\partial x} = A^{-1} \frac{\partial q}{\partial x} - q\, A^{-2} \left(\frac{\partial A}{\partial x} + \frac{\partial A}{\partial y} \frac{\partial y}{\partial x}\right) \qquad \text{II-13}$$

$$\frac{\partial v}{\partial t} = A^{-1} \frac{\partial q}{\partial t} - q\, A^{-2} \frac{\partial A}{\partial t} \qquad \text{II-14}$$

Equation II-11 may be rewritten as

$$A^{-1} \frac{\partial q}{\partial t} - q\, A^{-2} \frac{\partial A}{\partial t} + q\, A^{-1} \left(A^{-1} \frac{\partial q}{\partial x} - qA^{-2} \left[\frac{\partial A}{\partial x} + \frac{\partial A}{\partial y} \frac{\partial y}{\partial x}\right]\right)$$

$$+ g \left(\frac{\partial a}{\partial x} + \frac{\partial y}{\partial x} + q^2 n^2 A^{-2} R^{-4/3}\right) + M = 0 \qquad \text{II-15}$$

In addition to the St. Venant equation of motion, the kinematic wave and the St. Venant methods require the continuity equation given by

$$\frac{\partial A}{\partial t} + \frac{\partial q}{\partial x} - s = 0 \qquad \text{II-16}$$

where s = sources and sinks in m^2/sec

The assumptions which distinguish the three hydraulic computation methods and the resulting modifications to the transformed version of the St. Venant equation (II-15) and the continuity equation (II-16) will be presented later in this chapter.

The final three hydraulic computation methods are all independent of the fundamental hydraulic relationships as represented by the St. Venant equation.

A general description of all six hydraulic computation methods is provided below. A more detailed description of the mathematical formulations and numerical methods used for the backwater, St. Venant and kinematic wave hydraulic computation methods is presented in Appendix A.

1. Backwater Method

This method is a steady state hydraulic computation procedure in which all flows are assumed to be routed without any time lag. The depth of flow at any point is derived from the gradually varied flow equations. These equations take account of the geometric section properties and lead to a solution where depth of flow is not necessarily "normal depth".

This method is largely used in applications involving low flow analysis. It is not applicable to problems involving dynamic flow, although it can be used as an initial check when preparing cross section data for the dynamic flow computation methods.

The solution is derived by eliminating the time dependent term from the St. Venant equation of motion (Equation II-15), and then assuming the flow is known at all sections. A detailed description of the mathematical formulation and numerical methods used in the backwater computation is presented in Appendix A.

2. St. Venant Method

The full solution of the St. Venant method requires both the motion equation given by Equation II-15 and the continuity equation given by Equation II-16. If side flow momentum is neglected, Equation II-17 can be derived by substituting Equation II-16 into Equation II-15 and multiplying by A^3.

$$A^2 \frac{\partial q}{\partial t} + 2Aq \frac{\partial q}{\partial x} - q^2 \left(\frac{\partial A}{\partial x} + \frac{\partial A}{\partial y} \frac{\partial y}{\partial x}\right) +$$

$$g A^3 \left(\frac{\partial a}{\partial x} + \frac{\partial y}{\partial x} + q^2 n^2 A^{-2} R^{-4/3}\right) - Aqs = 0 \qquad \text{II-17}$$

Equations II-16 and II-17 form the two differential equations that must be solved. Equation II-17 is, of course, nonlinear; note that the cross sectional area A is a function of x, y and t.

Because of its proven reliability in solving complex nonlinear systems, the finite element method has been selected and programmed for solution of the St. Venant problem. The method was originally developed in the aerospace industry for structural analysis but has been extended in the last few years to more general problems in mechanics and engineering science and is well suited to this problem. Recently, solutions have been developed for two-dimensional versions of the Navier Stokes Equations, including all nonlinear terms [14]. The development of the method in this application follows the same general approach as described in reference [14] and the reader is referred to this reference and to reference [15] for background information and the more fundamental development of the method. A description of the complete mathematical formulation and application of the finite element technique to the St. Venant hydraulic computation method is presented in Appendix A.

3. Kinematic Wave Method

In the kinematic wave hydraulic computation method the equation of motion is simplified so that only the terms associated with bottom slope and friction effects remain. This means that the flow is assumed to be a known function of depth for all points. In most applications it is assumed to be the normal or friction flow. Solution of the two Equations II-16 and II-17 thus reduce to the single Equation II-16 with q as a function of y.

$$\text{i.e.,} \quad \frac{\partial A}{\partial t} + \frac{\partial q}{\partial x} - s = 0$$

The finite element method may again be used for this problem with only one degree of freedom (i.e., depth). A description of the mathematical formulation used with this method is presented in Appendix A.

4. Stage-Flow Relationship

The stage-flow method is a steady flow hydraulic computation procedure in which all flows are assumed to be routed without any time lag. The flow at any point is thus the accumulated flow from all upstream inflows and withdrawals. It is assumed that the depth of flow at any point may be directly interpolated from a specified stage-flow table.

This method is primarily suited to applications involving low flow analysis where water surface profile analysis has already been completed. It is unsuitable to applications involving dynamic flow.

5. Muskingum Routing Method

This hydrologic routing method is an approximate numerical procedure which satisfies only the continuity equation in the sense that total flow is preserved.

The method is derived from an assumption that relates storage in a section to instantaneous levels of flow into and out of the section. The expression relating storage to inflow and outflow is

$$S = K(O) + X(K)(I - O) \qquad \text{II-18}$$

where S = total storage in the section
I and O = inflow to and outflow from the section, and
K and X = empirical coefficients used in calibration

It should be noted at this time that K has the units of time and is some measure of travel time for the section. X is a dimensionless coefficient with a value that must be between 0 and .5.

Consider equations at time 1 and 2 for the beginning and end of a time step Δt respectively. The change of storage Δs in the time step may be written from considerations of inflow and outflow as

$$\Delta S = \Delta t \text{ (Average Inflow - Average Outflow)} \qquad \text{II-19}$$

$$= \Delta t \; [(I_1 + I_2)/2 - (O_1 + O_2)/2] \qquad \text{II-20}$$

Rewriting II-18 for ΔS

$$\Delta S = K(O_2 - O_1) + X(K)(I_2 - I_1 - O_2 + O_1) \qquad \text{II-21}$$

Combining Equations II-20 and II-21 to eliminate ΔS, an equation for O_2 may be developed,

$$O_2 = C_1I_2 + C_2I_1 + C_3O_1 \qquad \text{II-22}$$

where

$$C_1 = (\Delta t - 2KX)/(2K\ (1 - X) + \Delta t) \qquad \text{II-23}$$

$$C_2 = (\Delta t + 2KX)/(2K\ (1 - X) + \Delta t) \qquad \text{II-24}$$

$$C_3 = (2K\ (1 - X) - \Delta t)/(2K\ (1 - X) + \Delta t) \qquad \text{II-25}$$

Since these coefficients should be positive, X is limited to a value less than $\Delta t/2K$.

In practical applications of this method K is generally selected so that $K = \Delta t$ which requires $X \leq 0.5$.

The routine constructed for Muskingum routing differs from the four methods previously discussed in that in addition to the concept of nodal points, a series of control points are introduced. These control points are the identifiers for the routing sections used by Equation II-22 and thus they allow variable length control sections required to develop a good representation of the channel hydrograph. In contrast to other methods it should be noted that Δt is set equal to the frequency of data input of the upstream hydrograph and is considered fixed for the simulation. If the user desires $\Delta t = K$ he must adjust control points.

For routing of tributary flows, all inflows to a control section are grouped and applied at the upstream control point. After the flow rate has been determined, the depth is calculated based on the user specified stage flow relationships or normal depth. The velocities and channel cross sectional areas are then calculated based on the channel geometry data.

6. Modified Puls Routing Method

The Modified Puls flow computation method is a kinematic wave method in which outflow from a control section is a unique function of storage and thus of the storage indication parameter, SI,

$$SI = S/\Delta t + O/2 \qquad \text{II-26}$$

where S = volume of storage in routing reach, and

O = outflow = f (SI)

In practical application the storage indicator is computed from time step to time step by

$SI_2 = SI_1$ + Average inflow - Outflow at beginning of step

$$\text{or } SI_2 = SI_1 + (I_1 + I_2)/2 - O_1 \qquad \text{II-27}$$

with the same notation as for Muskingum routing.

The same concepts for control points and sections apply to the Modified Puls procedure as for the Muskingum method; the major difficulty with this method is the construction of the function f.

In the present development the function f is input as a series of table entries for outflow and storage (which is converted to the storage indicator) and linear interpolation is used to develop the function f as required.

Other hydraulic data (e.g., depth, velocity and cross section area) are computed in a manner identical to that used by the Muskingum routing method.

III. TEMPERATURE AND WATER QUALITY RELATIONSHIPS

The water quality model is designed to provide a detailed portrayal of the important processes that determine the thermal and water quality characteristics of lakes, reservoirs and streams. The conceptual framework of the model is based on fundamental characterizations of the dynamics of constituent transport, and chemical and biological kinetics. The mathematical relationships used to model these processes are summarized in this section and in Appendix B.

MODELING APPROACH

The modeling approach is based on the assumption that the dynamics of each chemical and biological component can be expressed by the law of conservation of mass and the kinetic principle. A very important assumption is that all chemical and biological rate processes occur in an aerobic environment. The models are not capable of simulating processes that occur under anaerobic or oxygen-devoid conditions. There are several default algorithms included to permit the simulation to continue until oxygen returns to the layer, but these results need to be interpreted with extreme caution. An appropriate use of the model would be to determine if anaerobic conditions might develop in an impoundment but not to predict the duration of anoxic conditions.

The fundamental principle of conservation of heat and mass is used to derive the following differential equation model for the dynamics of heat and biotic and abiotic materials.

$$V\frac{\partial C}{\partial t} = \Delta z \cdot Q_z \frac{\partial C}{\partial z} + \Delta z \cdot A_z \cdot D_c \frac{\partial^2 C}{\partial z^2} + Q_i \cdot C_i - Q_o \cdot C \pm V \cdot S \qquad \text{III-1}$$

where

C = thermal energy or constituent concentration in the reservoir or stream in appropriate units (e.g., kcal, mg/ℓ and MPN/100 ml)

V = volume of the fluid element in m^3

t = time coordinate, seconds

z = space coordinate, meters (vertical for the reservoir and horizontal for the stream)

Q_z = vertical advection in m^3/sec

A_z = element surface area normal to the direction of flow in m^2

D_c = effective diffusion coefficient in m^2/sec

Q_i = lateral inflow in m^3/sec

C_i = inflow thermal energy or constituent concentration in appropriate units

Q_o = lateral outflow in m^3/sec

S = all sources and sinks in appropriate units (e.g., kcal/sec, mg/ℓ/sec, etc.)

The above general expression is appropriate for temperature and those constituents which are passively transported with the movement of water. For those constituents which are assumed affixed to the bottom or are mobile (i.e., fish), the differential equation model is simply

$$V\frac{\partial C}{\partial t} = \pm V \cdot S \qquad \text{III-2}$$

The source and sink term for temperature is limited to external heat fluxes. For the water quality constituents, sources and sinks may include settling, first order decay, reaeration, chemical transformations, biological uptake and releases, growth, respiration, and mortality including predation.

The following general expressions include the various components of the source and sink term for an abiotic constituent

$$S_1 = \underbrace{V_s \frac{\partial C_1}{\partial z}}_{\textit{settling}} + \underbrace{K_2 (C_1^* - C_1)}_{\textit{reaeration}} - \underbrace{K_{d1} C_1}_{\textit{decay}} + \underbrace{K_{d2} C_2}_{\textit{chemical transformation}}$$

$$- \underbrace{\Sigma G_n C_n F_n}_{\textit{biotic uptake}} + \underbrace{\Sigma G_n C_n E_n + \Sigma R_n C_n F_n}_{\textit{biotic byproducts}} + \underbrace{\Sigma M_n C_n}_{\textit{mortality}} \qquad \text{III-3}$$

and for a biological constituent

$$S_1 = \underbrace{V_s \frac{\partial C_1}{\partial z}}_{\textit{settling}} + \underbrace{C_1 (G_1 - R_1 - M_1)}_{\textit{growth, respiration \& mortality}} - \underbrace{\Sigma G_n C_n F_n}_{\textit{predation}} \qquad \text{III-4}$$

where

S_1 = source and sink for the constituent

V_s = constituent settling velocity

C = constituent concentration

K_2 = reaeration coefficient

C^* = concentration at saturation

K_d = decay coefficients

G = growth rate

F = factor relating growth to uptake and release of dependent constituents

E = factor relation growth to excretion of dependent constituents

R = respiration rate

M = mortality rate

A description of the source and sink terms for temperature and the individual water quality constituents is presented in the following sections.

THERMAL ANALYSIS

The temperature of the water is one of the most important parameters to be analyzed since nearly all rate coefficients are temperature dependent. Additionally, the diffusive mass transport mechanism within the reservoir is directly dependent upon the water density which in turn is dependent on temperature.

The external source and sink for heat considered in the reservoir model is heat exchange at the air-water interface. Within the stream model heat transfers at both the surface and stream bottom are considered. A description of the component of the source and sink terms are provided below.

Water Surface Heat Exchange

The transfer of heat to and from the water body occurs primarily at the air-water interface. The rate of heat transfer per unit of surface area can be expressed as the sum of the following five components:

$$H_n = q_{ns} + q_{na} - q_w - q_e - q_c \qquad \text{III-5}$$

where

H_n = net rate of heat transfer in kcal/m^2/sec

q_{ns} = net rate of short-wave solar radiation across the interface after losses by adsorption and scattering in the atmosphere and by reflection at the water surface

q_{na} = net rate of atmospheric long-wave radiation across the interface after losses by reflection at the water surface

q_w = rate of long-wave radiation from the water surface

q_e = rate of heat loss by evaporation

q_c = rate of convective heat exchange between the water surface and the overlying air mass

The basic physical formulation of each of these terms can be found in reports prepared by the Tennessee Valley Authority [16] and WRE [17].

Two methods based on the above formulation may be selected by the user to calculate the water surface heat flux; the heat budget method and the equilibrium temperature method.

1. Heat Budget Method

With the heat budget method, the five components of the total heat are aggregated into two groups; those which are dependent on the surface temperature and those which are not. The surface temperature dependent terms of equation III-5 (i.e., q_w, q_e and q_c) are linearized to simplify the solution technique resulting in the following expression.

$$H = \mu - \lambda T \qquad \text{III-6}$$

where

μ = $q_{ns} + q_{na} - 7.36 \times 10^{-2} - \rho L\ (a+bW)\ (\alpha_j - e_a - 6.1 \times 10^{-4}\ p\ T_a)$

λ = $1.17 \times 10^{-3} + \rho L\ (a+bW)\ (\beta_j + 6.1 \times 10^{-4}\ p)$

T = water temperature in degrees celsius

ρ = water density in kg/m^3

a = evaporation coefficient "a"

b = evaporation coefficient "b"

W = wind speed in m/sec

α_j, β_j = temperature dependent empirical coefficients summarized in Table III-1

e_a = vapor pressure of the overlying atmosphere in millibars

p = atmospheric pressure in millibars

T_a = dry bulb air temperature in degrees celsius

L = latent heat of vaporization in kcal/kg

2. Equilibrium Temperature Method

The equilibrium temperature approach to heat transfer at the air-water interface, developed by Edinger and Geyer [18], utilizes the concept of an "equilibrium temperature" and an overall rate coefficient for surface heat exchange. The "equilibrium temperature" is defined as the water temperature at which the net rate of heat exchange at the air-water interface is zero. The rate coefficient for surface heat exchange, when multiplied by the difference between the equilibrium and actual surface temperature, gives the net rate of heat transfer. The following formula describes this relationship:

$$H_n = K_e (T_e - T_s) \qquad \text{III-7}$$

where

H_n = the net rate of heat transfer in $kcal/m^2/sec$

K_e = the rate coefficient for surface heat exchange in $kcal/m^2/sec/°C$

T_e = the equilibrium temperature in degrees celsius

T_s = the surface water temperature in degrees celsius

TABLE III-1

Temperature Dependent Empirical Coefficient α and β

Temperature Range, °C	α_j	β_j
0 - 5	6.05	.522
5 - 10	5.10	.710
10 - 15	2.65	.954
15 - 20	-2.04	1.265
20 - 25	-9.94	1.659
25 - 30	-22.29	2.151
30 - 35	-40.63	2.761
35 - 40	-66.90	3.511

Values of α and β are numerically derived from a curve fit of temperature versus saturated vapor pressure data.

Both of the above methods (Equations III-6 and III-7) adequately represent the total heat flux at the water surface of a homogeneous water body. In the reservoir model, however, the shorter wave length components of visible solar radiation will penetrate beyond the surface element. That fraction which enters the second element must be subtracted from the heat flux to the surface element.

The amount of solar radiation which penetrates beyond the surface element is dependent on the light attenuation characteristics of the water. The presence of any suspended particulate material such as inorganic suspended solids, detritus and plankton changes the light attenuation characteristics of the water. These characteristics may continually change during the simulation period due to changes in the concentration of particulate material. The light energy or intensity at any depth is determined by the following relationship:

$$I = I_o e^{-kz} \qquad \text{II-8}$$

where

I = light intensity at any depth in kcal/m^2/sec

I_o = surface light intensity in kcal/m^2/sec

k = light extinction coefficient in 1/meter

z = depth in meters

The light extinction coefficient is an indicator of light transmissibility and is a function primarily of the suspended particulate material. Assuming that the effects of particulate material on light transmissibility are additive, the light extinction coefficient may be determined by:

$$k = k_o + \Sigma\, S \cdot C \qquad \text{III-9}$$

where

k = composite light extinction coefficient in 1/meter

k_o = extinction coefficient of pure water in 1/meter

S = shading/light attenuation constant for each particulate material in 1/m/mg/ℓ

C = particulate material concentration in mg/ℓ

With the original heat budget formulation, the magnitude of "μ" (Equation III-6) is simply reduced to account for this reduction in the heat flux to the surface element.

With the equilibrium temperature approach, it is more difficult to account for the reduced solar radiation component of the total heat flux since both the heat exchange coefficient and the equilibrium temperature are affected. Within the model, the increment of solar radiation which penetrates beyond the surface element is subtracted from the total surface heat flux calculated by Equation III-7. This approximation is adequate if the fraction of solar radiation passing on to the second element is small. If the combination of water clarity and element thickness results in a significant fraction of the total solar radiation penetrating beyond the surface element, then errors in the prediction of surface temperature may result. When the average secchi disk depth is greater than the element thickness, the heat budget approach is recommended.

Heat Exchange With the Sediments

Only heat exchange across the air-water interface was considered within the reservoir model. This approach is reasonable since the reservoir bottom area to volume ratio is usually relatively small. In the stream, however, this ratio may be quite large and heat exchange with the bottom may be significant. Within shallow streams, the rapid changes in temperature calculated by the model usually exceed observed values. Heat exchange with the bottom will have a moderating effect on water temperature fluctuations, reducing the maximum daily temperature by conducting heat away from the water to the cooler bottom sediments. During the night when the bottom temperature exceeds the water temperature, heat will be transferred from the bottom to the river water, thereby limiting the nighttime drop in river water temperature. The rate of heat exchange with the bottom sediment is approximated by:

$$H_b = K_c (T_b - T_w) \qquad \text{III-10}$$

where

H_b = the heat flux to and from the bottom sediments in $kcal/m^2/sec$

K_c = the heat conductance coefficient in $kcal/m^2/sec/°C$

T_b = the bottom sediment temperature in degrees celsius

T_w = the water temperature in degrees celsius

The temperature of the bottom sediment is calculated based on the heat flux (H) and the heat capacity of the bottom sediment

WATER QUALITY RELATIONSHIPS

These principal biological and chemical constituents considered in the water quality module are:

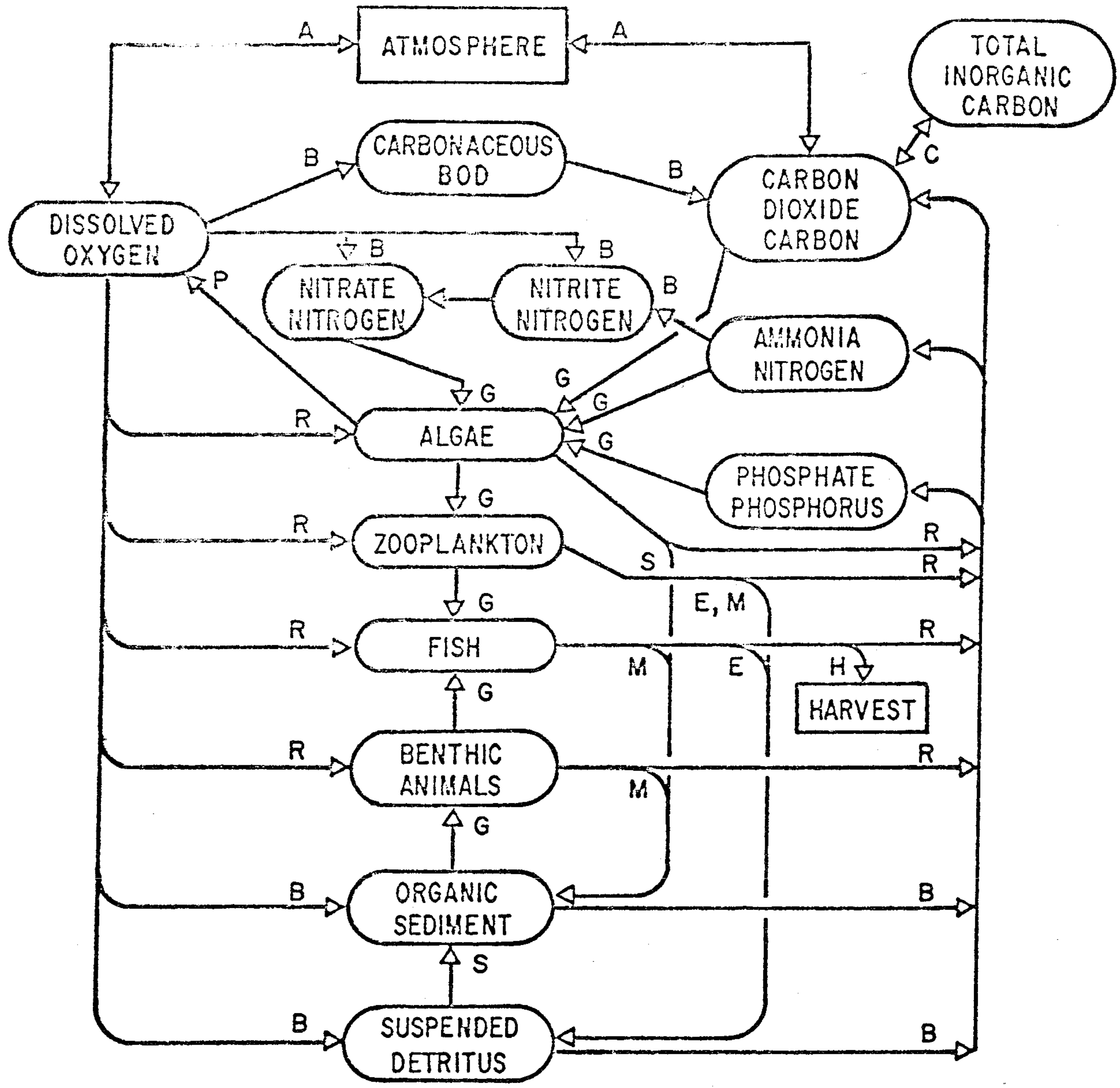
- Fish: three types with different optimum temperature ranges, different growth, respiration and mortality rates and difference feeding preferences
- Aquatic Insects (Stream module only): assumed to be associated with the substrate
- Benthic Animals: assumed to be associated with the substrate
- Zooplankton
- Phytoplankton: two types with different optimum temperature ranges, different growth and respiration rates, different sinking velocities and different nutrient requirements
- Benthic Algae (Stream module only): two types with different optimum temperature ranges, different growth and respiration rates and different nutrient requirements
- Detritus
- Organic Sediment (i.e., settled detritus)
- Inorganic suspended solids: five types with different settling velocities

- Inorganic sediment (i.e., settled inorganic suspended solids)
- Dissolved phosphate as phosphorus
- Total inorganic carbon
- Dissolved ammonia as nitrogen
- Dissolved nitrites as nitrogen
- Dissolved nitrates as nitrogen
- Dissolved biochemical oxygen
- Coliform bacteria
- Total alkalinity as calcium carbonate
- Total dissolved solids
- pH
- Unit toxicity (Stream module only)

The ecological processes within the lake environment are centered around phytoplankton. The trophic relationship between phytoplankton and zooplankton and the direct and reciprocal relationship between phytoplankton and nutrients normally controls the water quality conditions within the lake. The interrelationships between all constituents considered in the reservoir module are shown schematically in Figure III-1.

The ecological processes within the stream model, however, are centered around benthic algae where the trophic relationship between benthic algae and aquatic insects form the base of the food chain. Figure III-2 shows the interrelationships between constituents making up the food chain as represented in the stream module. The interrelationships between these food chain constituents and the remaining stream water quality constituents are similar to those depicted in Figure III-1.

Table III-2 describes the interdependence of constituents and Table III-3 the various processes which influence changes in concentration. The



A Aeration
B Bacterial Decay
C Chemical Equilibrium
E Excreta

G Growth
M Mortality
P Photosynthesis
R Respiration

S Settling
H Harvest

FIGURE III-1. Quality and Ecologic Relationships

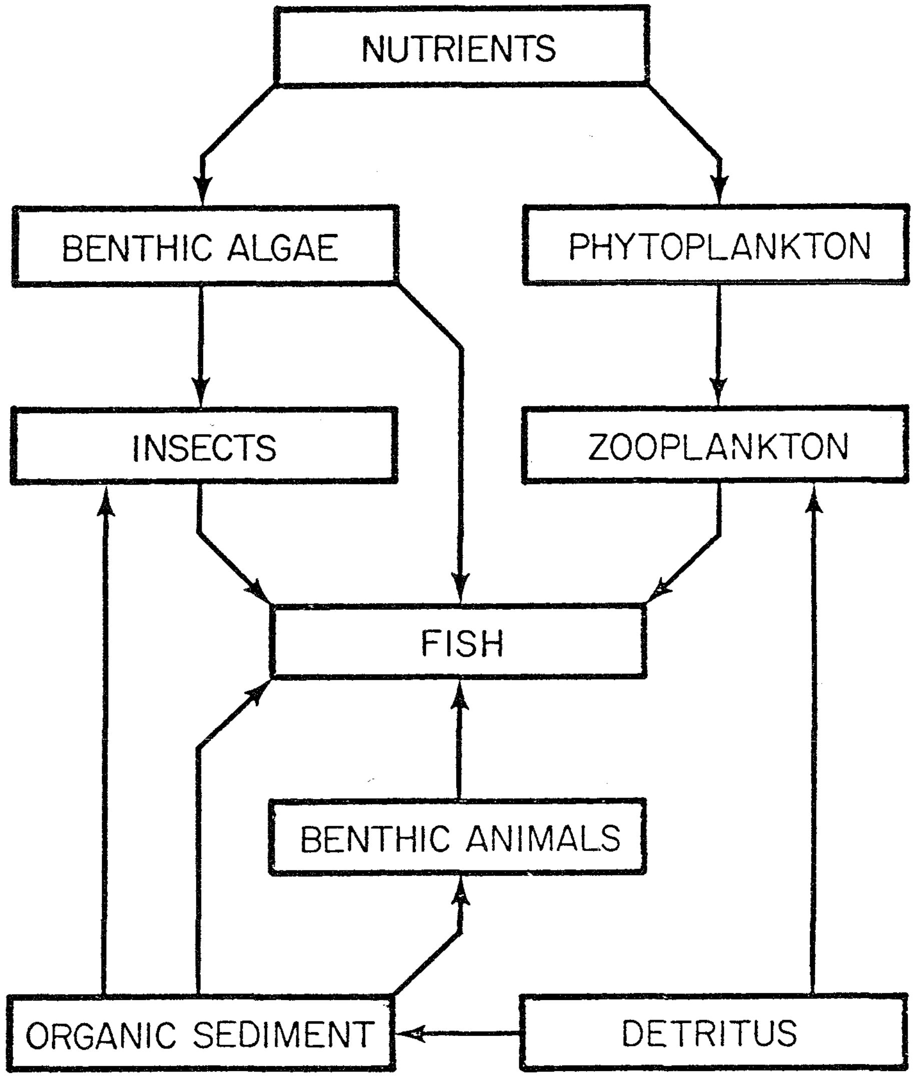


FIGURE III-2. Food Chain Relationships Within the Stream Model

TABLE III-2

Interdependence of Constituents

CONSTITUENT ↓ / DEPENDENT ON →	Temperature	Fish	Benthic Animals	Zooplankton	Aquatic Insects*	Phytoplankton	Benthic Algae*	Detritus	Inorganic Suspended Solids	Organic Sediment	Inorganic Sediment	Toxicity*	BOD	Coliform Bacteria	Total Inorganic Carbon	Ammonia	Nitrite	Nitrate	Phosphate	Oxygen	Alkalinity and TDS	Carbon Dioxide	pH
Temperature				K		K		K	K														
Fish	A		D	D	D		D			D		I								G			
Benthic Animals	A	L								D		I								G			
Zooplankton	A	L				D		D				I								G			
Aquatic Insects*	A	L					D			D		I								G			
Phytoplankton	A			L								I			D	D		D	D				
Benthic Algae*	A	L			I							I			D	D		D	D				
Detritus	A	E		E,I	E		J																
Inorganic Suspended Solids											J												
Organic Sediment	A		E			J		J															
Inorganic Sediment									J														
Toxicity*																							
BOD	A																			G			
Coliform Bacteria	A																						
Total Inorganic Carbon			B	B	B	B	B	B		B			B							G		M	
Ammonia	A		B	B	B	B	B	B		B													
Nitrite	A															B				G			
Nitrate	A																B			G			
Phosphate			B	B	B	B	B	B		B													
Oxygen	F	C	C	C	C		C	C		C			C				C	C					
Alkalinity and TDS																							
Carbon Dioxide	F,H														M						H		M
pH	H														H						H	H	

* Stream module only

LEGEND:

A - Affects rate of decay, respiration, growth or mortality
B - By-product of decay or respiration
C - Consumed by decay and respiration
D - Prey or nutrients required for growth
E - By-product of growth
F - Affects reaeration rates and saturation
G - Limits growth or decay if out of acceptable range

H - Affects chemical equilibrium
I - Affects mortality
J - Source through sedimentation or scour
K - Limits energy input by affecting light penetration
L - Consumed by growth of other constituents
M - At chemical equilibrium with other constituents

TABLE III-3

Basic Processes Influencing Constituents

Constituent	Conservative Constituent	Advected[1] & Diffused	Exchange Through Air-Water Interface	Rates Are Temp Dependent	Mass Increased By: Growth	Mass Increased By: By-Products of Other Constituents	Mass Decreased By: Mortality or Settling	Mass Decreased By: Respiration	Mass Decreased By: Grazed or Consumed By	Mass Decreased By: Decay
Temperature		X	X							
BOD		X		X						X
Coliforms		X		X						X
Fish (three types)				X	X		X	X	Man	
Insects[2]				X	X		X	X	Fish	
Benthos				X	X		X	X	Fish	
Zooplankton		X		X	X		X	X	Fish	
Phytoplankton (two types)		X		X	X		X	X	Zooplankton	
Benthic Algae (two types)[2]				X	X		X	X	Insects & Fish	
Detritus		X		X		X	X		Zooplankton	X
Phosphorous		X		X		X			Algae	
Ammonia		X		X		X			Algae	X
Nitrite		X		X		X				X
Nitrate		X		X		X			Algae	
Total Carbon		X	X	X		X			Algae	
Organic Sediment				X		X			Fish & Benthos	X
Alkalinity	X	X								
TDS	X	X								
Oxygen		X	X	X		X			Decay[3]	
Suspended Solids		X		X			X			
Inorganic Sediment						X				
Toxicity[2]	X	X								

1 Advected and diffused between segments and advected into and out of the system by inflow and outflow waters.

2 Stream module only

3 Consumed with decay of BOD, sediment, detritus, ammonia, nitrite and biota respiration.

processes described in these tables may be represented mathematically by mass balance equations similar to equation III-1 through III-4. The specific equations for the source and sink term for each of the water quality constituents is presented in Appendix B.

A more detailed description of the chemical and biological constituents and their interactions can be found in reports by Chen and Orlob [1], Chen et al [19], and Smith [7].

WATER QUALITY CONSTITUENT INTERACTION MODIFICATION

Included in both water quality modules is the capability of omitting a water quality constituent or holding the constituent at a constant value during the simulation. The only exception to the above is that the temperature disconnect and constant temperature options are not included in the reservoir model since vertical mass transport is a function of water density which is dependent on temperature.

Water Quality Constituent Disconnect

The water quality constituent disconnect capability allows the user to restrict the simulation to only those constituents of interest and of importance in the context of the specific study, thereby reducing computer cost and data preparation cost. This option must be used with extreme caution and care taken not to exclude a constituent which may directly or indirectly affect a constituent of interest.

Examples of the proper use of this option would be:

1. Evaluation of just water temperature where algae and other particulate material do not significantly alter the light attenuation characteristics of the water in a reservoir

2. Evaluation of only coliform bacteria distribution in a stream

3. Evaluation of fewer than 5 inorganic suspended solids groups

4. Evaluation of dissolved oxygen considering only BOD in a very polluted stream where the only significant dissolved oxygen sink is uptake related to BOD decay

In these examples all other constituents could be set to zero except for temperature. (Temperature is always simulated in the reservoir module and set to 20 degrees celsius in the stream module when the stream temperature is not simulated).

Improper uses of the disconnect option would be:

1. Evaluation of only dissolved oxygen and BOD in a stratified reservoir (it is very unlikely that the only significant dissolved oxygen sink in any reservoir would be uptake related to BOD decay)

2. Evaluation of nutrients within a reservoir or stream without simulating phytoplankton or benthic algae

3. Evaluation of total inorganic carbon without simulating alkalinity (alkalinity is necessary to determine the carbon dioxide component of total inorganic carbon)

Constant Water Quality Constituent

The constant water quality constituent option allows the user to simulate the effects of a constituent without actually simulating the constituent. As with the disconnect option, computer cost and data preparation costs are reduced. With the use of this option, the effects of the constituent are considered but the concentration of the constituent is held constant during the simulation. With the use of this option extreme care must be taken to assign realistic values for the constituents held constant.

Examples of proper use of this option might be:

1. Hold the temperature of a stream at a constant observed value.

2. Hold fish or benthic animal densities at observed or realistic level during a short duration stream simulation.

3. Hold organic sediment constant at a realistic level during a stream or reservoir simulation (i.e., constant benthic BOD and benthic nutrient source).

An example of an improper use of this option would be to hold phytoplankton constant during a year-long reservoir simulation (phytoplankton population are very dynamic and should never be held constant under normal circumstances).

Summary

Again it should be emphasized that a great deal of caution must be used when utilizing either of these options. The user should have a good understanding of the model concepts, particularly the constituent interaction (see Figures III-1 and 2 and Tables III-2 and 3) and understand the ramifications of omitting or holding a water quality constituent constant. If there is any doubt as to the significance of a constituent, or a realistic value for a constituent to be held constant cannot be determined, then the interaction modification option should not be used. Lack of data should never be used as a criterion for selecting which constituents are to be modeled and which are to be held constant or omitted.

In selecting the magnitude of a constituent to be held constant, it is advisable to perform hand calculations to determine the approximate effect of the constant constituent (e.g., dissolved oxygen uptake associated with a constant organic sediment level).

IV. PHYSICAL, CHEMICAL AND BIOLOGICAL RATE COEFFICIENTS

With the exception of the conservative constituents (i.e., alkalinity, TDS and unit toxicity) the differential equations representing water quality relationships incorporate one or more physical, chemical or biological coefficients. Most of these coefficients are based upon an empirical understanding of a process (e.g., the BOD decay rate is a simplified description or a complex microbial activity). Many of these coefficients are highly variable and depend upon such factors as regional climatic variation, time of day, synoptic weather patterns, system geometry (e.g., shallow stream, deep lake) and type and general levels of pollution. Table IV-1 lists the coefficients used in the equations and gives selected ranges that have been previously used in various simulations. Note that for some coefficients a single value is given. This is not necessarily intended to imply that the number is precisely known, but that little attention has been given to this coefficient or that little research has been conducted on the process.

Default values for many of these coefficients have been provided and are also listed in the following tables. In applying these models care must be taken to insure that the default values for all coefficients are appropriate for the stream or reservoir being modeled. Default coefficients may be overrridden by the user by specifying the appropriate coefficient code number along with the new coefficient value.

TABLE IV-1

Physical, Chemical and Biological Coefficients

	Coefficient Code		Default	Normal
	Reservoir	Stream	Value	Range
Carbon Fraction (by weight) of:				
Phytoplankton & Benthic Algae	1	1	.4	.4-.5
Zooplankton	4	4	.4	.4-.5
Aquatic Insects		7	.4	.4-.5
Benthic Animals	7	10	.4	.4-.5
Fish	10	13	.4	.4-.5
Detritus & Organic Sediment	13	16	.4	.2-.5
Nitrogen Fraction (by weight) of:				
Phytoplankton & Benthic Algae	2	2	.08	.07-.09
Zooplankton	5	5	.08	.07-.09
Aquatic Insects		8	.08	.07-.09
Benthic Animals	8	11	.08	.07-.09
Fish	11	14	.08	.07-.09
Detritus & Organic Sediment	14	17	.08	.05-.09
Phosphorus Fraction (by weight) of:				
Phytoplankton & Benthic Algae	3	3	.012	.01-.012
Zooplankton	6	6	.012	.01-.012
Aquatic Insects		9	.012	.01-.012
Benthic Animals	9	12	.012	.01-.012
Fish	12	15	.012	.01-.012
Detritus & Organic Sediment	15	18	.012	.005-.012

TABLE IV-1

Physical, Chemical and Biological Coefficients
(continued)

		Coefficient Codes			
		Reservoir	Stream	Default Value	Normal Range
Rate Coefficient Temperature Adjustment Factors					
Temperature Limits in degrees celsius					
Type 1 phytoplankton & benthic algae	T_1	135	186	5	0-10
	T_2	137	188	22	15-25
	T_3	139	190	25	20-30
	T_4	141	192	34	25-40
Type 2 phytoplankton & benthic algae	T_1	136	187	10	5-15
	T_2	138	189	28	20-30
	T_3	140	191	30	25-35
	T_4	142	193	40	30-45
Zooplankton	T_1	147	198	5	0-10
	T_2	148	199	28	15-30
	T_3	149	200	30	20-35
	T_4	150	201	38	30-40
Aquatic Insects	T_1		206	5	0-10
	T_2		207	28	15-30
	T_3		208	30	20-35
	T_4		209	38	30-40
Benthic Animals	T_1	155	214	5	0-10
	T_2	156	215	22	15-30
	T_3	157	216	25	20-35
	T_4	158	217	38	30-40
Type 1 Fish	T_1	171	230	5	0-5
	T_2	174	233	20	15-20
	T_3	177	236	20	15-25
	T_4	180	239	25	20-30
Type 2 Fish	T_1	172	231	10	5-15
	T_2	175	234	27	20-30
	T_3	178	237	30	25-35
	T_4	181	240	38	30-40

TABLE IV-1

Physical, Chemical and Biological Coefficients
(continued)

		Coefficient Codes			
		Reservoir	Stream	Default Value	Normal Range
Type 3 Fish	T_1	173	232	5	0-10
	T_2	176	235	22	20-30
	T_3	179	238	30	25-35
	T_4	182	241	36	30-40
Carbonaceous BOD decay	T_1	185	244	4	0-5
	T_2	186	245	30	25-35
Ammonia decay	T_1	189	248	4	0-5
	T_2	190	249	30	25-35
Nitrite decay	T_1	193	252	4	0-5
	T_2	194	253	30	25-35
Detritus & Sediment decay	T_1	197	256	4	0-5
	T_2	198	257	30	25-35
Q_{10} Temperature Coefficients					
Coliform bacteria die-off		199	258	1.04	1.03-1.06
Reaeration		*	263	1.022	1.02-1.025
BOD decay		200	264	0	1.03-1.06
Ammonia decay		201	265	0	1.02-1.03
Nitrite decay		202	266	0	1.02-1.03
Detritus & sediment decay		203	267	0	1.02-1.04
Non-growth related biological activity		204	268	0	1.02-1.04
Type 1 Fish Related Coefficients					
Maximum growth rate in 1/day		45	78	.02	.02-.03
Respiration rate in 1/day		48	81	.003	.001-.005
Natural mortality rate in 1/day		51	84	.002	.001-.005
Toxic mortality rate in 1/day/mg/ℓ			87	0	0-1

* No override capability is provided for the Q_{10} temperature coefficient for reaeration in the lake model.

TABLE IV-1

Physical, Chemical and Biological Coefficients
(continued)

	Coefficient Codes Reservoir	Stream	Default Value	Normal Range
Growth half saturation constant for grazing zooplankton in mg/ℓ	54	90	.2	.05-.2
Feeding preference number 1 relating benthic animals to zooplankton in m^2/ℓ	60	96	.005	.001-.01
Feeding preference number 2 relating aquatic insects to zooplankton in m^2/ℓ		99	.005	.001-.01
Assimilative efficiency	63	102	.5	.3-.6
Particulate fraction of excreta	66	105	.6	.5-.8
Type 2 Fish Related Coefficients				
Maximum growth rate in 1/day	46	79	.025	.02-.03
Respiration rate in 1/day	49	82	.003	.001-.005
Natural mortality rate in 1/day	52	85	.002	.001-.005
Toxic mortality rate in 1/day/mg/ℓ		88	0	0-1
Growth half saturation constant for grazing zooplankton in mg/ℓ	55	91	.2	.05-.2
Feeding preference number 1 relating benthic animals to zooplankton in m^2/ℓ	61	97	.005	.001-.01
Feeding preference number 2 relating aquatic insects to zooplankton in m^2/ℓ		100	.005	.001-.01
Assimilative efficiency	64	103	.5	.3-.6
Particulate fraction of excreta	67	106	.6	.5-.8

TABLE IV-1

Physical, Chemical and Biological Coefficients
(continued)

	Coefficient Codes			
	Reservoir	Stream	Default Value	Normal Range
Type 3 Fish Related Coefficients				
Maximum growth rate in 1/day	47	80	.02	.02-.03
Respiration rate in 1/day	50	83	.003	.001-.005
Natural mortality rate in 1/day	53	86	.002	.001-.005
Toxic mortality rate in 1/day/mg/ℓ		89	0	0-1
Growth half saturation constant for grazing benthic animals and/or aquatic insects in mg/m^2	56	92	500	100-2000
Feeding preference number 1 relating organic sediment to benthic animals and aquatic insects	62	101	.001	.001-.01
Feeding preference number 2 relating benthic algae type 1 to benthic animals and aquatic insects		95	.2	.1-.5
Feeding preference number 3 relating benthic algae type 2 to benthic animals and aquatic insects		98	.5	.5-1.
Assimilative efficiency	65	104	.5	.3-.6
Particulate fraction of excreta	68	107	.6	.5-.8
Benthic Animals Related				
Maximum growth rate in 1/day	39	71	.04	.02-.05
Respiration rate in 1/day	40	72	.008	.001-.01
Natural mortality rate in 1/day	41	73	.004	.001-.005
Growth half saturation constant for grazing organic sediment in mg/m^2	42	75	2000	100-2000
Assimilative efficiency	43	76	.6	.4-.8
Particulate fraction of excreta	44	77	.6	.5-.8

TABLE IV-1

Physical, Chemical and Biological Coefficients
(continued)

	Coefficient Codes			
	Reservoir	Stream	Default Value	Normal Range
Aquatic Insects Related				
Maximum growth rate in 1/day		61	.1	.05-.2
Respiration rate in 1/day		62	.01	.01-.03
Natural mortality rate in 1/day		63	.005	.002-.005
Toxic mortality rate in 1/day/mg/ℓ		64	0	0-1
Growth half saturation constant for grazing benthic algae type 1 in mg/m^2		65	1000	100-1000
Feeding preference number 1 relating benthic algae type 2 to benthic algae type 1		67	2.	1-2
Feeding preference number 2 relating organic sediment to benthic algae type 1		68	.05	.01-.1
Assimilative efficiency		69	.6	.4-.7
Particulate fraction of excreta		70	.6	.5-.8
Zooplankton Related				
Maximum growth rate in 1/day	30	51	.15	.1-.3
Respiration rate in 1/day	31	52	.015	.01-.03
Natural mortality in 1/day	32	53	.01	.005-.02
Toxic mortality rate in 1/day/mg/ℓ		54	0	0-1
Growth half saturation constant for grazing type 1 phytoplankton in mg/ℓ	33	55	.3	.2-.6
Feeding preference number 1 relating type 2 phytoplankton to type 1 phytoplankton	35	57	.5	.5-1.
Feeding preference number 2 relating detritus to type 1 phytoplankton	36	58	.2	.1-1.

TABLE IV-1

Physical, Chemical and Biological Coefficients
(continued)

	Coefficient Codes Reservoir	Stream	Default Value	Normal Range
Assimilative efficiency	37	59	.6	.5-.8
Particulate fraction of excreta	38	60	.6	.5-.8
Type 1 Phytoplankton Related				
Maximum growth rate in 1/day	16	19	2.	1.-2.
Respiration rate in 1/day	18	23	.15	.05-.20
Toxic mortality rate in 1/day/mg/ℓ		27	0	0-1
Growth half saturation constants				
Light energy in kcal/m^2/sec	20	31	.003	.002-.004
Phosphate as P in mg/ℓ	22	35	.03	.02-.05
Ammonia plus nitrate as N in mg/ℓ	24	39	.06	.04-.10
Carbon dioxide as C in mg/ℓ	26	43	.025	.02-.04
Sinking velocity in M/day	28		.5	0-2
Sinking velocity in M/day		47	0	0-2
Type 2 Phytoplankton Related				
Maximum growth rate in 1/day	17	20	2.5	1.-3.
Respiration rate in 1/day	19	24	.2	.05-.2
Toxic mortality rate in 1/day/mg/ℓ		28	0	0-1
Growth half saturation constants				
Light energy in kcal/m^2/sec	21	32	.004	.003-.006
Phosphate as P in mg/ℓ	23	36	.03	.02-.05
Ammonia plus nitrate as N in mg/ℓ	25	40	.06	.04-.10
Carbon dioxide as C in mg/ℓ	27	44	.025	.02-.04
Sinking velocity in M/day	29		.1	0-1
Sinking velocity in M/day		48	0	0-1

TABLE IV-1

Physical, Chemical and Biological Coefficients
(continued)

	Coefficient Codes		Default	Normal
	Reservoir	Stream	Value	Range
Type 1 Benthic Algae Related				
Maximum growth rate in 1/day		21	1.	.5-1.5
Respiration rate in 1/day		25	.07	.05-.2
Toxic mortality rate in 1/day/mg/ℓ		29	0	0-1
Growth half saturation constants				
Light energy in kcal/m^2/sec		33	.003	.002-.004
Phosphate as P in mg/ℓ		37	.03	.02-.05
Ammonia plus nitrate as N in mg/ℓ		41	.06	.04-.10
Carbon dioxide as C in mg/ℓ		45	.025	.02-.04
Scour rate in 1/day/m^2/sec		49	.02	0-1
Type 2 Benthic Algae Related				
Maximum growth rate in 1/day		22	1.2	.5-1.5
Respiration rate in 1/day		26	.1	.05-.2
Toxic mortality rate in 1/day/mg/ℓ		30	0	0-1
Growth half saturation constants				
Light energy in kcal/m^2/sec		34	.004	.003-.006
Phosphate as P in mg/ℓ		38	.03	.02-.05
Ammonia plus nitrate as N in mg/ℓ		42	.06	.04-.10
Carbon dioxide as C in mg/ℓ		46	.025	.02-.04
Scour rate in 1/day/m^2/sec		50	.1	0-.2
Decay Rates in 1/day				
Carbonaceous BOD decay rate	105	156	.3	.1-.3
Ammonia decay rate	106	157	.2	.05-.2
Nitrite decay rate	107	158	.5	.2-.5
Coliform die off rate	110	161	1.0	.5-2.
Detritus decay rate	108	159	.02	.005-.05
Organic sediment decay rate	109	160	.005	.001-.01

TABLE IV-1

Physical, Chemical and Biological Coefficients
(continued)

	Coefficient Codes		Default	Normal
	Reservoir	Stream	Value	Range
Stoichiometric Equivalences				
Carbon released with carbonaceous BOD decay	111	162	.2	.2
Oxygen consumed with ammonia (N) decay	112	163	3.5	3.5
Oxygen consumed with nitrite (N) decay	113	164	1.2	1.2
Oxygen consumed with detritus and organic sediment decay	114	165	1.6	1.6-2
Oxygen consumed with biomass respiration	115	166	1.6	1.6-2
Oxygen produced with algae growth	116	167	1.6	1.6
Settling Velocity in m/sec				
Detritus	117		.5	0-2
Detritus		168	0	0-2
Phytoplankton Type 1	28		.5	0-2
Phytoplankton Type 1		47	0	0-2
Phytoplankton Type 2	29		.1	0-1
Phytoplankton Type 2		48	0	0-1
Shading/Light Attenuation Constant in 1/m/mg/ℓ for:				
Phytoplankton Type 1	118	169	.2	.15-.2
Phytoplankton Type 2	119	170	.2	.15-.2
Zooplankton	120	171	.02	.01-.05
Detritus	121	172	.1	.01-.25

TABLE IV-1

Physical, Chemical and Biological Coefficients
(continued)

	Coefficient Codes			
	Reservoir	Stream	Default Value	Normal Range
Suspended Solids Number 1*	122	173	0	0-.5
Suspended Solids Number 2*	123	174	0	0-.5
Suspended Solids Number 3*	124	175	0	0-.5
Suspended Solids Number 4*	125	176	0	0-.5
Suspended Solids Number 5*	126	177	0	0-.5

* See Table IV-2 for relationship between partical size and the Shading/ Light Attenuation Constants.

Chemical Composition of Biota and Detritus

The chemical composition data specify the chemical makeup (i.e., carbon, nitrogen and phosphorus) of all organic materials within the model. To maintain continuity of mass, the composition of all organic constituents (i.e., biota, detritus and organic sediment) must be kept the same since all biota cycle carbon, nitrogen and phosphorus proportional to their own chemical makeup.

Rate Coefficients Temperature Adjustment Factors

The rates at which chemical and biological processes take place in the aquatic environment are normally a function of temperature, therefore rate coefficients describing these processes must be adjusted to the ambient temperature. Two approaches are used within the models to make the required temperature adjustments (see Figure IV-1).

1. Temperature Limits

The temperature limit method assumes that the rate at which a reaction takes place is a function of two exponential curves similar to those depicted in Figure IV-1. The temperature tolerances define the curves used to modify the growth, respiration, and mortality rates of the biota and the decay rates of the abiotic substances. The temperatures, T_1 and T_4, are the lower and upper tolerance limits, respectively, for growth and decay. The temperatures, T_2 and T_3, define the optimum range at which the growth or decay rate is a maximum. The upper range of the optimum temperature, T_3, and the upper tolerance limit, T_4, for biota respiration and mortality and decay processes are assumed outside the range of normal prototype temperatures and need not be specified.

2. Temperature Coefficients

The "Q_{10}" method assumes that the rate at which a reaction takes place increases exponentially with increases in temperature. The rate coefficient at any temperature can be calculated by:

$$R_a = R_{20} \cdot Q_{10}^{(T_a - 20)} \qquad \text{IV-1}$$

where R_a = rate coefficient adjusted to the ambient temperature

R_{20} = rate coefficient at 20 degrees celsius

Q_{10} = Q_{10} temperature coefficient

T_a = ambient temperature in degrees celsius

The relationship between temperature and the correction factor for a typical temperature coefficient (i.e., Q_{10} = 1.04) is shown in Figure IV-1.

When the default Q_{10} temperature coefficients are used, the Q_{10} temperature correction factor is applied to the reaeration coefficients and coliform die-off rates and the temperature limit approach is applied to all others.

At the users option, the Q_{10} approach may be used for any or all decay rates and biota respiration and mortality rates by assigning an appropriate value to the respective Q_{10} coefficient. If this option is chosen, the value of the corresponding rate coefficient would then correspond to a temperature of 20 degrees celsius instead of the maximum rate and may need to be reduced (e.g., the default BOD decay rate of 0.3 is an appropriate maximum value while a value of 0.2 is appropriate at 20°C).

Maximum Specific Growth Rates

The maximum specific growth rate is the maximum fractional increase in biomass which occurs at optimum temperatures (i.e., $T_2 \leq T_a \leq T_3$) with unlimited nutrients, prey or other food sources. The growth rate at sub-optimal ambient conditions is determined by:

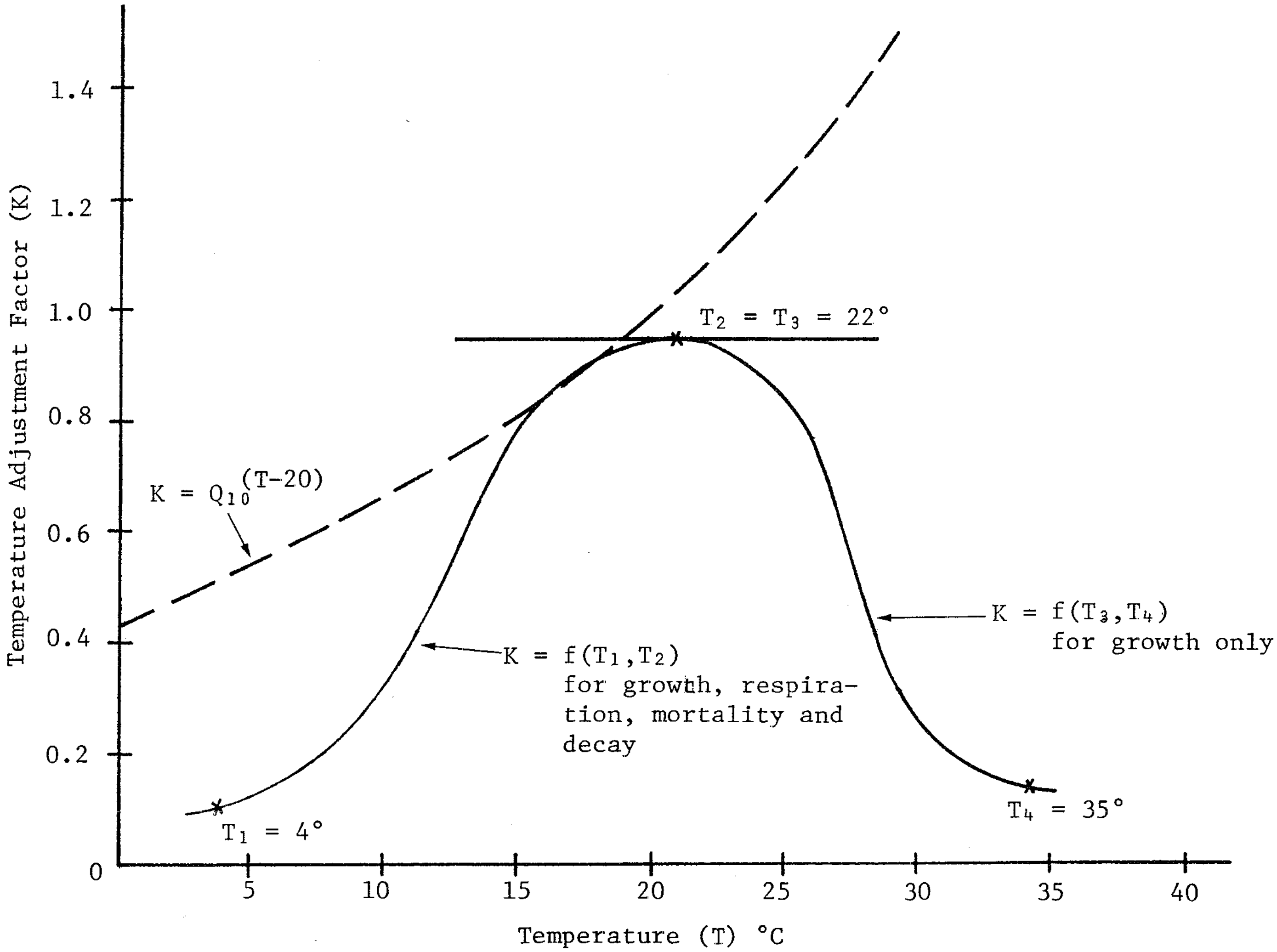


FIGURE IV-1

Rate Coefficient Temperature
Adjustment Factors

$$G_a = \hat{G} \cdot K_t\left(\frac{F}{F_2 + F}\right) \qquad \text{IV-2}$$

where G_a = growth rate at ambient conditions in 1/day

$\hat{G}$ = maximum growth rate in 1/day

K_t = rate coefficient temperature adjust factor

F = concentration of nutrients, prey or other food supply in mg/ℓ

F_2 = half saturation constant in mg/ℓ

Half Saturation Constants

The half saturation constants or Michaelis-Menton constants are used to adjust the growth rate of an organism to the available nutrient, prey or other food supply. The half saturation constant is the concentration of the nutrient, prey or other food source at which an organism will grow at half its maximum rate.

Respiration Rates

The respiration rate is that fraction of the biomass which is converted back to inorganic carbon, nitrogen and phosphorus by the normal process of respiration of the organism. Respiration rates at ambient conditions are a function of the rate coefficient temperature adjustment.

Mortality Rates

The mortality rate is the fraction of the biomass which is converted to detritus or organic sediment by death of the particular organism. Within the reservoir model only natural mortality is considered while both natural and toxicity induced mortality is considered in the stream. The mortality rate under ambient conditions is determined by:

$$M_a = K_t\left(M_1 + M_2 \cdot T_u \cdot \frac{O_2^*}{O_2}\right) \qquad \text{IV-3}$$

where M_a = mortality rate under ambient conditions in 1/day

K_t = rate coefficient temperature adjustment factor

M_1 = natural mortality rate in 1/day

M_2 = toxicity induced mortality in 1/day/mg/ℓ

T_u = unit toxicity in mg/ℓ

O_2^* = dissolved oxygen concentration at saturation in mg/ℓ

O_2 = dissolved oxygen concentration in the ambient in mg/ℓ

Note that mortality for algae is incorporated directly into the algal respiration term and algae are assumed to become sediment when they settle to the bottom of a stream or reservoir.

Feeding Preference

Feeding preferences are used to relate concentrations or secondary food sources to the primary food source. This allows input of a single half saturation constant per organism to relate growth to an equivalent concentration of its primary food source. The equivalent concentration of the primary food source is determined by:

$$F = F_1 + \Sigma P_n F_n \qquad \text{IV-4}$$

where F = equivalent concentration of the primary food source in mg/ℓ

F_1 = concentration of primary food source

P_n = feeding preference factor for food source "n"

F_n = concentration of the secondary food source

Note that several feeding preference factors must account for both the desirability of the food source and differences in units (e.g., the primary prey for fish type 1 is zooplankton which are in mg/ℓ units and the secondary prey is benthic animals which are in mg/m^2 units).

Assimilation Efficiency

The assimilation efficiency is that fraction of the ingested food that is absorbed or assimilated by the organism. The assimilation efficiency also controls the amount of food consumed and the amount of excrement. The amount of a particular food source consumed is determined by:

$$GZ_1 = \frac{G \cdot C}{AE} \; \frac{P_1 F_1}{\Sigma P_n \cdot F_n} \qquad \text{IV-5}$$

and the amount of exreta determined by:

$$EX = \Sigma GZ_n - G \cdot C \qquad \text{IV-6}$$

where GZ = the amount of food source consumed in mg/ℓ

G = the predator growth rate in 1/day

C = predator concentration in mg/ℓ

AE = assimilation efficiency

P = feeding preference factor

F = concentration of the food source

EX = total excrement in mg/ℓ

Particulate Fraction of Excreta

An organisms waste products or excrement may be in either a dissolved or particulate form. The particulate fraction of excreta controls the ratio between the two forms. The particulate form contributes to the detritus or sediment pool and the remaining dissolved form is returned to the nutrient pool. Dissolved oxygen consumption resulting from the feeding process is proportional to the non-particulate form.

Decay Rates

The decay rate is that fraction of the constituent which is removed or converted to other constituents by bacterial or chemical decomposition. In some cases this decay is dependent on the presence of oxygen (e.g., BOD, NH_3, and NO_2 may be generally considered as aerobic reactions). However, decay of sediments and detritus may be either aerobic or anaerobic with different decay rates for each type. Such refinements are not presently incorporated in the model, although oxygen dependent reactions are programmed to be inhibited by a lack of available oxygen.

Stoichiometric Equivalences

Stoichiometric equivalence is the ratio of the amount of two constituents needed for a given chemical or biologic reaction (e.g., 3.5 grams of oxygen are consumed when one gram of ammonia nitrogen is oxidized to nitrite).

Settling Velocity

The settling velocity defines the rate of fall of algae, detritus and inorganic suspended solids through the water column. It is of particular significance in the reservoir model where algae and detritus settling into the hypolimnetic region may create a significant oxygen sink. No default settling velocity (i.e., default settling velocity of zero) is provided for inorganic suspended solids since the partical size and therefore the settling velocity must be user specified. Table IV-2 provides typical settling velocities for different suspended solids classes.

Shading/Light Attenuation Constants

The shading/light attenuation constants relate light attenuation characteristics within the water body to suspended particulate material. No default values for the shading/light attenuation constants (i.e., default shading/ light attenuation constants of zero) have been provided since partical size is an input item. Typical values are provided in Table IV-2.

TABLE IV-2

Suspended Solids Characteristics

Class	Particle Size (mm)	Temperature* (°C)	Settling Velocity* (cm/sec)	Light Attenuation Constant (1/m/mg/ℓ)
Colloidal	.001	-	0	.2 - .5
Very fine silt	.004-.008	5	.006	.1 - .2
		20	.008	
		35	.010	
Fine silt	.008-.016	5	.012	.05 - .1
		20	.019	
		35	.024	
Medium silt	.016-.031	5	.041	.02 - .05
		20	.068	
		35	.086	
Coarse silt	.031-.0625	5	.11	.01 - .02
		20	.18	
		35	.23	
Very fine sand	.0625-.125	5	.49	0 - .01
		20	.61	
		35	.81	

* Settling velocities and their relationship with temperature were obtained from personal correspondence with Dr. Michael Gee, HEC.

Fish Harvest Rates

The fish harvest rate is that fraction of the total fish biomass removed by predation and fishing within a 30 day period (i.e., 1/month units). Fish harvest rates which vary with time of year and the type of fish, normally range from zero during periods of no fishing to .2 to .5 per month for desirable fish types during periods of intensive fishing.

No default values have been provided (i.e., default fishing rates of zero) since harvest rates are specific to prototype situations. Fish harvest rates may be input using the coefficient code numbers listed in Table IV-3.

TABLE IV-3

Fish Harvest Coefficient Code Numbers

Fish Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Coefficient Code Number											
Reservoir Model												
Fish Type 1	69	70	71	72	73	74	75	76	77	78	79	80
Fish Type 2	81	82	83	84	85	86	87	88	89	90	91	92
Fish Type 3	93	94	95	96	97	98	99	100	101	102	103	104
Stream Model												
Fish Type 1	120	121	122	123	124	125	126	127	128	129	130	131
Fish Type 2	132	133	134	135	136	137	138	139	140	141	142	143
Fish Type 3	144	145	146	147	148	149	150	151	152	153	154	155

Insect Emergence Rate

The insect emergence rate is the fraction of the aquatic insect biomass which matures and leaves the water body to become a terrestrial organism during a 30 day period.

No default values are provided for emergence rates (i.e., default emergence rates of zero) since they vary with the aquatic insects species and the geographical location. Emergence rates appropriate for streams of the Pacific Northwest as reported by Chen [20] are presented in Table IV-4.

TABLE IV-4

Aquatic Insect Emergence Rates

Month	Coefficient Code	Emergence Rate (1/month)
Jan	108	.4
Feb	109	0
Mar	110	.4
Apr	111	0
May	112	.1
Jun	113	.1
Jul	114	.15
Aug	115	.15
Sep	116	.1
Oct	117	.07
Nov	118	0
Dec	119	0

Gas Exchange Rates

The rate of gas transfer (i.e., carbon dioxide and oxygen) through the air-water interface in both the stream and reservoir models is calculated using the following expression:

$$R = k \cdot K_2(G^* - G) \qquad \text{IV-7}$$

where R = rate of gas transfer in mg/ℓ/day

K_2 = the reaeration coefficient for oxygen in 1/day

k = 1 for oxygen transfer and 0.78 for carbon dioxide transfer

G^* = concentration of dissolved oxygen or carbon dioxide at saturation.

G = ambient concentration of dissolved oxygen or carbon dioxide.

While this expression is used for both the stream and reservoir simulation, K_2 is determined differently for each.

1. Reservoir Model

For the reservoir model, the following expression is used.

$$K_2 = (a + b\ V^2)\ \frac{1}{\Delta z} \qquad \text{IV-8}$$

where K_2 = the reaeration coefficient for oxygen in 1/day
a,b = empirical coefficients* (i.e., 0.50 and 0.025, respectively)
V = wind speed in meters per second
Δz = the surface element thickness in meters

2. Stream Model

For the stream simulation, the user has the option of selecting any one of the following seven methods for computing the dissolved oxygen reaeration coefficient:

(1) Churchill et. al. $$K_2 = 5.031\ \frac{V^{.969}}{H^{1.673}} \qquad \text{IV-9}$$

(2) O'Connor & Dobbins $$K_2 = 3.951\ \frac{V^{.5}}{H^{1.5}} \qquad \text{IV-10}$$

(3) Owens et. al. $$K_2 = 5.346\ \frac{V^{.67}}{H^{1.85}} \qquad \text{IV-11}$$

(4) Langbien and Durum $$K_2 = 5.133\ \frac{V}{H^{1.333}} \qquad \text{IV-12}$$

* The values of a and b were numerically derived from a curve fit of data presented by Kanwisher [21]

(5) Thackston and Krenkel $K_2 = 24.95 \, (1 + F^{.5}) \, \frac{V^*}{H}$ IV-13

(6) Tsivoglou and Wallace $K_2 = 3.78 \, \frac{\Delta h}{\Delta t}$ or $K_2 = 13600 \, (S)(V)$ IV-14

(7) Input K_2 directly

where K_2 = reaeration coefficient in 1/day
V = stream velocity in m/sec
H = hydraulic depth in meters
F = Fronde number = $V/\sqrt{Hg}$
V^* = shear velocity, meters/sec = $(H \cdot S \cdot g)^{.5}$
Δh = water surface elevation change, meters
Δt = time of travel corresponding to Δh, days
S = slope of water surface, meters/meters
g = acceleration due to gravity, meters^2/sec

The default method for computing reaeration is the O'Connor and Dobbins method. The user may select one of the other methods by specifying a coefficient code number of 259 along with the method number.

V. SOLUTION TECHNIQUE FOR WATER QUALITY

The reservoir and stream quality modules of the WQRRS model use similar techniques for solving the differential equations which represent the response of the water quality and ecological constituents. For those constituents which are passively transported with the movement of water (i.e., advection and diffusion) a Gaussian reduction scheme is used to solve the set of simultaneous equations. For those constituents which are assumed affixed to the bottom or are self mobile (i.e., fish) the equations are solved by simply multiplying the time derivatives by the computation time step increment.

The differential equations are coupled between constituents (e.g., there are terms in the oxygen equation that depend on BOD and other constituents), however, the constituents are processed sequentially beginning with least dynamic constituents and regressing to the most dynamic. Sources and sinks resulting from this coupling are assumed constant over the time step. The magnitude of the source and sink term is a function of the present concentration of the coupled constituents (e.g., end of time step concentration for constituents previously processed and beginning of time step concentration for constituents yet to be processed).

For reactions that demand oxygen, the model checks for oxygen availability before processing the parameter and adjusting the demand rate to reflect this availability.

As an example of the solution technique the general mass balance equation III-1 will be used: i.e.,

$$\bar{v} \frac{\partial C}{\partial t} = \Delta z \cdot Qz \frac{\partial C}{\partial z} + \Delta z \cdot Az \cdot Dc \frac{\partial C^2}{\partial z^2} + Q_i C_i - Q_o C \pm \Delta S$$

The equation is rewritten in a form where a finite difference scheme is used to describe all the derivative processes. For element i adjacent to elements i-1 and i+1 (see Figure V-1) the general mass balance equation becomes

$$\bar{v}_i \left[\frac{\partial C}{\partial t}\right]_i = C_{i-1}\left\{\left[\frac{A_z D_z}{\Delta z}\right]_i + Qu_i\right\} - C_i\left\{\left[\frac{A_z D_z}{\Delta z}\right]_i + \left[\frac{A_z D_z}{\Delta z}\right]_{i+1} + Qd_i\right.$$

$$\left. + Qu_{i+1} + Qw + \frac{\partial \bar{v}}{\partial t}\right\} + C_{i+1}\left\{\left[\frac{A_z D_z}{\Delta z}\right]_{i+1} + Qd_{i+1}\right\} + \Sigma Q_x C_x \pm \bar{v}S \qquad \text{V-1}$$

where

subscripts i, i-1, i+1 denote element numbers

$\bar{v}$ = the volume of the fluid element

C = the constituent concentration

t = computation time step increment

A_z = cross-sectional area at the fluid element boundary

D_z = effective diffusion coefficient

Δz = element thickness

Qu = upward advective flow between elements

Qd = downward advective flow between elements

Qw = flow removed from the element

Qx = inflow rate to the element

Cx = constituent concentration in the inflow

S = sources and sinks

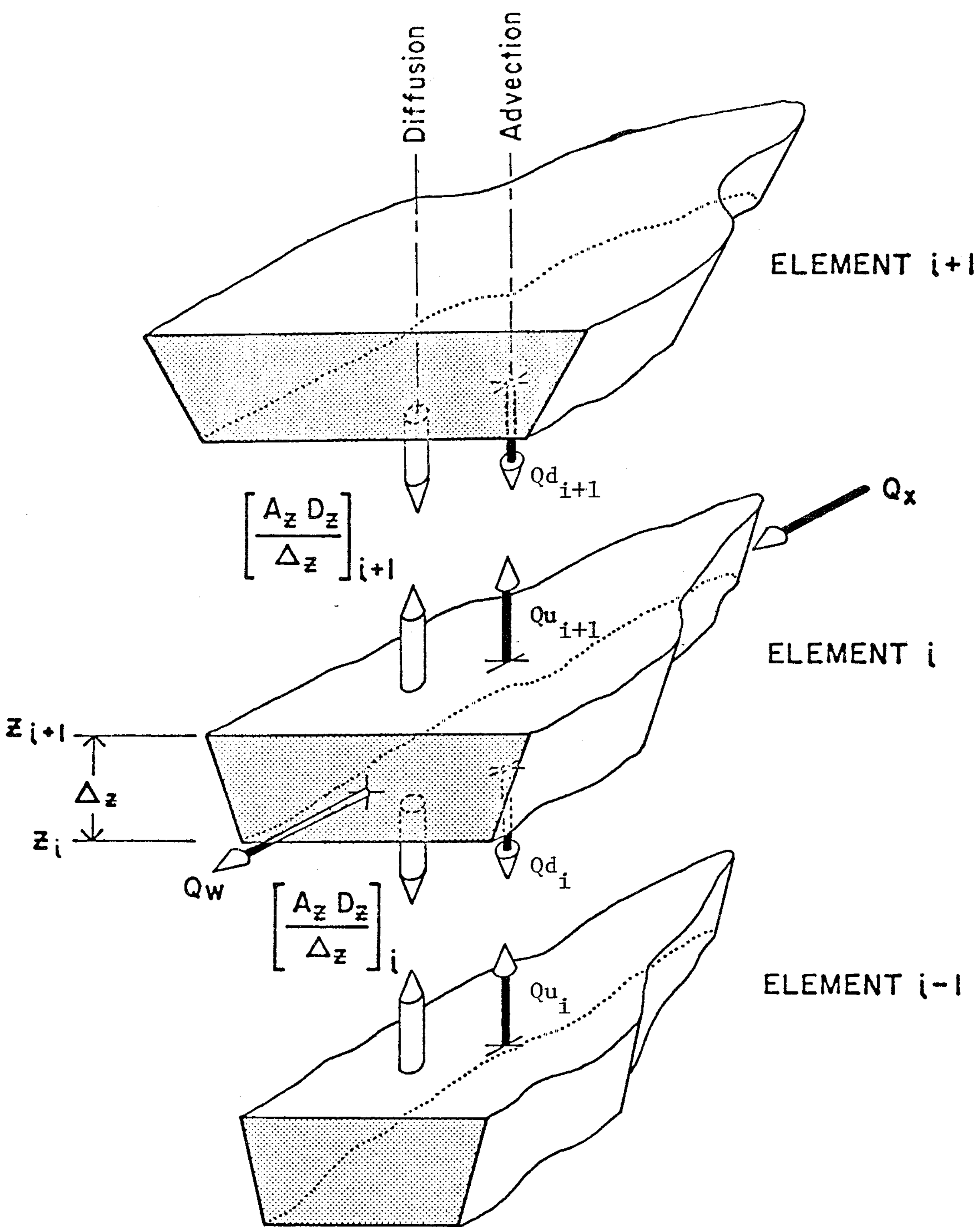


FIGURE V-1

Physical Mass Transfers Between Elements

A finite difference equation of this type is formed for each element and integrated with respect to time. The system of finite difference mass balance equations represents the response of the constituent within the entire stream or reservoir system and, with the aid of a numerical integration technique, the equations are solved with respect to time.

The mass balance for any constituent, c, at any element, i, can take the form

$$\bar{v}_i \dot{c}_i = c_{i-1} s_{i-1} - c_i s_i + c_{i+1} s_{i+1} + p_i \qquad \text{V-2}$$

where

$\bar{v}_i$ = volume of element i

$\dot{c}_i$ = time rate of change of concentration c in element i

c_i = concentration of c in element i

s_i = the bracketed terms of the mass balance equations (i.e., advection and diffusion)

p_i = the constant term for each element i (i.e., sources and sinks)

The complete system of mass balance equations for the n elements can be written in the matrix form

$$[v]\ \{\dot{c}\} = [s]\ \{c\} + \{p\} \qquad \text{V-3}$$

where

[v] is an n x n matrix with the element volumes on the diagonal and zeroes elsewhere

$\{\dot{c}\}$ is a column matrix of the rates of change of c in each of the n elements

[s] is an n x n matrix of the coefficients which multiply the dependent variable, c.

$\{c\}$ is a column matrix of the concentrations c at each segment

$\{p\}$ is a column matrix of the constant terms for each segment

To integrate the basic equation over time, introduce the following numerical approximation for each element:

$$c_{t+\Delta t} = c_t + \frac{\Delta t}{2} (\dot{c}_t + \dot{c}_{t+\Delta t}) \qquad \text{V-4}$$

where

c_t, $c_{t+\Delta t}$ = the values of the dependent variable at the beginning and end of an integration interval, respectively

$\dot{c}_t$, $\dot{c}_{t+\Delta t}$ = the values of the rate of change of the dependent variable at the beginning and end of an integration interval, respectively

Δt = the length of an integration interval

At any point in time c_t and $\dot{c}_t$ are known, thus the expression becomes

$$c_{t+\Delta t} = B + \frac{\Delta t}{2} \dot{c}_{t+\Delta t} \qquad \text{V-5}$$

where

$$B = c_t + \frac{\Delta t}{2} \dot{c}_t$$

Equation V-5 rewritten in matrix form is

$$\{c\} = \{B\} + \frac{\Delta t}{2} \{\dot{c}\} \qquad \text{V-6}$$

where

$\{c\}$ = a column matrix of the concentrations at the end of the time interval

$\{B\}$ = a column matrix of the terms defined in V-5

$\{\dot{c}\}$ = a column matrix of the time rates of change of the concentrations c

Substituting V-6 into V-3,

$$[v]\ \{\dot{c}\} = [s]\ \{B\} + \frac{\Delta t}{2}\ [s]\ \{\dot{c}\} + \{p\} \qquad \text{V-7}$$

or

$$[s^*]\ \{\dot{c}\} = \{p^*\} \qquad \text{V-8}$$

where

$$[s^*] = [v] - \frac{\Delta t}{2}\ [2]$$

$$\{p^*\} = [s]\ \{B\} + \{p\}$$

Equation V-8 forms the basis for a solution, as there is only one unknown in the equation, $\{\dot{c}\}$. The following recursive scheme can be used for the numerical solution of equation V-8.

1. Form the vector $\{B\}$ from the initial condition or the solution just completed.
2. From the known hydraulic solution (assumed to be computed externally) and known boundary conditions, define the conditions which will exist at the end of the interval.
3. With known values of $[v]$, $[s]$, and $\{p\}$, form $[s^*]$ and $\{p^*\}$.
4. Solve for $\{\dot{c}\}$ at time $(t + \Delta t)$.
5. Computer $\{c\}$ by substitution in equation V-6.

The above recursive scheme is that used in both computer codes and has proven to be very stable.

VI. PROGRAM STRUCTURE

GENERAL SYSTEM STRUCTURE

The river basin water quality program is a modular set of mathematical computer models developed specifically for dynamic analysis of water quality in river and reservoir systems. Three separate but integrable modules are included within the river basin water quality program. The reservoir module is a stand alone water quality program, while the stream analysis programs consist of a dynamic flow computation module and a dynamic stream water quality module. A permanent tape or disk file (stream hydraulics interface) is required to transfer data between the two stream modules.

The system analysis procedure for river basin water quality modeling can be performed with the reservoir results being used as input to the stream quality module or vice versa. The transfer of data between the quality modules is accomplished using a permanent tape or disk file (reservoir/stream quality interface).

RESERVOIR MODULE ROUTINES

The reservoir module is composed of a main program and nineteen subroutines. The computational sequence is shown on Figure VI-1 and the relationship between routines is shown on Figure VI-2. A description of the function of each routine is provided below.

PROGRAM MAIN is the executive program controlling operation of the reservoir module. It begins by reading, processing and printing job titles, simulation and print controls, external tape and file assignments, invariant meteorological data, and miscellaneous physical data. It then calls

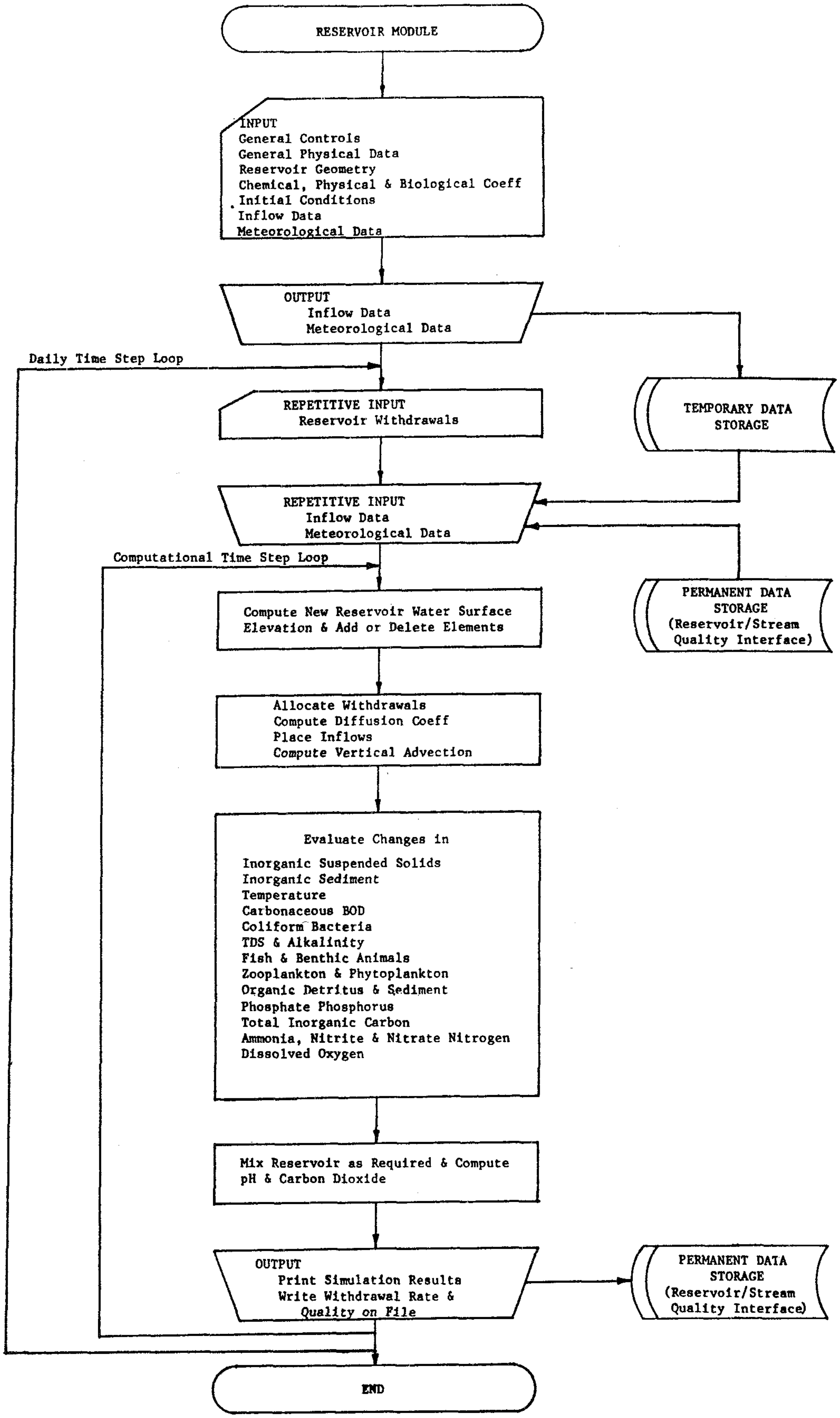


FIGURE VI-1

Reservoir Module Computational Sequence

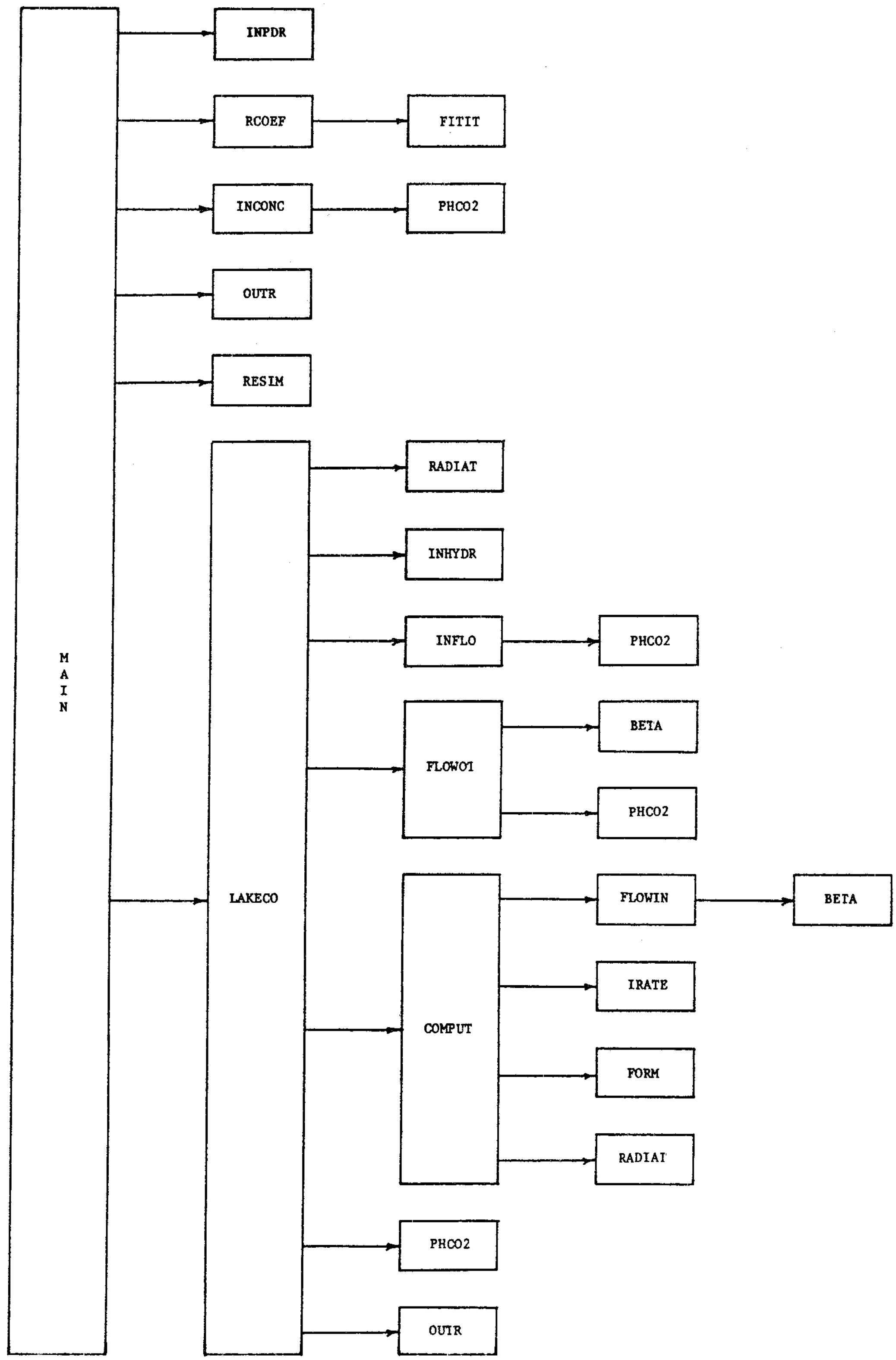


FIGURE VI-2

Reservoir Module Structure

INPDR to input reservoir geometry data, RCOEF to input physical, chemical and biological coefficients, INCONC to input and OUTR to print the initial quality conditions and RESIM to input tributary inflow and meteorological data. Finally LAKECO is called which controls the dynamic quality simulation of the reservoir.

SUBROUTINE INPDR inputs all reservoir geometry data. It begins by reading and printing the effective reservoir width at the outlet elevations, the effective reservoir length at all tributary inflow locations, the depth-area table and the width at withdrawal levels. Element volumes, average cross-sectional areas and other physical parameters are then calculated and printed.

SUBROUTINE RCOEF reads and prints all chemical, physical and biological coefficients. Default values are provided for most coefficients, therefore the user need only input those coefficients he wishes to change. No default values are provided for sediment related coefficients since all coefficients are a function of sediment size which is also user specified. The rate coefficients are converted to internal units and temperature adjustment factors are set up for the temperature-dependent coefficients. FITIT is called to form a quadratic relationship between temperature and inorganic suspended solids settling rates.

SUBROUTINE FITIT fits a second order curve through three points using a least squares method.

SUBROUTINE INCONC reads the initial water quality conditions. Either uniform or depth varying initial quality conditions may be assigned. If non-uniform initial quality conditions are specified, two or more sets of initial quality cards are read, establishing points of known quality. The quality of any remaining elements is determined by straight line interpolation.

PHCO2 is called to compute the initial concentrations of total inorganic carbon and carbon dioxide. This subroutine is separated into two sections. The first section calculates the total inorganic carbon

(CO_2+HCO_3^-+CO_3^{--}) and carbon dioxide (CO_2) concentrations based on equilibrium relationships with pH and alkalinity. This section is used to determine the concentrations of these constituents in the inflow and in the lake at the beginning of the simulation. The second section utilizes the same equilibrium relationships to determine the pH and CO_2 concentration based on alkalinity and total inorganic carbon. This section is used to calculate the pH and CO_2 concentration in the withdrawals and within the lake.

SUBROUTINE OUTR is the routine which prints the initial conditions and the simulation results. After unit conversions and minor calculations are performed, general information about the simulation is printed. The tributary inflow and combined outflow quantity and quality are printed along with a summary of the outflow distribution resulting from the selective withdrawal scheme. Finally, the status of the fish crop and a summary of the water quality conditions within the reservoir are printed.

SUBROUTINE RESIM is separated into two sections. In the first section, tributary inflow data are read and a temporary or permanent disk or tape file containing a continuous record of daily average tributary inflow rates and quality is created. It begins by reading controls which define the length of record and which tributary inflow quality data are to be read and printed. Tributary inflow data may be read at any time interval with the rate or quality held constant until overridden by a new value. In the second section, meteorological data are read and printed and a temporary or permanent disk or tape file containing a continuous record of meteorological data created. Meteorological data may be input at irregular day intervals, however, a pre-specified hourly interval must be maintained during the day (e.g., hourly meteorological data input at the first and fifteenth day of each month). The daily weather pattern is repeated until overridden by new data.

SUBROUTINE LAKECO is the routine which controls the dynamic quality simulation of the reservoir. After minor initialization, it calls RADIAT to input the initial meteorological data, INHYDR for the initial withdrawal rates and outflow allocation and INFLO for the initial tributary inflow rates and quality. The withdrawal rate and quality are then written on a file (quality interface) for use as input to subsequent quality simulations of the stream or reservoir immediately downstream. Upon entering the daily computational loop, the reservoir volume is computed and checked to see that the maximum volume has not been exceeded. If the maximum has been exceeded, the quality simulation is terminated, however the inflow and withdrawal rates are read and the reservoir volume calculated and printed for the remainder of the simulation period. Within the inner loop representing the fundamental time step, the water surface elevation is computed and the need for adding or deleting an element due to a rising or falling water surface is determined. An element is added when the water surface elevation increases to half the element thickness above the surface element and deleted when the water surface elevation falls below the midpoint of the surface element. When the number of elements change, the water quality of each element is adjusted up or down so that the water quality of the new surface element is the same as the previous surface element. After COMPUT is called to evaluate the environmental changes, a check is made to see if a portion or all of the reservoir is subject to convective mixing. If due to cooling at the water surface, the density gradient is less than the minimum permissible for stability, the reservoir is mixed to a level where all density gradients are greater than the minimum required for stability. PHCO2 is then called to compute the pH and dissolved carbon dioxide concentration for each element. INHYDR is called to allocate the withdrawal to the various outlets, FLOWOT is called to compute the end of time step withdrawal quality and OUTR is called to print a summary of the simulation results. The withdrawal quality is written on the quality interface file and finally RADIAT, INHYDR and INFLO are called to input new meteorological, withdrawal and inflow data as required for the next time step.

SUBROUTINE RADIAT is separated into three sections. The first section is called only if the equilibrium temperature concept is being used. The equilibrium temperature, heat exchange coefficient, shortwave solar radiation, wind speed and vapor pressure are read from the equilibrium data file and processed. Sections two and three are used if the heat budget approach is being used. Section two reads a set of meteorological data from the meteorological data file generated in RESIM, makes necessary unit conversions, and then by straight line interpolation generates meteorological data for each hour of the day. The long wave atmospheric and shortwave solar radiation are calculated at hourly intervals. The meteorological data are then averaged over the computational time step and the saturated vapor pressure is calculated. On the first pass through sections one and two, data files are positioned so that the date of the meteorological data corresponds to the simulation date. If the proper data cannot be found, the simulation is terminated. In the third section, the appropriate meteorological data are assigned and the surface heat exchange coefficients and evaporation rate are calculated.

SUBROUTINE INHYDR is divided into two sections. The first section reads withdrawal data from cards. On the first pass through this section, withdrawal data for time periods prior to the beginning of the simulation are bypassed. The second section contains two options for determining reservoir releases. The first option computes the appropriate gate setting for achieving an outflow temperature closest to the temperature objective by allocating a user specified fraction of the total outflow to the bottom outlet and the remainder to other outlets. If the temperature objective is outside the reservoir temperature range, the best single outlet is used. The outflow through each gate is then checked against the user specified maximum for that gate and the outflow is reallocated if the maximum is exceeded. Under the second option, reservoir gate settings are prespecified by the user.

SUBROUTINE INFLO reads and processes tributary inflow rates and quality. First, all inflow data generated by previous simulations are read from reservoir/stream quality interface files. The remaining inflow data are read from the inflow data file generated in RESIM. PHCO2 is then called to calculate the influent total inorganic carbon and carbon dioxide concentrations. On the first pass through the subroutine, the inflow data file is positioned so that the simulation date corresponds to the inflow data date. If the proper date cannot be found, the simulation is terminated.

SUBROUTINE FLOWOT is the routine that determines the allocation of outflow from the individual elements and is divided into two sections. In the first section outflows are allocated using the Debler-Craya method. Initializations are performed and then a check is made to determine if the reservoir is stratified at the outlet elevation. If stratified, Debler's criterion is used to allocate the withdrawals from the appropriate elements. If the reservoir is unstratified at or within two elements of the outlet elevation, the theory of Craya is used to allocate the withdrawal. If the actual outflow is greater than Craya's critical flow, the excess is allocated from the region of stratification using Debler's criterion. Finally, after all the outflows have been allocated, and the outflow quality for each withdrawal has been determined, the water quality of the combined outflow from the reservoir is calculated. PHCO2 is called to compute the pH and CO_2 concentrations in the combined outflow. The second section allocates withdrawals using the selective withdrawal technique developed at the U.S. Army Engineers Waterways Experiment Station.

FUNCTION BETA determines the density gradient in the water column by a least squares fit.

SUBROUTINE COMPUT is the routine that computes the environmental change for each constituent. First, the effective diffusion coefficients are computed and FLOWIN called to allocate the inflow to the reservoir on an element-by-element basis. A mass balance of all inflows and outflows is made to determine the vertical advective flow between elements. RADIAT is then called to obtain the surface heat exchange coefficients and the shortwave solar radiation to be used in the temperature and algae calculations. Next, the shortwave solar radiation is distributed throughout the water column and the new temperature distribution is computed. The chemical and biological coefficients are then adjusted for temperature changes and the remaining constituents are processed sequentially.

Two computational methods are used to determine the new concentrations of the various constituents. For constituents which are advected through the system, a set of simultaneous linear equations representing the response of the entire system is utilized. For each constituent, a tridiagonal matrix is set up which represents those effects directly related to the concentration of the constituent, such as growth or decay of the constituent. A column matrix which accounts for changes in the constituents which are dependent on inflows and other constituents (e.g., the dependence of dissolved oxygen on BOD) is also set up. FORM is then called to assemble the simultaneous equations and determine the new concentration of the constituent. On the first pass through COMPUT, IRATE is called to estimate the initial time rate of change before entering FORM. For those constituents which are not advected (e.g., fish and constituents affixed to the bottom), the time rate of change is determined and multiplied by the time step increment to determine the change in concentration.

SUBROUTINE FLOWIN is the routine which distributes the inflow waters to the appropriate elements. First, the proper entry level is found by matching the density of the inflow water with water of like density in the reservoir. If the inflow water enters a stratified region, BETA is called to determine the slope of the density gradient. The inflow is then distributed to the appropriate elements based on Debler's criterion. If the inflow enters a region of convective mixing, the flow is distributed evenly throughout the mixed region. Finally, the amount of each constituent which is added to each element by the tributary inflow is calculated for later use in COMPUT as a part of the column matrix.

SUBROUTINE IRATE estimates the initial time rate of change of constituents prior to the call to FORM. This is done only on the first pass through COMPUT.

SUBROUTINE FORM generates a set of simultaneous linear equations by combining the appropriate matrices generated in COMPUT. The equations are then solved by Gaussian elimination to yield the constituent concentrations at the end of the time step.

STREAM HYDRAULIC MODULE ROUTINES

The stream hydraulics module is composed of a main program and nineteen subroutines. The computational sequence is shown in Figure VI-3 and the relationship between routines is shown in Figure VI-4. A description of the function of each routine is provided below.

PROGRAM MAIN is the executive program controlling operation of the stream hydraulics module. It begins by reading, processing and printing job titles, simulation and print controls, external tape and file assignments and tributary inflow and withdrawal locations. It then calls TSFLOW to input STORM [22] generated hydrographs, TFLOW to input and process the remaining tributary inflow and withdrawal data and INPDS to input the physical description of the stream system. After the element locations of the tributary inflows and withdrawals are determined, the daily time step loop is entered where HYDROL is called to input the initial point and non-point inflow and withdrawal rates and downstream stage control data. Then, depending on the routing method, one of five subroutines are called to perform the hydraulic simulation.

SUBROUTINE TSFLOW reads and prints STORM generated tributary inflow hydrographs. Flow data which is outside the limits of the simulation period are bypassed and the remaining data is written on temporary files for later processing in TQUAL.

SUBROUTINE TFLOW generates a tape or disk file containing tributary inflow and withdrawal data. Tributary inflow and withdrawal rates are first read and printed. Flow data are read at any time interval and intermediate flow values determined by straight line interpolation. These flow data are then combined with STORM hydrograph data contained on the temporary file written in TSFLOW to form a continuous record of inflow and withdrawal rates for the simulation period. These data are then written on a temporary or permanent tape or disk file for later use during the simulation.

SUBROUTINE INPDS reads, prints and processes general physical data describing the stream system. It begins by reading and printing stream

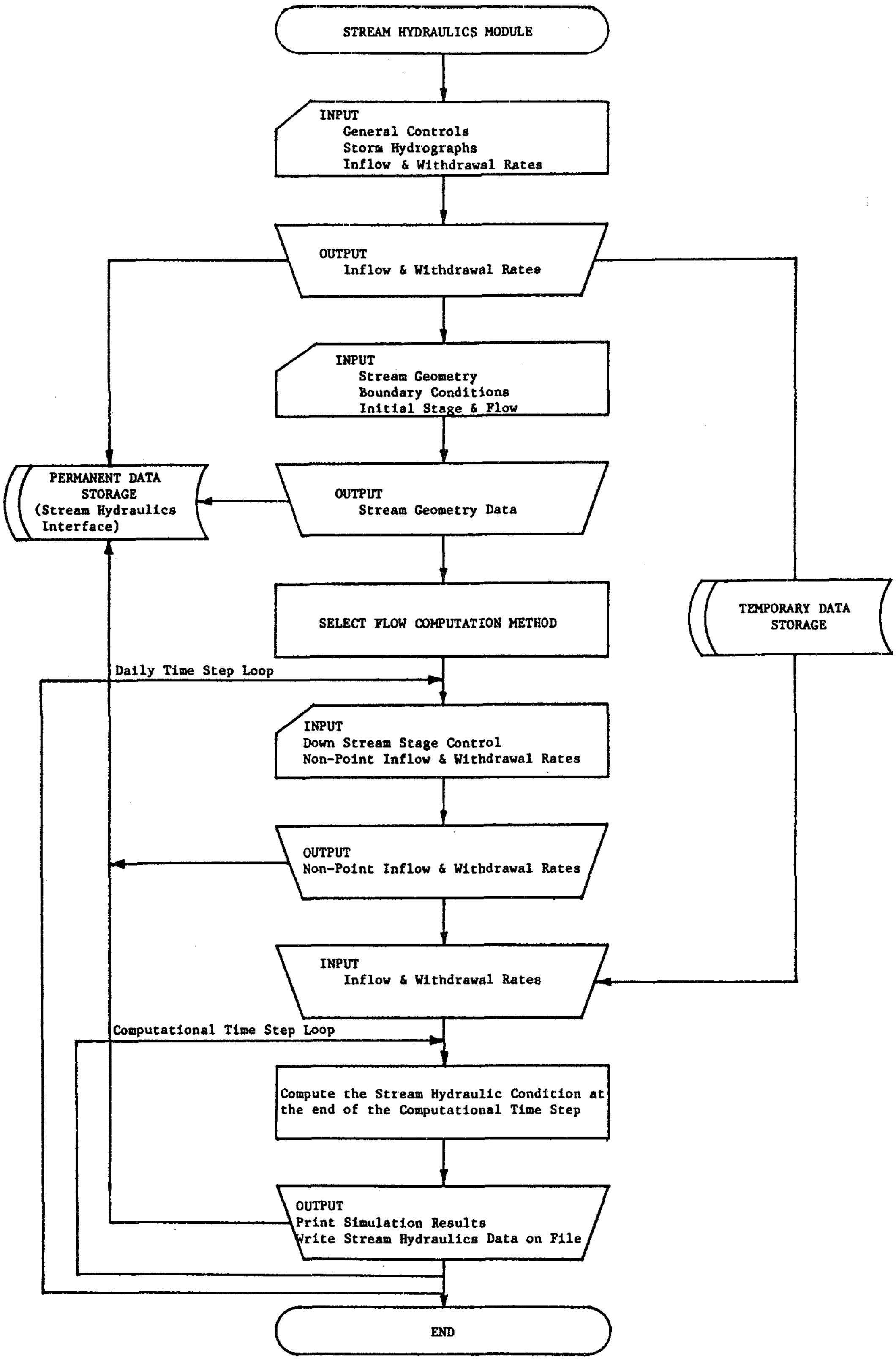


FIGURE VI-3

Stream Hydraulics Module Computational Sequence

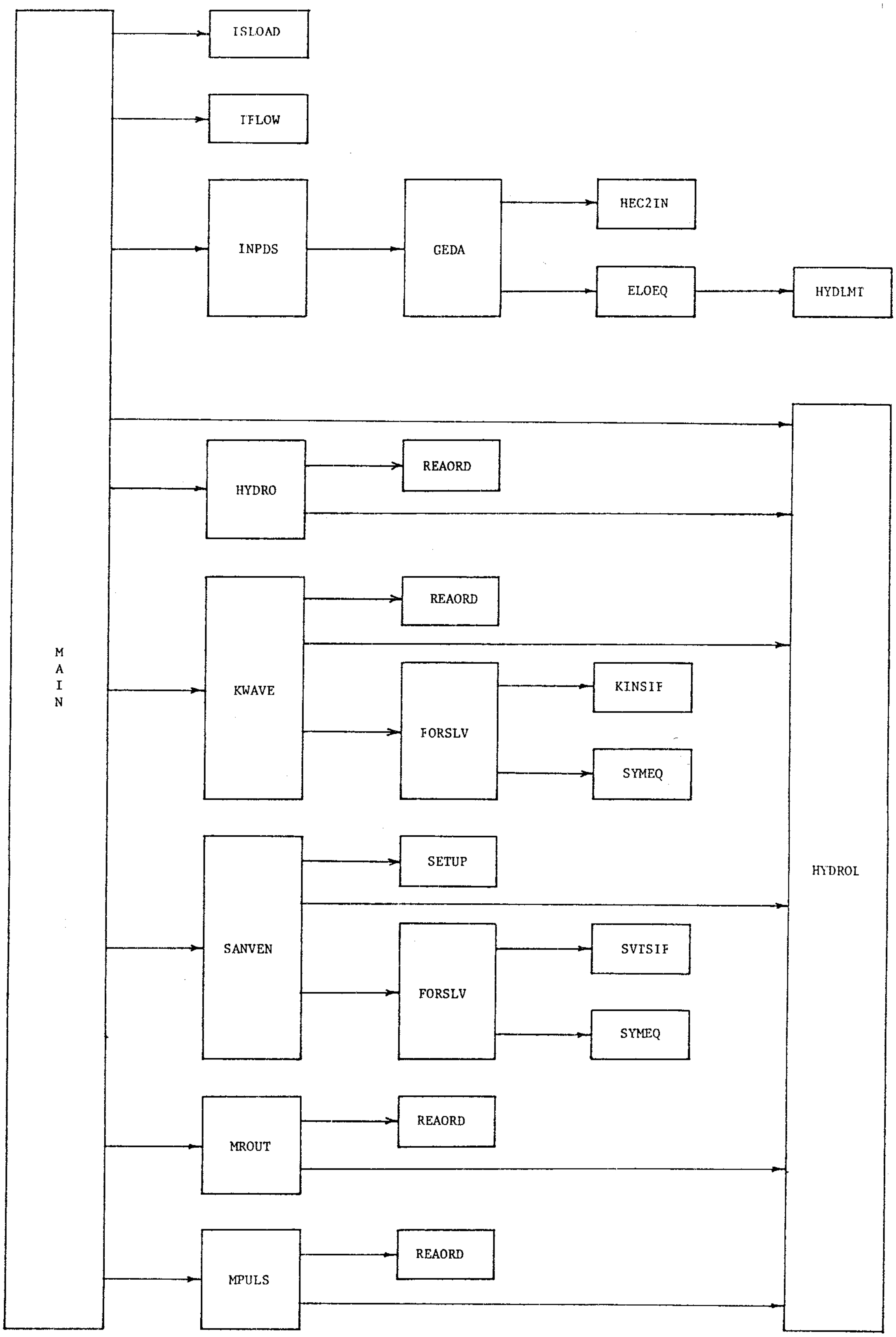


FIGURE VI-4

Stream Hydraulics Module Structure

reach and intersection definition data. (For definitions of these terms, see Figure VII-1). Then the channel cross section data is input by either reading cross section geometry cards or by calling GEDA which reads and processes cross section coordinate cards in HEC-2 [23] format. After printing and further processing of the cross section data, the channel bottom or energy grade line elevation and the boundary condition specifications are read and printed. Additional geometric data are then calculated and interpolation arrays set up. Finally, all stream physical data required by the stream quality module are written onto a permanent tape or disk file for use during subsequent quality simulations.

SUBROUTINE GEDA controls the processing of channel cross section coordinate data. It begins by reading all reach numbers and stage flow relationships corresponding to the channel cross sections. Titles and controls are read and HEC2IN is called to input and ELOEQ to process the channel cross section coordinate data. Additional channel cross section geometry data are calculated, and, at the users option, written on a permanent tape or disk file for later use in subsequent hydraulic simulations.

SUBROUTINE HEC2IN reads and processes channel cross section coordinate data.

SUBROUTINE ELOEQ makes minor computations and calls HYDLMT to compute additional channel cross section geometry data.

SUBROUTINE HYDLMT computes much of the channel geometry data required by the flow computation routines from the channel cross section coordinate data.

SUBROUTINE HYDROL inputs daily downstream stage controls and inflow and withdrawal rates. It begins by positioning the inflow data file and reading daily downstream stage controls. NPFLOW is called to input non-point flow data and the inflow hydrographs and withdrawal rates are read and printed.

SUBROUTINE HYDRO determines the steady flow hydraulics of the stream system (i.e., stage flow and backwater hydraulic computation methods).

On the first pass through the subroutine, REAORD is called to establish the proper order of hydraulic analysis and HYDROL to input the initial downstream stage controls and the initial inflow and withdrawal rates. The downstream stage and inflow and withdrawal rates are then calculated for the appropriate time by straight line interpolation. The steady state flows and depths are then computed for each stream segment. Depths are computed using either a steady-state back-water computation or the prescribed stage flow curve. Finally, the simulation results are printed and the flow rates, cross section areas and depths are written onto a permanent tape or disk file for use during subsequent quality simulations.

SUBROUTINE REAORD surveys the intersection data and establishes an acceptable computation order for routing flows downstream.

SUBROUTINE KWAVE is the driving routine for the kinematic wave hydraulic computation method. On the first pass through the subroutine, REAORD is called to establish the proper order of hydraulic analysis, initial flow rates, depths, cross sectional areas and other hydraulic data are read or estimated and HYDROL is called to input the initial inflow and withdrawal rates. Within the computational time step loop, tributary inflow and withdrawal rates are calculated for the appropriate time by interpolation and allocated to the proper elements. FORSLV is repeatedly called until a converged solution for depth at the end of the time step is achieved. The results are then printed and written onto a permanent tape or disk file for use during the quality simulation.

SUBROUTINE FORSLV performs the matrix assembly and solution of equations for both the kinematic wave and St. Venant hydraulic computation methods. It calls SVTSTF to develop element relationships for the St. Venant method and KINSTF to develop similar relationships for the kinematic wave method. SYNEQ is called to solve the simultaneous equations.

SUBROUTINE KINSTF generates the element relationships for the kinematic wave finite element method using the current approximation to the hydraulic properties to develop the appropriate coefficients.

SUBROUTINE SYNEQ solves an unsymmetrical set of equations in a sparse matrix form using a modified Gauss reduction scheme.

SUBROUTINE SANVEN is the driving routine for the St. Venant hydraulic computation method. On the first pass through the routine, variable time step controls are read, SETUP is called to input the initial flow rates and depths, and develop tables for interpolation of parameters and set up control arrays, then HYDROL is called to input the initial inflow and withdrawal rates. Within the computational time step loop, FORSLV is repeatedly called until the nonlinear problem converges. The results are then printed and written onto a permanent tape or disk file for use during the quality simulation.

SUBROUTINE SETUP reads initial flow rates and depths and creates the control arrays such as the structure of the equations that allow simultaneous solutions for the whole network system.

SUBROUTINE SVTSTF generates the element relationships for the St. Venant finite element method using the current approximation to the hydraulic properties to develop the appropriate coefficients.

SUBROUTINE MROUT is the driving routine for the Muskingum hydrologic routing computation method. On the first pass through the subroutine, REAORD is called to establish the proper order of flow analysis. The Muskingum routing factor tables are read and HYDROL is called to input the initial inflow and withdrawal rates. Within the computational time step loop, tributary inflow and withdrawal rates are calculated for the appropriate time by interpolation and allocated to the proper elements. The flow is then routed through the stream system using the Muskingum routing technique. Other hydraulic data are then computed and the results printed and written onto a permanent tape or disk file for use during the quality simulation.

SUBROUTINE MPULS is the driving routine for the modified Puls hydrologic routing computation method. On the first pass through the routine REAORD is called to establish the proper order of flow analysis, the storage vs. outflow tables are read and HYDROL is called to input the initial inflow and withdrawal rates. Within the computational time step loop, tributary inflow and withdrawal rates are calculated for the appropriate time by interpolation and allocated to the proper elements. The flow is then routed through the stream system using the modified Puls routing technique. Other hydraulic data are then computed and the results printed and written onto a permanent tape or disk file for use during the quality simulation.

STREAM QUALITY MODULE ROUTINES

The stream hydraulics module is composed of a main program and nineteen subroutines. The computational sequence is shown on Figure VI-5 and the relationships between routines is shown on Figure VI-6. A description of the function of each routine is provided below.

PROGRAM MAIN is the executive program controlling operation of the river quality module. It begins by reading, processing and printing job titles, simulation and print controls, external tape and file assignments, tributary inflow and withdrawal locations, and invariant meteorological data. It then calls RCOEF to input physical, chemical and biological coefficients, TQUAL to input tributary inflow quality and meteorological data, INPDS to input the physical description of the stream, and INCONC to input and OUTS to print the initial quality conditions. Finally STREAM is called which controls the dynamic quality simulation of the stream system.

SUBROUTINE RCOEF reads and prints all chemical, physical and biological coefficients. Default values are provided for most coefficients, therefore the user need only input those coefficients he wishs to change. No default values are provided for sediment related coefficients since all coefficients are a function of sediment size which is also users specified option. The rate coefficients are then converted to appropriate units and temperature adjustment factors are set for the temperature-dependent coefficients. FITIT is called to form a relationship between temperature and inorganic suspended solids settling rates.

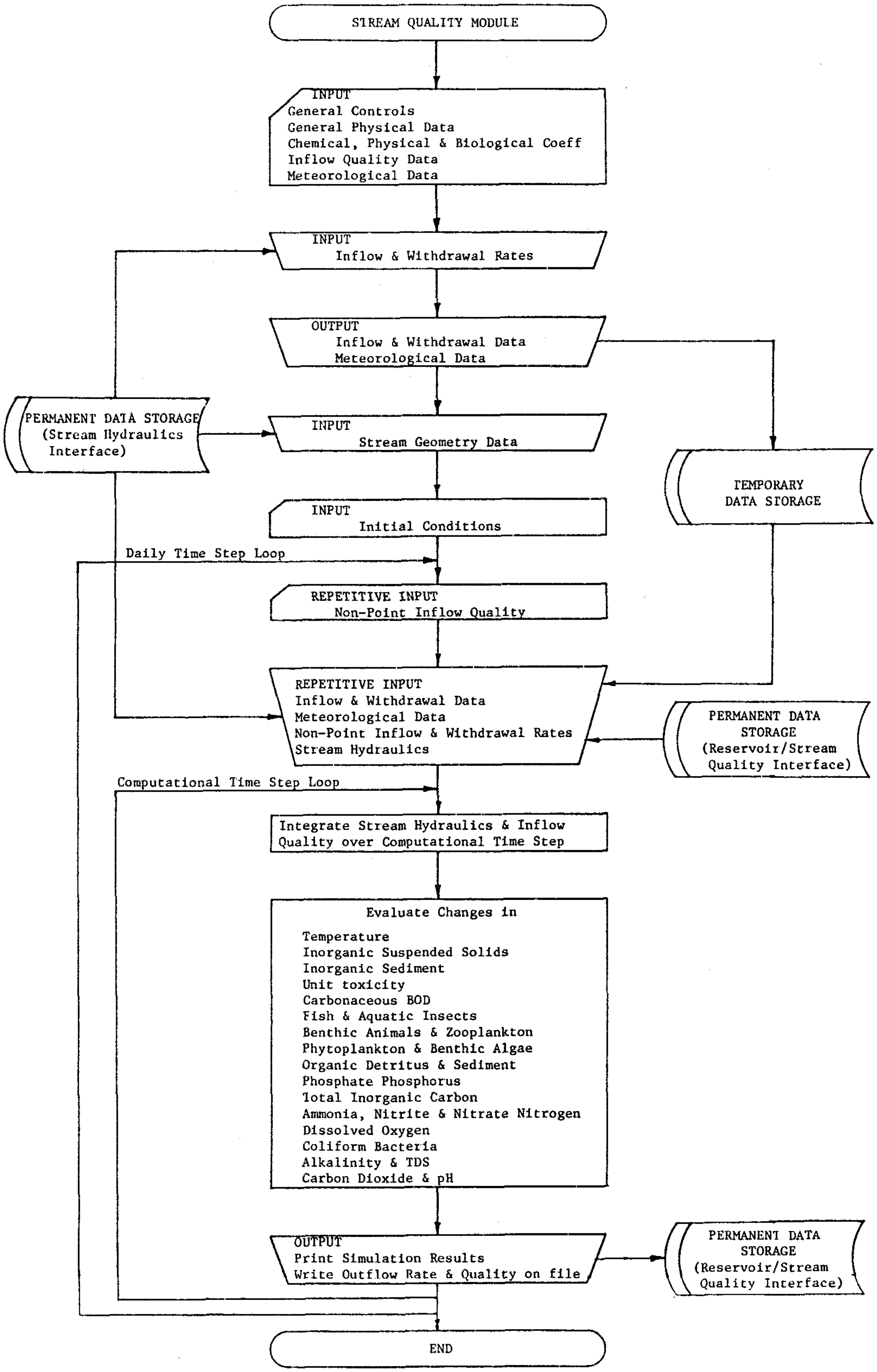


FIGURE VI-5

Stream Quality Module Computational Sequence

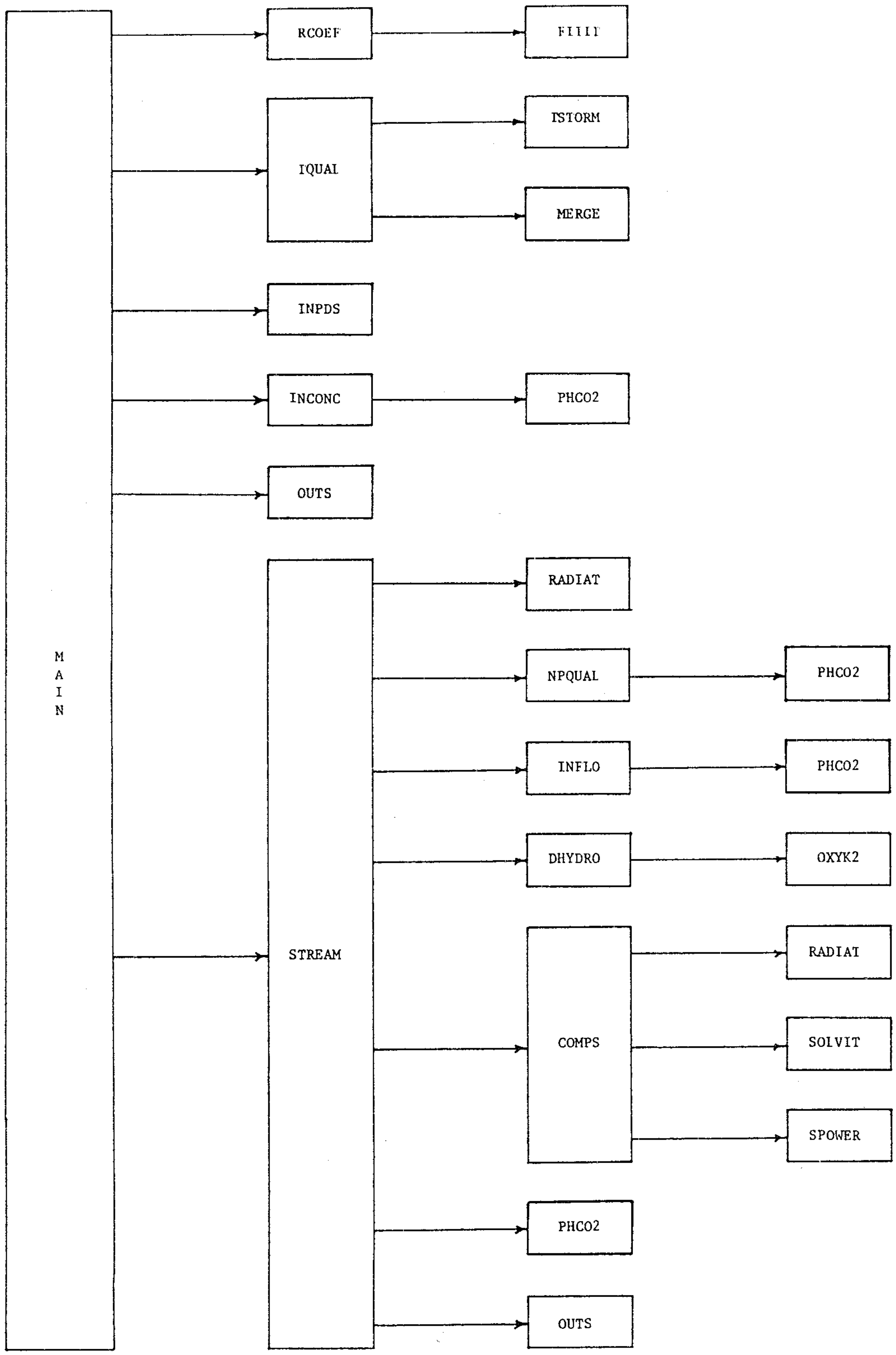


FIGURE VI-6

Stream Quality Module Structure

SUBROUTINE FITIT fits a second order curve through three points using a least squares method.

SUBROUTINE TQUAL is separated into two sections. The first section controls the input of tributary inflow quality data. Subroutine TSTORM is called to input STORM [22] generated tributary inflow rates and quality. Controls are then read which define the length of inflow record and which tributary inflow quality data are to be read and printed. Tributary inflow data may be read at any time interval with the quality held constant until overridden by a new value. After all data has been read, printed and written on temporary files, MERGE is called to generate a continuous record of inflow rates and quality. Meteorological data may be input at irregular data intervals, however, a pre-specified hourly interval must be maintained during the day (e.g., hourly meteorological data input for the first and fifteenth of each month). The daily weather pattern is repeated until overridden by new data. These data are also written on temporary or permanent tape or disk files for later use during the simulation.

SUBROUTINE TSTORM reads STORM generated tributary inflow rates and quality. Flow and quality data which is outside the limits of the simulation period are bypassed and the remaining data is written on temporary files for later processing in MERGE.

SUBROUTINE MERGE combines into one continuous record, inflow quality data contained on temporary files written in subroutines STORM and TQUAL and inflow data contained on the stream hydraulics/quality interface unit. The continuous record of inflow rate and quality is then written on a temporary or permanent tape or disk file for later use during the simulation.

SUBROUTINE INPDS reads invariant stream geometry data from the file generated by the stream hydraulics module. Additional stream geometry data are then calculated and the element connectivity determined.

SUBROUTINE INCONC reads the initial water quality conditions. Uniform initial quality conditions are assigned to all elements between specified river mile locations. PHCO2 is called to compute the initial concentrations of total inorganic carbon and carbon dioxide.

SUBROUTINE PHCO2 is separated into two sections. The first section calculates the total inorganic carbon ($CO_2+HCO_3^-+CO_3^{--}$) and carbon dioxide (CO_2) concentrations based on equilibrium relationships with pH and alkalinity. This section is used to determine the concentrations of these constituents in the inflow and in the stream at the beginning of the simulation. The second section utilizes the same equilibrium relationships to determine the pH and CO_2 concentrations based on alkalinity and total inorganic carbon. This section is used to calculate the pH and CO_2 concentrations in the outflow and within the stream as the simulation progresses.

SUBROUTINE OUTS is the routine which prints initial conditions and the simulation results at specified intervals. Three user-specified print options are available. The first is a summary of the stream hydraulics and reaeration coefficients. The second is an abbreviated summary of the simulation results where several constituents have been combined (e.g., the individual nitrogen forms are summed and reported as total nitrogen). The third is a comprehensive summary of the simulation results in which the concentration of all constituents plus fish growth rates are printed. A comprehensive summary of inflow quality is provided with either quality print option.

SUBROUTINE STREAM is the routine which controls the dynamic quality simulation of the stream system. Within a daily computatinal loop, it calls RADIAT for a set of meteorological data, NPQUAL to input non-point inflow quality and INFLO for inflow and withdrawal rates and inflow quality. DHYDRO is called to input a set of stream hydraulics data and determine the appropriate computational time step increment based on the minimum element resident time. RADIAT is again called to average meteorological data over the time step increment. Inside the computational time step loop, DHYDRO is called to extract the appropriate stream hydraulics data and external inflow loadings. After the environmental changes have been evaluated in COMPS, PHCO2 is called to compute the pH and dissolved carbon dioxide concentration for each element. OUTS is called to print the simulation results and the quantity and the flow rate through the most downstream element is stored on a permanent tape or disk file for future use in subsequent simulation of the stream or reservoir immediately downstream.

SUBROUTINE RADIAT is separated into four sections. The first section is called only if the equilibrium temperature concept is being used. The equilibrium temperature, heat exchange coefficient, shortwave solar radiation, wind speed and vapor pressure are read from the equilibrium data file and processed. Sections two through four are entered if the heat budget approach is being used. Section two reads a set of meteorological data from the meteorological data file, makes necessary unit conversions, and then by straight line interpolation generates meteorological data for each hour of the day. The long wave atmospheric and shortwave solar radiation are calculated at hourly intervals. On the first pass through sections one and two, the files are positioned so that the date on the meteorological data file corresponds with the simulation date. If the proper data cannot be found, the simulation is terminated. In the third section the meteorological data are averaged over the computational time step and the saturated vapor pressure is calculated. In the fourth section, the appropriate meteorological data are assigned and the surface heat exchange coefficients and evaporation rate are computed.

SUBROUTINE NPQUAL reads nonpoint inflow quality data. On the first pass through the subroutine quality data for time periods prior to the beginning of the simulation are bypassed. After the appropriate data set is found, uniform non-point quality is assigned to all elements between specified river mile locations and PHCO2 is called to compute the concentrations of total inorganic carbon and carbon dioxide in the inflow.

SUBROUTINE INFLO reads and processes tributary inflow rates and quality. First, all inflow data generated by previous simulations are read from quality interface files, and then the remaining inflow data are read from the inflow data file. On the first pass through the subroutine, the inflow data file is positioned so that the simulation date corresponds to the inflow data date. If the proper date cannot be found, the simulation is terminated. PHCO2 is then called to calculate the influent total inorganic carbon and carbon dioxide concentrations.

SUBROUTINE DHYDRO is also divided into two sections. In section one, stream flow, depth and cross-sectional area data generated by the stream hydraulics module are read from tape. Necessary interpolation is done and an appropriate computational time step increment is determined based on the minimum element flow-through time. The second section is entered at each time step to compute inflow and withdrawal rates and the volume, surface area, and other physical characteristics of each element. OXYK2 is called to determine the reaeration rates.

SUBROUTINE OXYK2 computes reaeration rates for oxygen and carbon dioxide exchange with the atmosphere using any one of seven methods.

SUBROUTINE COMPS is the routine that computes the changes in each constituent over the time step. First, the invariant elements of the coefficient matrix representing the effects of advection and diffusion are set up. RADIAT is then called to obtain both the surface heat exchange coefficients for each element and the shortwave solar radiation to be used in the algal calculations. The temperature is then computed and the physical, chemical, and biological coefficients adjusted to these new temperatures. The remaining constituents are processed sequentially.

Two computational methods are used to determine the new concentrations of the various constituents. For constituents which are advected through the stream system, a set of simultaneous linear equations representing the response of the entire system is utilized. First, one column matrix is set up which represents those effects related directly to the concentration of the constituent being considered, such as growth or decay of the constituent. A second column matrix which accounts for changes in the constituents which are dependent on inflows and other constituents (e.g., the dependence of dissolved oxygen on BOD) is set up. SOLVIT is then called to form the simultaneous equations and determine the new concentration of the constituent. For those constituents which are not advected (e.g., fish and constituents affixed to the bottom), the time rate of change is determined and multiplied by the time step increment to determine the change in concentration.

SUBROUTINE SOLVIT is separated into two sections. The first is entered only once to complete the coefficient matrix cross-reference by adding the terms generated by the Gaussian reduction scheme. The second section forms a set of simultaneous linear equations by combining the invariant coefficient matrix with the two column matrices generated by COMPS. The equations are then solved utilizing a sparce matrix, banded, Gaussian elimination method yielding the constituent concentrations at the end of the time step.

SUBROUTINE SPOWER determines the suspended solids carrying capacity of each stream segment using the stream power concept.

VII. DATA PREPARATION AND CALIBRATION

The data requirements for the three modules of WQRRS are extensive and varied. To a large extent these data requirements will be adequately described in Chapter VIII. In this chapter, only those data which require some insight into their preparation and the extent to which the data should be modified during the calibration process is discussed.

RESERVOIR MODULE

The data requirements for the reservoir module fall under the general categories of:

- Simulation controls
- Physical data
- Physical, chemical and biological coefficients
- Initial quality conditions
- Meteorological data
- Inflow data, and
- Withdrawal specifications

Reliable estimates or measurements of each data are essential for calibrating the model to obtain valid simulation results.

Simulation Controls

Simulation or job controls include length of simulation definition, water quality interaction specifications, input and print controls, tape and file controls and other general data which control operation of the module. Those data for which additional information is required for proper selection is presented in tabular form below.

Variable	Description
IDAY	The first day of simulation should be during a period of the year when the prototype is unstratified (usually in the early spring). Beginning the simulation under unstratified conditions make initial condition specifications much simpler since vertical variations in temperature and quality need not be specified.
NHOI	Proper selection of the computation time step increment is extremely important. The length of the time step should be such that no more than one element is added or deleted during any given time step. The addition or deletion of more than one element per time step may result in significant mass balance errors. The time step cannot be greater than one day.
ITEST	The water quality constituent interaction modification options should be used with caution. The use of these options is discussed in detail in Chapter III.
IWES	Both the WES withdrawal option and the Debler-Craya withdrawal option adequately allocate withdrawals from the individual elements. The WES withdrawal method is a more vigorous method, however, it requires more computer time. These two methods are described in Chapter III.
IEQF and IMETF	These input unit numbers determine the method of surface heat exchange computation. The heat budget method is normally recommended (i.e., IEQF = 0). A discussion of the two methods is provided in Chapter III.

Physical Data

Physical data include general reservoir geometry data, dispersion characteristics, inflow and withdrawal location data and the table of reservoir elevation versus surface area and width at the withdrawal location (e.g., width of dam at the outlet elevation). Those data for which additional insight is required for proper selection is presented below. Discussion of the invariant meteorological data which is normally placed in this category has been included in the meteorological data section.

Variable	Description
SDZ	The thickness of the elements is normally about 1 meter, however, element thicknesses less than 1 meter may be required for shallow impoundments to achieve the correct representation of stratification and achieve the correct compensation point for the simulation of phytoplankton. In some instances, elements as thick as 3 meters can be used if the reservoir is deep and a relatively rough simulation is acceptable. The choice of the length of computational time step and the element thickness should result in no more than one element being deleted or added during a time step (e.g., the element volume should always be larger than the change in reservoir volume during a time step). The number of elements (a maximum of 100 is allowed) is also determined by the element thickness (e.g., number of elements = [ELMAX-ELMIN]/SDZ).
EDMAX	The Secchi disc depth is the measure of light transparency for the distribution of light energy with depth. The value should reflect non-bloom conditions since the program adjusts the light extinction coefficient to account for decreased light penetration as a function of the increase in algal concentrations and any other particulate material considered in the model run. During calibration, it may be necessary to change the Secchi disc to influence the location of the thermocline. The thermocline will be deeper with increases in Secchi disc depth.
BPCT	The fraction of the total withdrawal allowed through the lowest outlet is used with the selective withdrawal option. Higher values will result in lower temperature objectives being met, however, large withdrawals from the bottom outlet may result in low dissolved oxygen concentration in the outflow during periods of low DO in the hypolimnion. A trade-off between low temperature and low DO must be made when selecting the value of BPCT.
GMIN	The water column minimum stability is the density gradient above which mixing of the water column will occur. The value is usually zero when daily time steps are used and may range up to .001 kg/m^2/meter when shorter time steps are specified. A positive value will cause the thermocline to form more quickly and delay destratification.
	Effective Diffusion Coefficients
GWSH, A1, A2 and A3	The magnitude of the effective diffusion coefficients is a function of these variables and either the density gradients when the stability method is specified, or wind speed when the wind method is specified. A discussion of the significance of each variable along with typical values is provided in Chapter II.

Variable	Description

1. Stability Method

   To begin calibration, it is recommended that the following values be assigned:

$$GWSH = 2. \times 10^{-6}$$

$$A1 = 5. \times 10^{-5}$$

$$A3 = -.7$$

   During calibration, A3 is normally held constant at this value. Decreases in the values of either or both GSWH and A1 will result in smaller effective diffusion coefficients and sharper gradients.

2. Wind Method

   If the wind method is selected, the following initial values are recommended:

$$GSWH \text{ (i.e., } D_{min}) = 1 \times 10^{-6}$$

$$A1 = 2 \times 10^{-5}$$

$$A2 = 4.6$$

$$A3 \text{ (i.e., } D_{max}) = 5 \times 10^{-4}$$

   During calibration, A2 and A3 can normally be kept at these values. Increasing the value of GSWH and A1 will result in decreased gradients. The effect of changes in GSWH is most pronounced in the hypolimnion, while changes in the value of A1 affects mixing primarily in the epolimnion and metalimnion.

RLEN — The effective reservoir length (i.e., positive values of RLEN only) will determine the width of the inflow layer. A discussion of how this width is used to allocate inflow waters is provided in Chapter III.

WOUT — The virtual width is used in the allocation of withdrawals under the WES withdrawal method. A discussion of how this width is used is provided in Chapter II.

Physical, Chemical and Biological Coefficients

Before beginning the calibration process, it is strongly recommended that all default values shown in Table IV-1 be reviewed to ensure that they adequately represent the processes which normally take place under conditions expected in the prototype. Any unrealistic coefficients should be overridden with an appropriate value at the time of the first calibration run and coefficients with no default values assigned if a non-zero value is appropriate. After the first calibration run is performed, the results should be checked for reasonableness and against measured data. If necessary, some of the coefficients may then have to be changed to modify simulation results. This process should be repeated until satisfactory results are obtained. To some extent, this can be done in conjunction with the effective diffusion coefficient calibration, however, the final diffusion coefficients should be set before the final physical, chemical and biological coefficients are established.

Because of the large number of coefficients and the complex interrelationships between constituents, it is often desirable to select a realistic value for certain coefficients and leave them constant throughout the calibration while varying the remaining. The following table is a summary by constituent of the coefficients which are recommended for change during the calibration process. In some instances it may be necessary to vary more coefficients than the ones recommended below to affect a greater change. To calibrate some water quality constituents, it may also be necessary to change the value of coefficients pertaining to related constituents (e.g., to calibrate algae, it may be necessary to adjust the half saturation constant for zooplankton).

Constituent	Constant Coefficients	Variable Coefficients
Fish	Temperature limits* Feeding preferences Assimilation efficiency Particulate fraction of excreta Harvest rate	Maximum growth rate Mortality rate Respiration rate Half saturation constant

* Temperature limits should be set at reasonable values for the particular species being modeled prior to calibration and held constant during the calibration process.

Constituent	Constant Coefficient	Variable Coefficient
Benthic Animals	Temperature limits* Assimilation efficiency Particulate fraction of excreta	Maximum growth rate Mortality rate Respiration rate Half saturation constant Half saturation constant and assimilation of efficiency type 3 fish
Zooplankton	Temperature limits* Feeding preference Assimilation efficiency Particulate fraction of excreta	Maximum growth rate Mortality rate Respiration rate Half saturation rate Half saturation constant of assimilation efficiency of fish types 1 and 2
Phytoplankton	Temperature limits* Half saturation constants Settling velocity	Maximum growth rate Respiration rate Half saturation constants and assimilation efficiency of zooplankton
Detritus	Temperature limits* Settling velocity	Decay rate
Organic Sediment	Temperature limits*	Decay rate
Inorganic Suspended Solids		Settling rates Initial deposition at tributary inflow point
Phosphate Phosphorus	Chemical composition of biota and detritus	Phytoplankton growth rate Particulate fraction of zooplankton and fish excreta

* Temperature limits should be set at reasonable values for the particular species being modeled prior to calibration and held constant during the calibration process.

Constituent	Constant Coefficient	Variable Coefficient
Total Inorganic Carbon	Stoichiometric equivalence between carbon and BOD Chemical composition of biota and detritus	Phytoplankton growth rate Particulate fraction of zooplankton and fish excreta
Ammonia Nitrogen	Temperature limits* Chemical composition of biota and detritus	Decay rate Phytoplankton growth rate Particulate fraction of zooplankton and fish excreta
Nitrite Nitrogen	Temperature limits*	Decay rate Ammonia decay rate
Nitrate Nitrogen	Nitrite decay rate	Phytoplankton growth rate
Oxygen	Stoichiometric equivalence	Phytoplankton growth rate Sediment decay rate** Particulate fraction of zooplankton and fish excreta
Coliforms	Temperature coefficient*	Die-off rate

Initial Quality Conditions

To the extent possible, the initial conditions should be based on measured data. For constituents which are not easily measured, such as fish, zooplankton, benthic animals, and organic sediment, an estimate should be made followed by a year of simulation. Then the amount of each of these constituents should be reestimated so that the net change over the year is small. This procedure may also have to be used for other constituents if no data exist. If very little data exist for all constituents, it will probably be

* Temperature limits should be set at reasonable values for the particular species being modeled prior to calibration and held constant during the calibration process.

** Both the sediment decay rate and the initial sediment amount may require modifications during calibration.

impossible to calibrate the model reliably.

Ideally, the simulation should begin when the reservoir is isothermal or at the time of minimum stratification so that the formation of the density stratification is not dictated by initial conditions. If the reservoir is ice covered during a portion of the year, only the ice free period should be simulated since this program does not presently have ice cover calculations.

Meteorological Data

With the use of the "equilibrium temperature method", data must be input at daily intervals, the preparation of this data is described in the Corps report "Thermal Simulation of Lakes" [24]. The following discussion applies only to the "heat budget method".

Meteorological data is often the most plentiful and easily obtained data. Most Class A weather stations have monthly averages of the five weather parameters (i.e., dry and wet bulb or dew point temperatures, cloud cover, wind speed, and atmospheric pressure) required by the model. Magnetic tapes containing this data at 3 hour intervals are often available from the National Weather Center, NOAA, Ashville, N.C.

Data should be input in sufficient detail to accurately define the meteorological conditions. For verification of temperature in an existing reservoir, a 3 hour update interval is desirable.

Of the five weather parameters required with the heat budget method, the atmospheric pressure is relatively unimportant and the standard pressure at the reservoir elevation is generally adequate. The other four parameters are all important in determining the heat exchange at the air-water interface. Cloud cover is important in the algae computation since it determines the amount of light energy which is available for photosynthesis. Reaeration of oxygen and carbon dioxide is a function of wind speed. Wind speed is also important if the user has selected the wind mixing method for computing effective diffusion.

During calibration it may be necessary to adjust the evaporation coefficients "a" and "b" of equation III-6 to obtain acceptable surface temperatures. Increasing the magnitude of either coefficient a or b will result in lower surface temperatures. The default value of "b" is 1.5×10^{-9} but may vary by as much as $\pm$ 50%. The default value of "a" is zero, however, values up to 2×10^{-9} are reasonable.

Inflow Data

Inflow data should be input in sufficient detail to give an accurate representation of flow rates and a reasonable representation of the inflow water quality characteristics during the simulation period. The concentration of nutrients (i.e., NH_3, NO_3 and PO_4) in the inflow water is of particular importance. If there is insufficient data on inflowing nutrient concentration, reasonable values may be assigned, however, a sensitivity analysis where inflowing nutrient concentrations are varied should be performed. The sensitivity analysis would yield the range of water quality conditions which could be expected within the lake.

Modification of inflow water quality is not recommended to affect changes in water quality during calibration.

Withdrawal Specifications

Daily average withdrawal rates should be input in sufficient detail to accurately represent the outflow conditions during the simulation period. During calibration, flows through individual gates should be specified or temperature objectives set at the measured withdrawal temperatures.

STREAM HYDRAULICS MODULE

The stream hydraulics module is capable of simulating hydraulic behavior under sub-critical flow conditions in a branched and looped (i.e., flow around an island) stream system. The stream system is represented by a series of reaches each consisting of elements bounded by node points. The hydraulics of the stream system are computed at each of the node points using one of six hydraulic computation methods. An example of a typical stream system is shown in Figure VIII-1.

The major categories of data which describe and control the simulation of the stream hydraulics module are:

- Simulation controls
- STORM generated inflow data
- Other inflow and withdrawal data
- Stream geometry data
- Boundary conditon specifications
- Flow computation method specific data
- Depth control, and
- Non-point inflow and withdrawal data

Reliable estimates or measurements of the data are essential for use and calibration of the model.

Simulation Controls

Simulation or job controls include length of simulation, hydraulic computation method selection, computation time step specification, tape or file assignments and other data which control operation of the module.

The proper selection of a routing method and the choice of a computational time step are very important in the calibration and use of a routing method. The latter is more a question of numerical accuracies because some-

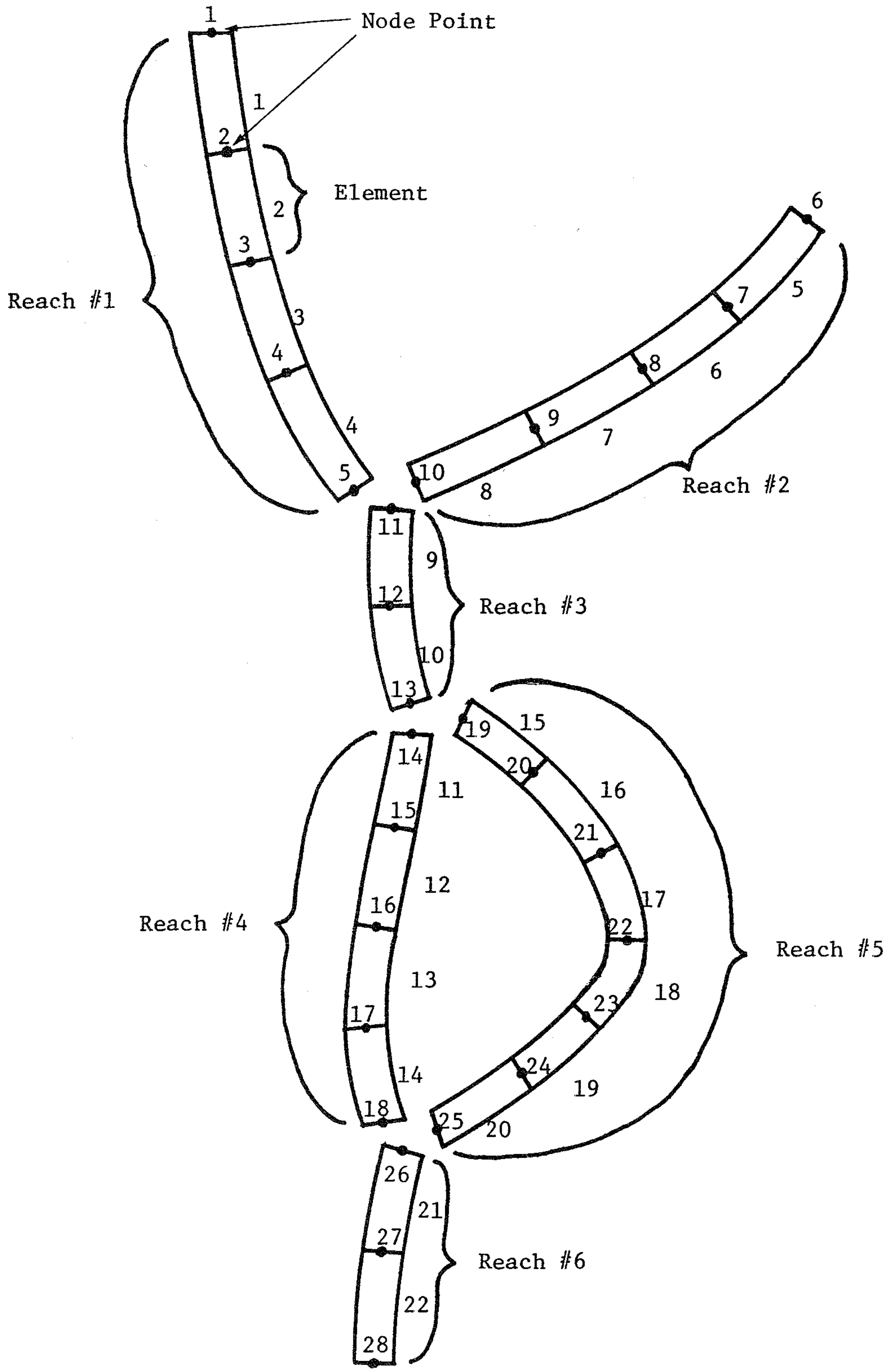


FIGURE VII-1

Model Representation of a
Typical Stream System

what erroneous results, which might initially be attributed to geometry or friction, are really a question of computational time step compatability with the physical system and routing procedure.

Actual experience with different physical problems is extremely helpful in selecting the time step and routing method. In most cases, unless the inflows are highly dynamic and the channel geometry or friction varies severely from one section to another, a computational time step of 1 hour is sufficient. Checking flow continuity is a good test to tell if the time step is too large. Output of total flow volume past each node during the day is printed for this purpose.

A second and imminently important decision is the choice of the routing method. Again, actual experience will give the engineer the intuition and judgment necessary for effective and efficient program usage. However, a few guidelines are worth mentioning. First, carefully examine the type of physical problem to be simulated. Each of the routines was derived from equations which emphasize different physical characteristics. These dependencies can best be understood by reading the text and the assumptions in Chapter II. Secondly, consider trying one of the steady flow methods to give an upper bound on stage and flow. Then, if the problem dictates, select a time dependent method and compare with the steady flow solution for reasonableness in stage, flow, travel time of peaks, continuity, etc. A final consideration is computer costs. Decreased time steps will result in a proportional increase in computer costs. Also, the St. Venant and kinematic wave methods require significantly more computer time than the other methods.

STORM Generated Inflow Data

STORM generated hydrograph data are prepared automatically by the STORM program [22]. A complete description of the data required by the STORM program can be found in the reference and will not be covered here.

Other Inflow and Withdrawal Data

Inflow and withdrawal rates should be input in sufficient detail to give an accurate representation of the flow at all point inflow locations. When STORM generated hydrographs are input, base flows representing non-storm conditions must be specified. The order of input must be as follows: The base flow for STORM generated hydrographs, all other point inflows and finally all withdrawals.

Stream Geometry Data

Stream geometry data include reach and element lengths, intersection definitions, channel cross section geometry data and energy grade line or channel bottom elevations. The reach length should correspond to the actual length of the stream reach. The element length which is normally between .5 and 2 miles should be such that an even number of elements will result. If more than one element length is specified (i.e., GEOM2 cards), an even number of each element size must also be maintained. If a water quality analysis is planned, the element length should also reflect the level of detail required by that analysis.

When either the St. Venant method or kinematic wave solutions are specified, element length should not exceed one mile. If unstable solutions result, shorter element lengths may be required.

Channel cross section data should represent the actual channel geometry to the extent practical. These data may be input in one of two forms. The first form utilizes channel cross section coordinate data input using HEC-2 [23] format. These data define the cross section by a series of x-y coordinate points. Variable Mannings "n" values may be specified and conveyance limits set to restrict the flow to a portion of the cross section. The area within the channel cross section but outside the conveyance limits is used for channel storage volume only. Figure VIII-2 shows the geometric representation of a typical channel cross section.

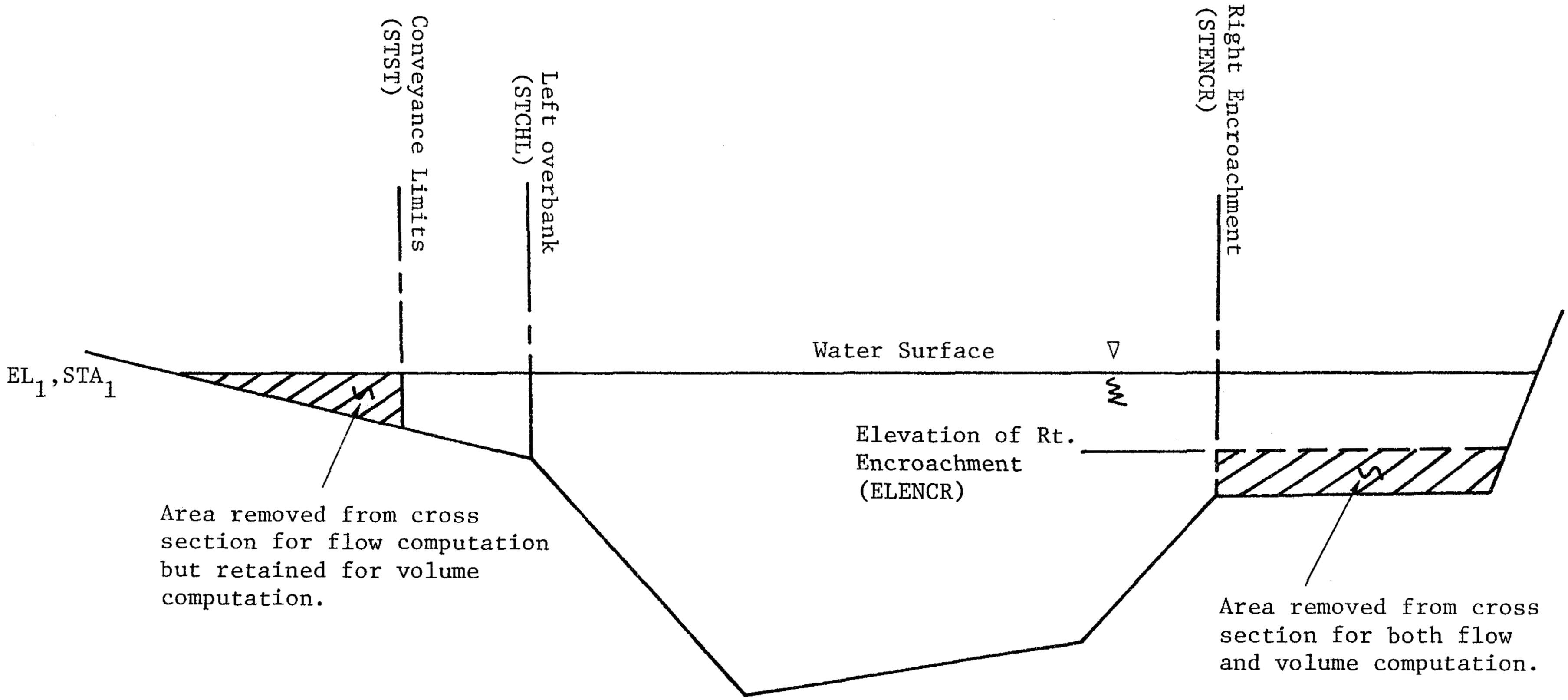


FIGURE VII-2

Typical Channel Cross Section Representation

The second type of channel cross section data (i.e., GEOM4) is in the form of a table of elevation versus channel characteristics. This data if generated automatically from channel cross section coordinates (i.e., HEC-2 format data) will eliminate the need to reprocess the channel cross section coordinate data during each simulation.

During calibration, slight modification in the friction factors (i.e., Mannings "n"), conveyance limits and channel geometry may be required to reproduce measured flow data.

Boundary Condition Specifications

Boundary conditions include flow, stage and stage versus flow relationship and are normally specified at the extremities of the stream system (e.g., upstream ends of reach 1 and 2 and downstream end of reach 6 of the example stream system shown in Figure VII-1). When using the St. Venant and backwater methods, stage or stage versus flow boundary conditions may be specified at reach intersections (e.g., specify stage vs. flow relationship at the downstream end of reach 5 of the example stream system shown in Figure VII-1) to simulate the effects of weirs or other control structures. The St. Venant method allows the specification of flow at either, but not both, the upstream or downstream end of any reach. When a flow boundary condition is specified, the channel flow will equal the inflow at that location (e.g., referring to Figure VII-1, a flow boundary condition specified at the upstream end of reach 5 would result in a channel flow equal to the inflow to node 19). All other hydraulic computation methods allow the specification of flow boundaries at only the upstream end of any reach. The boundary conditions required by the model are dependent on the hydraulic computation method selected by the user. Table VII-1 summarizes the boundary conditions required by the various hydraulic computation methods.

When flow boundary conditions are specified, the channel flow rate is set equal to the tributary inflow rate at that location. When a stage versus flow boundary condition is specified, the stage-flow relation input with the stream geometry data is used. The specification of stage boundary conditions requires the input of a continuous record of stage versus time data (i.e., DD1 and DD1A cards) as the simulation progresses.

TABLE VII-1

Boundary Condition Requirements

Hydraulic Computation Method	Downstream			Upstream	
	Flow	Stage	Stage vs. Flow	Flow	Stage
Stage-flow				X	
Backwater		X	X	X	
Kinematic wave				X	
St. Venant*	X	X	X	X	X
Muskingum routing				X	
Modified Puls				X	

* Only one of the two types of boundary conditions may be specified at the upstream end of any given reach. Only one of the three types of boundary conditions may be specified at the downstream end of any given reach.

Flow Computation Method Specific Data

No flow computation method specific data is required for either the stage-flow or backwater hydraulic computation methods. The other four methods, however, all require additional data.

The St. Venant method is provided with the capability of adjusting the time step during the simulation using one of two user specified options.

With the first option, times are specified after which the time step increment is increased automatically up to a maximum value. This option allows the user to specify a relatively short time step at the beginning of the simulation to overcome numerical instability problems and then the program will gradually increase the time step to save computer time.

The second option allows the user to specify different time step increments at different times during the simulation. This option should be used to specify short time steps during periods of very dynamic flow and longer time steps for more uniform flow conditions.

Both the St. Venant and kinematic wave methods require initial estimates of depth and flow. Normally the specification of average flow and depth by reach is adequate. If the depth or flow within the reach is quite varied, it may be necessary to input the depth and flow at each node. These data may be prepared automatically using the backwater method.

The Muskingum routing method requires control point data and routing criteria, K and x. The modified Puls method requires both control point and storage-outflow data. The selection and significance of these data can best be understood by reading the appropriate sections in Chapter II.

Depth Control

Depth control data are required for each reach where depth boundary conditions are specified. These data must be input for each day of simulation.

Non-Point Inflow and Withdrawal

Non-point inflows and withdrawals include all flow which can be represented by a line source or sink. Groundwater inflow and outflow, local storm related inflow and minor poorly defined agricultural returns and diversions could also be considered non-point flow. These flow rates can be input at any time interval greater than 24 hours and represent average daily conditions from the input point in time until the input is updated with a new value.

Both control and non-point inflow and withdrawal data are input as the simulation progresses, therefore proper phasing of the data is essential.

STREAM QUALITY MODULE

The data requirements for the stream quality module fall under the general categories of:

- Simulation controls
- Physical data (i.e., Tributary location and Invariant Meteorological data)
- Physical, chemical and biological coefficients
- STORM generated inflow data - same as stream hydraulics module
- Inflow data - same as reservoir module
- Meteorological data - same as reservoir module
- Initial condition, and
- Non-point inflow data - same as stream hydraulics module

Many of the guidelines presented previously in this chapter pertaining to the data requirements of the reservoir and stream hydraulics modules are applicable to the data requirements of the stream quality module. In this section, only those data requirements which differ from, or are in addition to, the data requirements previously presented will be discussed.

Simulation Controls

The time step increment or simulation interval and total length of simulation differ from those recommended in the reservoir section.

The simulation interval required by the stream module is actually the maximum allowable time step. The actual computational time step increment is determined within the program and is a function of the minimum element volume resident time. The simulation interval should normally be four hours or less so that diurnal variations in quality, particularly temperature and dissolved oxygen, can be examined.

If the user is mainly interested in quality constituents which are transported passively with the movement of water (i.e., dissolved and suspended materials) then a simulation period of twice the total resident time of the stream system is often sufficient. Longer simulation periods similar to those recommended for the reservoir simulation are required if the seasonal changes in fish, aquatic insects, benthic animals and benthic algae are of interest.

The previous discussion pertaining to the water quality interaction specifications also applies to the stream module, however, one item is worth mentioning. Representing toxicity induced mortality by the unit toxicity concept is often unrealistic. For this reason, it is recommended that unit toxicity not be simulated unless the user understands the unit toxicity concept completely and can interpret the results accordingly.

Physical, Chemical and Biological Coefficients

The previous discussion for the reservoir module applies to the stream quality module with the exception of settling velocities.

In this module, the settling velocities of both phytoplankton and detritus should normally be zero since stream velocities are usually sufficiently high to prevent deposition.

In the inorganic suspended solids computation, the particle size and not the settling velocity is of primary importance. Two computational approaches are employed to determine the inorganic suspended solids concentration. For solids with particle sizes larger than 0.065 millimeters, the stream power concept described by Yang and Stall [25], is used. With this method, the suspended solids transport capacity is calculated based on stream hydraulics. If the transport capacity is larger than the solids concentration, it is assumed that there is sufficient inorganic sediment available and the solids deficit is made up by scour. If the solids concentration exceeds the transport capacity, the excess is immediately deposited to the sediment bed. Solids with particle sizes smaller than 0.065 millimeters are treated as conservative except for deposition below user-specified velocities.

Scour of the bottom sediment is not presently considered for these smaller particles, because the state-of-the-art is not well defined.

Several of the water quality constituents included in the stream module are not considered in the reservoir module. The coefficients pertaining to these constituents which the user should consider holding constant or changing during the calibration period is presented below.

Constituent	Constant Coefficient	Variable Coefficient
Benthic Algae	Temperature limits* Half saturation constants Settling velocity	Maximum growth rate Respiration rate Scour rate
Aquatic Insects	Temperature limits* Feeding preferences Assimilation efficiency Particulate fraction of excreta Emergence rate	Maximum growth rate Mortality rate Respiration rate Half saturation constant

Initial Conditions

Except when the system flow-through time is large (i.e., week or more), initial conditions are relatively unimportant with the exception of those constituents which are not advected (e.g., fish, aquatic insects, benthic animals, benthic algae and sediment) or constituents being held constant. The effect of the initial conditions on advected constituents will normally be minimal within a time span equal to the system flow-through time. If the study period does not exceed the flow-through rate, the initial conditions should be carefully selected.

Included with the initial condition specification is the effective thermal capacity and thermal conductance coefficient of the stream bed. If the user wishes not to include the moderating effect of the stream bed on water temperature, the thermal conductance coefficient should be set

* Temperature limits should be set at reasonable values for the particular species being modeled prior to calibration and held constant during the calibration process.

to zero. If the moderating influence of the stream bed is to be included, an initial value of .5 to 1. meter is recommended for the thermal capacity and 0.025 to 0.075 kcal/m^2/sec/°C for the conductance coefficient. During calibration both values may be adjusted to obtain the proper diurnal variation in water temperature. If should be noted that the combination of a long time step, large conductance coefficient and a small thermal capacity may result in numerical instabilities in the temperature computation.

VIII. INPUT DATA DESCRIPTION

GENERAL

The input to the Reservoir, Stream Hydraulics and Stream Quality Modules may be inserted from cards or as card images on magnetic tape or other auxiliary input devices such as a disk file. A detailed description of the input data cards required by the three modules is provided in this section. This description includes the variable location, FORTRAN variable name, value and data description.

Variable locations for each input card are shown by field number. Each card is divided into ten fields of eight columns each. Field 1 is always reserved for card identification, which must be left justified. The different values a variable may assume and their associated conditions are described below. Some variables simply indicate the program option to be used by specifying the numbers -1, 0 or 1. For those having a + sign shown under the column "value", the numerical value of the variable is entered as input. For those having a - sign shown under the column "value", the input is to be a negative value. Where the variable value is shown as zero, the variable may be left blank.

Data for variables beginning with the letters I through N are integers and should not include decimals, but should be right justified in their field. Data for variables beginning with letters A through H and O through Z are floating point variables and should be right justified in their field if the decimal points are not punched.

Four blank cards must follow the data cards to signal the end of the run. When a multi-project job is to be processed during the same run (stacked jobs), the data cards for the last job only are to be followed by four blank cards.

RESERVOIR MODULE

The input data requirements for the Reservoir Module can be separated into the following categories:

1. Job Titles (TITLE cards).

2. Job controls (JOB cards) which include water quality constituent interaction modification specifications, input and print controls, tape and file assignments and other general data which control operation of the module.

3. Physical data (PHYS cards) such as invariant meteorological data, general reservoir geometry data, dispersion characteristics, inflow and withdrawal location data, and the table of reservoir elevation versus surface area and width at dam.

4. Chemical, physical and biological coefficients. (COEFF and SSOL cards).

5. Initial quality conditions (INIT cards).

6. Time variant inflow data (INFL cards) which includes the quality parameters to be read, length and description of inflow record and the inflow rates and water quality constituent concentrations.

7. Time variant meteorological data (WEATH cards).

8. Time variant withdrawal rates and temperature objectives (OUTL cards).

All data categories are input via the card reader except for categories 6, 7 and 8. These three categories, may be input via tape or disk files at the users option. Categories 6 and 7 are processed and written on files for later use during the simulation. At the users option, the files may be made permanent and also used during subsequent simulation, thus eliminating the need to reread and reprocess this data.

A detailed description of the data card requirements are presented below and followed by a summary of input cards showing the sequential arrangement of cards.

DATA CARD REQUIREMENTS

Job Title Cards*- Three cards required

Field	Variable	Value	Description
1		TITLE**	Card identification
2-10	TITLE	alpha	Job title to be printed on the first page of printout.

Job Control Card 1

Field	Variable	Value	Description
1		JOB1	Card identification
2	IDAY	+	Date of first day of simulation; year, month and day (e.g., 560701).
3	LDAY	+	Date of last day of simulation; year, month and day.
4	NHOI	+	Simulation time interval in hours (usually between 6 and 24 hours).
5	NHMI	+	Meteorological data interval in hours (usually between 1 and 6 hours).

*These cards and all remaining cards in this description are required cards unless the specific card description defines it as being optional.

**Field 1 is always reserved for card identification, which must be left justified.

JOB2-JOB2A

Job Control Card 2 - Water Quality Constituent Interaction Modification Option

Field	Variable	Value	Description
1		JOB2	Card identification
2	ITEST(1)	*	Temperature option
3	ITEST(2)	*	Dissolved oxygen option
4	ITEST(3)	*	5-day carbonaceous BOD option
5	ITEST(4)	*	Coliform bacteria option
6	ITEST(5)	*	Organic detritus option
7	ITEST(6)	*	Amonnia option
8	ITEST(7)	*	Nitrate option
9	ITEST(8)	*	Nitrite option
10	ITEST(9)	*	Phosphate option

Job Control Card 2A - Water Quality Constituent Interaction Modification Option

Field	Variable	Value	Description
1		JOB2A	Card identification
2	ITEST(10)	*	Total dissolved solids option
3	ITEST(11)	*	Type 1 phytoplankton option
4	ITEST(12)	*	Type 2 phytoplankton option
5	ITEST(13)	*	Zooplankton option
6	ITEST(14)	*	Total inorganic carbon and pH option
7	ITEST(15)	*	Alkalinity option
8	ITEST(16)	*	Organic sediment option
9	ITEST(17)	*	Benthic animals option
10	ITEST(18)	*	Type 1 fish option

* -1 - specifies constituent to be held constant at its initial value in quality analysis.
  0 - specifies constituent set to zero and ignored in quality analysis.
  1 - specifies normal constituent treatment in quality analysis.

Job Control Card 2B - Water Quality Constituent Interaction Modification Option

Field	Variable	Value	Description
1		JOB2B	Card identification
2	ITEST(19)	*	Type 2 fish option
3	ITEST(20)	*	Type 3 fish option
4	ITEST(21)		
5	ITEST(22)		
6	ITEST(23)	*	Inorganic suspended solids groups 1 through 5 option
7	ITEST(24)		
8	ITEST(25)		
9	ITEST(26)	*	Inorganic sediment option

Job Control Card 3

Field	Variable	Value	Description
1		JOB3	Card identification
2	NOUTS	+	Number of outlets; maximum of 18**
3	IWES	0	Index to select WES withdrawal option.
		+	Index to select Debler/Craya withdrawal option.
4	NTRIBS	+	Number of tributaries entering the reservoir; maximum of 10.
5	NPOINT	+	Number of points defining the initial concentration profiles; maximum of 100.

* -1 - specifies constituent to be held constant at its initial value in quality analysis.
0 - specifies constituent set to zero and ignored in quality analysis.
1 - specifies normal constituent treatment in quality analysis.

** One uncontrolled spillway, one flood control outlet and two wet wells with 8 outlets each.

Job Control Card 4

Field	Variable	Value	Description
1		JOB4	Card identification
2	IPRT	+	Normal printout interval, output will be printed every IPRT days.
3	IVAL	+	Output will be printed every IVAL hours within each day specified by IPRT (JOB4 card, field 2). IVAL should be a multiple of NHOI (JOB1 card, field 4).
4	INTP	+	Vertical layer printout frequency (e.g., a 1 prints every layer, a 2 prints every other layer, etc.).
5	ICT	0	Index that specifies the input water temperature data is in degrees Celsius.
		1	Index that specifies the input water temperature data is in degrees Fahrenheit.
6	ICM	0	Index that specifies the input data other than meteorological (WEATH1 cards) is in metric units.
		1	Index that specifies the input data other than meteorological data (WEATH1 cards) is in English units.
7	NSD	+	Number of "additional" print days shown on the JOB5 card other than those specifies by the "normal" printout interval, IPRT (JOB4 card, field 2); maximum of 45.

Job Control Card 5*

Field	Variable	Value	Description
1		JOB5	Card identification
2-10	NDAYP(I)	+	Print days other than those specified by the normal printout interval, IPRT (JOB4 card, field 2). Use year, month and day.

*Include only if NSD (JOB4 card, field 7) is positive. Use up to 9 numbers per card. Use as many cards as needed for all NSD (JOB4 card, field 7) values.

Job Control Card 6* - Tape or file related data

Field	Variable	Value	Description
1		JOB6	Card identification.
2	ITAPE	+	Any positive number will assign magnetic unit 10 for output of reservoir discharge rate and quality data for input to subsequent simulations of downstream river reaches or reservoirs.
		0	Data will not be saved for further analysis.
3	IFILE	+	Any positive number will assign magnetic unit 11 for output of reservoir discharge hydrograph for input to hydraulics module.
		0	Data will not be saved for further analysis.
4 5 6	JTAPE(1) JTAPE(2) JTAPE(3)	+	Positive numbers will assign magnetic units 12-14 for input of flow and quality data from previous simulation of upstream river reaches and reservoirs. Zero to 3 units may be assigned. A zero or blank will indicate that no input unit from previous analysis will be used.
7 8 9	NHP(1) NHP(2) NHP(3)	+	Inflow rate and quality data interval on input units JTAPE (JOB6 card, field 4-6). Set to zero if the corresponding JTAPE is equal to zero.
10	LPLOT	+	Any positive number will assign magnetic units 89-93 for output of simulation results for use in reservoir plot routines.
		0	Not interested in using plot routines.

*The numbers identified below may need to be assigned a magnetic tape or disk name using the specific job control language for the users computer system. No action is necessary for Harris 500 computer users.

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JOB7

Job Control Card 7* - Tape or file related data

Field	Variable	Value	Description
1		JOB7	Card identification.
2	IEQF	+	Any positive number will assign magnetic unit 17 for input of meteorological data for use in calculating surface heat exchange rates using the equilibrium temperature approach.
		0	The heat budget approach to surface heat exchange will be used.
3	IMETF	+	Any positive number will assign magnetic unit 15 for output of processed meteorological data generated from data on unit LMF (WEATH1 cards).
		0	Used if IEQF (JOB7 card, field 2) is positive.
		-	Any negative number will assign magnetic unit 15 for input of processed meteorological data generated by a previous simulation.
4	IINFL	+	Any positive number will assign magnetic unit 16 for output of processed tributary inflow and quality data generated from data on unit LQF (INFL cards).
		-	Any negative number will assign magnetic unit 16 for input of processed tributary inflow and quality data generated by a previous simulation.
5	LMF	+	Any positive number will assign magnetic unit 17 for input of raw meteorological data (WEATH1 cards). Use a 5 for card input. May be left blank if IMETF (JOB7 card, field 3) is negative or IEQF (JOB7 card, field 2) is positive.
6	LQF	+	Any positive number will assign magnetic unit 18 for input of raw tributary inflow and quality data (INFL cards). Use a 5 for card input. May be left blank if IINFL (JOB7 card, field 3) is negative.
7	LOF	+	Any positive number will assign magnetic unit 19 for input of reservoir release data (OUTL cards). Use a 5 for card input.

*The numbers identified below may need to be assigned a magnetic tape or disk name using the specific job control language for the users computer system. No action is necessary for Harris 500 computer users.

Physical Description Card 1

Field	Variable	Value	Description
1		PHYS1	Card identification
2	IDEW	1	Wet bulb temperature is required (WEATH1 card, field 5).
		0	Dew point temperature is required (WEATH1 card, field 5).
3	AA	+	Evaporation coefficient (usually zero).
4	BB	+	Evaporation coefficient (usually $1.5 \times 10^{-9*}$).
5	XLAT	+	North latitude of reservoir site in degrees.
6	XLON	+	West longitude of reservoir site in degrees.
		-	East longitude of reservoir site in degrees.
7	TURB	+	Atmospheric turbidity factor (range from 2 for clear unpolluted atmosphere to 5 for highly polluted atmosphere).

* The most general way to code exponential numbers is ± xx.xxE+ee (e.g., 1.5E-09). Some computers can accept the sample coded as 1.5-9.

PHYS2

Physical Description Card 2

Field	Variable	Value	Description
1		PHYS2	Card identification
2	SDZ	+	Thickness of vertical layer in feet or meters (usually about 1 meter).
3	ELMAX	+	Maximum water surface elevation in feet or meters.
4	ELMIN	+	Elevation of bottom of reservoir in feet or meters.
5	RESEL	+	Initial water surface elevation in feet or meters.
6	EDMAX	+	Secchi disk reading in feet or meters. The effects of all particulate materials being modeled or held constant should be excluded.
7	XQPCT	+	Fraction of the solar radiation absorbed in the top XQDEP(PHYS2 card, field 8) depth.*
8	XQDEP	+	Depth in which XQPCT (PHYS2 card, field 7) of the solar radiation is absorbed in feet or meters (usually 1.0 feet).
9	BPCT	+	Maximum fraction of total outflow allowed through the lowest port of one of the wet wells when using the selective withdrawal option (e.g., .25 is 25% of the total flow).

* XQPCT = 0.265[.087 - .73 ln (EDMAX in meters)] + 0.614

Physical Description Card 3A* - Effective diffusion, stability method only

Field	Variable	Value	Description
1		PHYS3A	Card identification
2	GMIN	+	Water column minimum stability in kg/m^3/meter
3	GSWH	+	Water column critical stability in kg/m^3/meter
4	A1	+	Diffusion coefficient when the water column stability is less than GWSH (PHYS3A card, field 2) in m^2/second
5			Not used
6	A3	-	Empirical constant for computing diffusion coefficients based on density gradients.

Phsyical Description Card 3B* - Effective diffusion, wind method only

Field	Variable	Value	Description
1		PHYS3B	Card identification
2	GMIN	+	Water column minimum stability in kg/m^3/meter
3	GSWH	+	Minimum allowable diffusion coefficient in m^2/second.
4	A1	+	Empirical constant for computing diffusion coefficients based on wind speed.
5	A2	+	Empirical constant for computing diffusion coefficients based on wind speed.
6	A3	+	Maximum allowable diffusion coefficient, in m^2/second.

* Use either, but not both, the PHYS3A or this PHYS3B card. See text, page 13 for discussion of difference in theory and typical data values.

PHYS4

Physical Description Card 4

Field	Variable	Value	Description
1		PHYS4	Card identification
2-10	RLEN(K)	+	Effective length of reservoir in feet or meters at each tributary inflow point. This value is divided into the surface area of the layer into which the inflow penetrates to calculate the effective width for use in the allocation of inflow to the individual elements. NTRIBS (JOB3 card, field 4) values are required. If NTRIBS=10, an additional PHYS3 card is required with the effective length for Tributary 10 in field 2.
		-	The inflow will be allocated to all elements down to the level of like density within the lake.

PHYS5

Physical Description Card 5*

Field	Variable	Value	Description
1		PHYS5	Card identification
2	ELOUT	+	Center-line elevation of the outlet in feet or meters.
3	WOUT	+	Virtual width** of outlet in feet or meters.
4	OUTMAX	+	Maximum allowable flow rate through outlet in cfs or cms.
5	NN	1	The outlet is a port in wet well Number 1†
		2	The outlet is a port in wet well Number 2†
		3	The outlet is flood control outlet††
		4	The outlet is the uncontrolled spillway††

* One card required for each outlet (NOUTS cards, JOB3, field 2)

** The virtual width is the actual outlet area divided by the depth of a vertical layer, SDZ (PHYS2 card, field 2).

† The outlet ports of a wet well must be input in ascending order. The number of ports can range from 1 to 8 and the maximum allowable flow should be the same for all ports of the wet well. Only one port of each wet well will be operated to meet the temperature objective except when the flow through the bottom port is limited to a fraction (i.e., BPCT, PHYS2 card, field 9 < 1) of the total flow. In this case, the two lowest ports may be operated. If the flow through the lowest port is limited to a fraction of the total flow, the wet well with the lowest port should be designated wet well Number 1.

†† Only one flood control outlet and one uncontrolled spillway is allowed and they are not affected by the maximum fraction allowed through the bottom outlet.

PL

Outlet constituent suboptimization objective function parameters; required card.

One PL card is required for each water quality constituent being considered for outlet optimization. A maximum of 10 quality constituents can be considered. Only advected parameters being simulated (i.e., ITEST=1, JOB2-2B cards) will be considered.

Field	Variable	Value	Description
1		PL	Card identification
2	LPARAM	0	Selective withdrawal based on temperature only. Suboptimization objective function will not be used.
		+ or -	Quality constituent number (see ITEST subscripts, JOB 2-2B cards) to be included in the outlet optimization. A negative number signals the final PL card.
3	WEIT	0	The parameter will not be considered in the outlet quality optimization. The specification of zero weighting allows removal of parameters from outflow optimization without altering outflow target data (Cards OUTL2-2A).
		+	Relative weights to be assigned to each constituent in overall suboptimization objectives function. Only the relative magnitude is important since the input values are normalized during the computation.
4-9	PLYNML	+ or -	a through f values for outlet constituent suboptimization objective function parameters. A discussion of the parameters for the outlet constituent suboptimization is provided in the outlet gate selection section of Chapter II

Physical Description Card 6* - Reservoir depth, area and width table

Field	Variable	Value	Description
1		PHYS6	Card identification
2	D1	+	Elevation in feet or meters
3	AREA	+	Reservoir area at elevation D1 in acres or square meters (must be greater than zero).
4	WIDTH	+	Effective reservoir withdrawal width at elevation D1 in feet or meters (normally the dam width at elevation D1).
5	VOL	+	Reservoir volume below elevation ELMIN (PHYS2 card, field 4). Input on first card only to account for any "dead storage" below elevation ELMIN.

Default Coefficient Override Card**

Field	Variable	Value	Description
1		COEFF	Card identification
2	ICODE(1)	+	Coefficient code number (see Tables IV-1 through IV-4.
		-1	Denotes final default coefficient override value.
3	RATE(1)	+	New value for coefficient corresponding to ICODE(1).
4 5 6 7 8 9	ICODE(2) RATE(2) ICODE(3) RATE(3) ICODE(4) RATE(4)	+ -1	Coefficient code numbers and corresponding new values of coefficients.

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* Repeat PHYS6 card as necessary to define reservoir depth, area and width between elevations ELMIN and ELMAX (PHYS2 card, fields 4 and 3) beginning at the bottom and progressing to the top. The depth D1 on the first card must equal ELMIN and the depth D1 on the last card must equal ELMAX.

** Repeat as necessary to redefine any or all of the chemical, physical and biological coefficients listed on Tables IV-1 through IV-4. The final card must have a -1 in one of the ICODE fields.

SSOL1-SSOL2

Inorganic Suspended Solids Card 1*

Field	Variable	Value	Description
1		SSOL1	Card identification
2	TY(1)	+	Three pairs of settling velocity, cm/sec (TY) versus temperature, °C (TX) for inorganic suspended solids. These three points define the curve from which settling velocities will be calculated for a given water temperature.
3	TX(1)		
4	TY(2)		
5	TX(2)		
6	TY(3)		
7	TX(3)		

Inorganic Suspended Solids Card 2**

Field	Variable	Value	Description
1		SSOL2	Card identification
2	ISETL(1)	+	Number of elements which receive the initial deposition of suspended solids group 1.
		0	No initial deposition of suspended solids group 1.
		-1	All elements down to the inflow entry level will receive the initial deposition of suspended solids group 1 in proportion to the element volume.
3	SSLOST(1)	+	Fraction of suspended solids group 1, immediately lost by deposition to the top ISETL (SSOL2 card, field 2) elements.
4	ISETL(2)	+ 0 -1	Repeat sets of ISETL and SSLOST for each suspended solids group being modeled. Controlled by ITEST (JOB2B cards, field 4 through 8).
5	SSLOST(2)		
6	ISETL(3)		
7	SSLOST(3)		
8	ISETL(4)		
9	SSLOST(4)		

* One card is required for each suspended solids group being modeled. Controlled by ITEST (JOB2B card, field 4 through 8).

** One card is required for each tributary inflow. If five suspended solids groups are being modeled, (i.e., ITEST(25)=1, JOB2B card, field 8) two cards for each tributary inflow are required with ISETL(5) and SSLOST(5) defined on the second card, fields 2 and 3. Omit all SSOL2 cards if no inorganic suspended solids are being modeled.

Initial Conditions Card 1 - Fish Densities

Field	Variable	Value	Description
1		INIT1	Card identification
2	FISH(1)	+	Type 1 fish density in Kg/Ha.
3	FISH(2)	+	Type 2 fish density in Kg/Ha.
4	FISH(3)	+	Type 3 fish density in Kg/Ha.
5	AREA	+	**Surface area in hectares (default value is initial reservoir water surface).**

Initial Conditions Card 2* - Water Quality at Specified Elevation

Field	Variable	Value	Description
1		INIT2	Card identification
2	TA	+	Elevation at which quality parameters are specified.
3	TEMP	+	Temperature in °C or F.
4	OXY	+	Dissolved oxygen in mg/l.
5	BOD	+	5-day carbonaceous BOD in mg/l.
6	COLIF	+	Coliform bacteria in MPN/100 ml.
7	SEDMT	+	Organic sediment (settled detritus) in mg/m^2.
8	DETUS	+	Organic Detritus in mg/l.
9	CNH3	+	Ammonia as nitrogen in mg/l.
10	CNO3	+	Nitrate as nitrogen in mg/l.

*The cards, INIT2, INIT3 and INIT4, in that order, are repeated for NPOINT (JOB3 card, field 5) elevations. The order of repetition is from lowest elevation to highest elevation. Input data should at least include the quality data at the reservoir bottom and at the elevation of the initial water surface, RESEL(PHYS2 card, field 5). Isoquality profiles can be initiated with NPOINT = 1. Any parameter on this card can be left blank if the corresponding ITEST (JAB2, JOB2A or JOB2B card) value equals zero.

Initial Conditions Card 3* - Water Quality at Specified Elevation

Field	Variable	Value	Description
1		INIT3	Card identification
2	CNO2	+	Nitrite as nitrogen in mg/l
3	PO4	+	Phosphate as phosphorus in mg/l
4	TDS	+	Total dissolved solids in mg/l
5	BEN	+	Benthic animals in mg/m^2.
6	ALGAE(1)	+	Type 1 phytoplankton in mg/l
7	ALGAE(2)	+	Type 2 phytoplankton in mg/l
8	ZOO	+	Zooplankton in mg/l
9	PH	+	pH in pH units
10	ALKA	+	Alkalinity as calcium carbonate in mg/l.

Initial Conditions Card 4* - Water Quality at Specified Elevation

Field	Variable	Value	Description
1		INIT4	Card identification
2 3 4 5 6	SSOL(1) SSOL(2) SSOL(3) SSOL(4) SSOL(5)	+	Inorganic suspended solids groups 1 through 5 in mg/l
7	SSED		Inorganic sediment in mg/m^2.

*The cards, INIT2, INIT3 and INIT4, in that order, are repeated for NPOINT (JOB3 card, field 5) elevations. The order of repetition is from lowest elevation to highest elevation. Input data should at least include the quality data at the reservoir bottom and at the elevation of the initial water surface, RESEL(PHYS2 card, field 5). Any parameter on this card can be left blank if the corresponding ITEST (JOB2, JOB2A or JOB2B card) value equals zero.

Inflow Rate and Quality Card 1* - Input via unit LQF (JOB7 card, field 6)

Field	Variable	Value	Description
1		INFL1	Card identification
2	ICON(2)	**	Temperature in °C or °F.
3	ICON(3)	**	Dissolved oxygen in mg/l
4	ICON(4)	**	5-day carbonaceous BOD in mg/l
5	ICON(5)	**	Coliform bacteria in MPN/100 ml.
6	ICON(6)	**	Organic detritus in mg/l
7	ICON(7)	**	Ammonia as nitrogen as mg/l
8	ICON(8)	**	Nitrate as nitrogen in mg/l
9	ICON(9)	**	Nitrite as nitrogen in mg/l
10	ICON(10)	**	Phosphate as phosphorus in mg/l

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* INFL1 cards determine which inflow quality parameters will be input via sets of INFL3 and INFL4 cards or sets of INFL3 and INFL5 cards. One set is required for each non-zero value of ICON(I) for each tributary inflow. ICON(1) controls the reading of tributary flow rate and is set internally to 1 (e.g., tributary flow rates are always read). Omit all INFL cards if IINFL (JOB7 card, field 4) is negative.

** -1 - Inflow quality data will be read but not printed.
 0 - Inflow quality data will not be read.
 +1 - Inflow quality data will be read and printed.

Inflow Rate and Quality Card 1A* - Input via unit LQF (JOB7 card, field 6)

Field	Variable	Value	Description
1		INFL1A	Card identification
2	ICON(11)	**	Total dissolved solids in mg/l
3	ICON(12)	**	Type 1 phytoplankton in mg/l
4	ICON(13)	**	Type 2 phytoplankton in mg/l
5	ICON(14)	**	Zooplankton in mg/l
6	ICON(15)	**	pH in pH units
7	ICON(16)	**	Alkalinity as $CaCO_3$ in mg/l

Inflow Rate and Quality Card 1B* - Input via unit LQF (JOB7 card, field 6)

Field	Variable	Value	Description
1		INFL1B	Card identification
2	ICON(17)	**	Suspended solids groups 1 through 5 in mg/l
3	ICON(18)		
4	ICON(19)		
5	ICON(20)		
6	ICON(21)		

* INFL1 cards determine which inflow quality parameters will be input via sets of INFL3 and INFL4 cards or sets of INFL3 and INFL5 cards. One set is required for each non-zero value of ICON(I) for each tributary inflow. ICON(1) controls the readings of tributary flow rate and is set internally to 1 (e.g., tributary flow rates are always read). Omit all INFL cards if IINFL (JOB7 card, field 4) is negative.

** -1 - Inflow quality data will be read but not printed
 0 - Inflow quality data will not be read.
 +1 - Inflow quality data will be read and printed.

Inflow Rate and Quality Card 2* - Input via unit LQF (JOB7 card, field 6)

Field	Variable	Value	Description
1		INFL2	Card identification
2	IIDAY	+	First day of inflow rate and quality record for all tributaries; year, month and day.
3	LLDAY	+	Last day of inflow rate and quality record for all tributaries; year, month and day.

Inflow Rate and Quality Card 3*† - Input via unit LQF (JOB7 card, field 6)

Field	Variable	Value	Description
1		INFL3	Card identification
2	IDINT	+	Inflow rate and quality data update interval in hours. Inflow data is input using a series of INFL4 cards under this option.
		0	Inflow data is input at variable time intervals using a series of INFL5 cards under this option.
3-7	CON(I)	alpha	Description of inflow data.

* Omit all INFL cards if IINFL (JOB7 card, field 4) is negative.

† Repeat sets of INFL3 and INFL4 or sets of INFL3 and INFL5 cards for each parameter and each tributary (excluding those input via JTAPE, JOB6 card, field 4-6). Controlled by INFL1, INFL1A and INFL1B cards.

INFL4

Inflow Rate and Quality Card 4*† - Input via unit LQF (JOB7 card, field 6)

Field	Variable	Value	Description
1		INFL4	Card identification
2-10	CONC(I)**	+	Inflow rate (cms or cfs) or inflow quality in appropriate units.

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* Repeat sets of INFL3 and INFL4 or sets of INFL3 or INFL5 cards for each parameter and each tributary (excluding those input via JTAPE, JOB6 card, field 4-6). Controlled by INFL1, INFL1A and INFL1B cards. Omit all INFL cards if IINFL (JOB7 card, field 4) is negative.

† The number of INFL4 cards is determined by the length of inflow data record (INFL2 cards, fields 2 and 3) and the inflow data update interval (INFL3 card, field 3). (e.g., 60 day of record with 4 hour update interval would require 60 x 24/4 = 360 values and a total of 40 cards).

** A negative value for temperature will result in an inflow temperature equal to the daily average dry bulb air temperature less the input temperature value.

A negative value for oxygen signifies a fraction of saturation.

A negative value of BOD denotes BOD values which include the oxygen demands of ammonia, nitrite and detritus. These BOD values will be reduced commensurated with the concentration of the other constituents.

Inflow Rate and Quality Card 5*† - Input via unit LQF (JOB7 card, field 6)

Field	Variable	Value	Description
1		INFL5	Card identification
2	ITIME**	+	Time of observation; year, month, day and hour (e.g., 56070100)
		-1	Denotes the end of the data set.
3	CONC***	+	Inflow rate (cms or cfs) or inflow quality in appropriate units.
4	ITIME	+	Sets of time and corresponding inflow rate of quality
5	CONC	-1	
6	ITIME		
7	CONC		
8	ITIME		
9	CONC		

* Repeat sets of INFL3 and INFL4 or sets of INFL3 of INFL5 cards for each parameter and each tributary (excluding those input via JTAPE, JOB6 card, field 4-6). Controlled by INFL1, INFL1A and INFL1B cards. Omit all INFL cards if IINFL (JOB7 card, field 4) is negative.

† Use one or more INFL5 cards to input the inflow rate or quality over the length of the inflow data record.

** The first time of observation must be on or before hour zero of IIDAY (INFL2 card, field 2).

*** A negative value for temperature will result in an inflow temperature equal to the daily average dry bulb air temperature less the input temperature value.

A negative value for oxygen signifies a fraction of saturation.

A negative values of BOD denotes BOD values which include the oxygen demands of ammonia, nitrite and detritus. These BOD values will be reduced commensurated with the concentration of the other constituents.

WEATH1

Weather Data Card 1* - Input via unit LMF (JOB7 card, field 5)

Field	Variable	Value	Description
1		WEATH1	Card identification
2	ITIME**	+	Time of observation; year, month, day and hour.
3	CLOUD	+	Fraction of sky that is cloud covered.
4	DBT	+	Dry bulb air temperature in °F.
5	DPT	+	Wet bulb or dew point air temperature in °F. Controlled by IDEW (PHYS1 card, field 3).
6	APRESS	+	Barometric pressure in inches of mercury
7	WIND	+	Wind speed in mph.
8		0	Not used
9		0	Not used
10	IEND	0	Denotes other than last day of weather data.
		-1	Denotes last day of weather data. The minus one must be included on all cards for the last day.

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* The WEATH1 card is repeated at NHMI (JOB1 card, field 5) intervals during a day. [24/NHMI] WEATH1 cards are required per day (i.e., if NHMI=3, 8 WEATH1 cards would be required per day). This data would define the meteorological conditions at hours 0, 3, 6,.....18 and 21. The meteorological conditions at hour 24 would be set equal to hour 0 of the next day if data were input at daily interval. If other than daily data, hour 24 would be set equal to hour 0 of the same day. Sets of WEATH1 cards can be input at any interval. Omit if IEQF (JOB7 card, field 2) is positive or if IMETF (JOB7 card, field 3) is negative.

** The time of the first observation must be on or before the first day of simulation (JOB1 card, field 2).

Weather Data Card 2* - Input via unit IEQF (JOB7, field 2)

Field	Variable	Value	Description
1		WEATH2	Card identification
2	ITIME*	+	Time of observation; year, month and day
3	XTE	+	Equilibrium temperature in degrees C.
4	XKE	+	Coefficient of surface heat exchange in $kcal/m^2/sec/C$
5	XQNS	+	Short wave solar radiation in $kcal/m^2/sec$.
6	XWIND	+	Wind speed in meters/sec.
7	EA	+	Vapor pressure in millibars.

* One card representing average meteorological conditions is required for each day of simulation. These cards can be obtained directly from the "Thermal Simulation of Lakes" computer program [24] available at the HEC. Omit if IEQF (JOB7 card, field 2) is zero.

** The time of the first observation must be on or before the first day of simulation (JOB1 card, field 2).

OUTL1-OUTL1A

Outlet Gate Operation Card 1* - Input via unit LQF (JOB7 card, field 7) Use to specify reservoir releases explicitly by gate

Field	Variable	Value	Description
1		OUTL1	Card identification
2	ITIME**	+	Time of observation; year, month and day
		-	Time of observation; year, month and day; however, negative time denotes final OUTL1 card.
3	FLOW(1)	+	Release rate through gate number one (lowest gate) in cms or cfs.
4 5 6 7 8 9 10	FLOW(2) FLOW(3) FLOW(4) FLOW(5) FLOW(6) FLOW(7) FLOW(8)	+	Release rate through gates 2 through 8 in cms or cfs.

Outlet Gate Operation Card 1A* - Continuation of card OUTL1 and required only if NOUTS (JOB3 card, field 2) is greater than 8. Two 1A cards are required if NOUTS=18

Field	Variable	Value	Description
1		OUTL1A	Card identification
2	FLOW(9)	+	Release rate for remaining gates in cms or cfs
.	.	.	
.	.	.	
.	.	.	
	FLOW(NOUTS)	+	

* Either OUTL1 or OUTL2 cards may be input at any interval.

** The time of the first observation must be on or before the first day of simulation (JOB1 card, field 2).

Outlet Gate Operation Card 2* - Input via unit LQF (JOB7 card, field 7) Use to specify water quality release objectives

Field	Variable	Value	Description
1		OUTL2	Card identification
2	ITIME**	+	Time of observation; year, month and day
		-	Time of observation; year, month and day; however, negative time denotes final OUTL2 card.
3	FLOW(1)	-1	Index to call selective withdrawal option
4	FLOW(2)	+	Total flow to be released in cfs or cms
5	FLOW(3)	+	Outflow objective for temperature (F or C) or other water quality parameter. One value is required for each parameter considered in the outlet suboptimization objective function. The order of input must conform with the order of input of PL cards.
6	FLOW(4)	+	
7	FLOW(5)	+	
8	FLOW(6)	+	
9	FLOW(7)	+	
10	FLOW(8)	+	

Outlet Gate Operation Card 2A* - Continuation of Card OUTL2 and required only if the number of PL cards exceeds 6.

Field	Variable	Value	Description
1		OUTL2A	Card identification
2	FLOW(9)	+	Outflow objectives for remaining water quality parameters. A maximum of 10 parameters may be considered.
3	FLOW(10)	+	
4	FLOW(11)	+	
5	FLOW(12)	+	

NOTE: USE 4 BLANK CARDS AT THE END OF THE DATA DECK

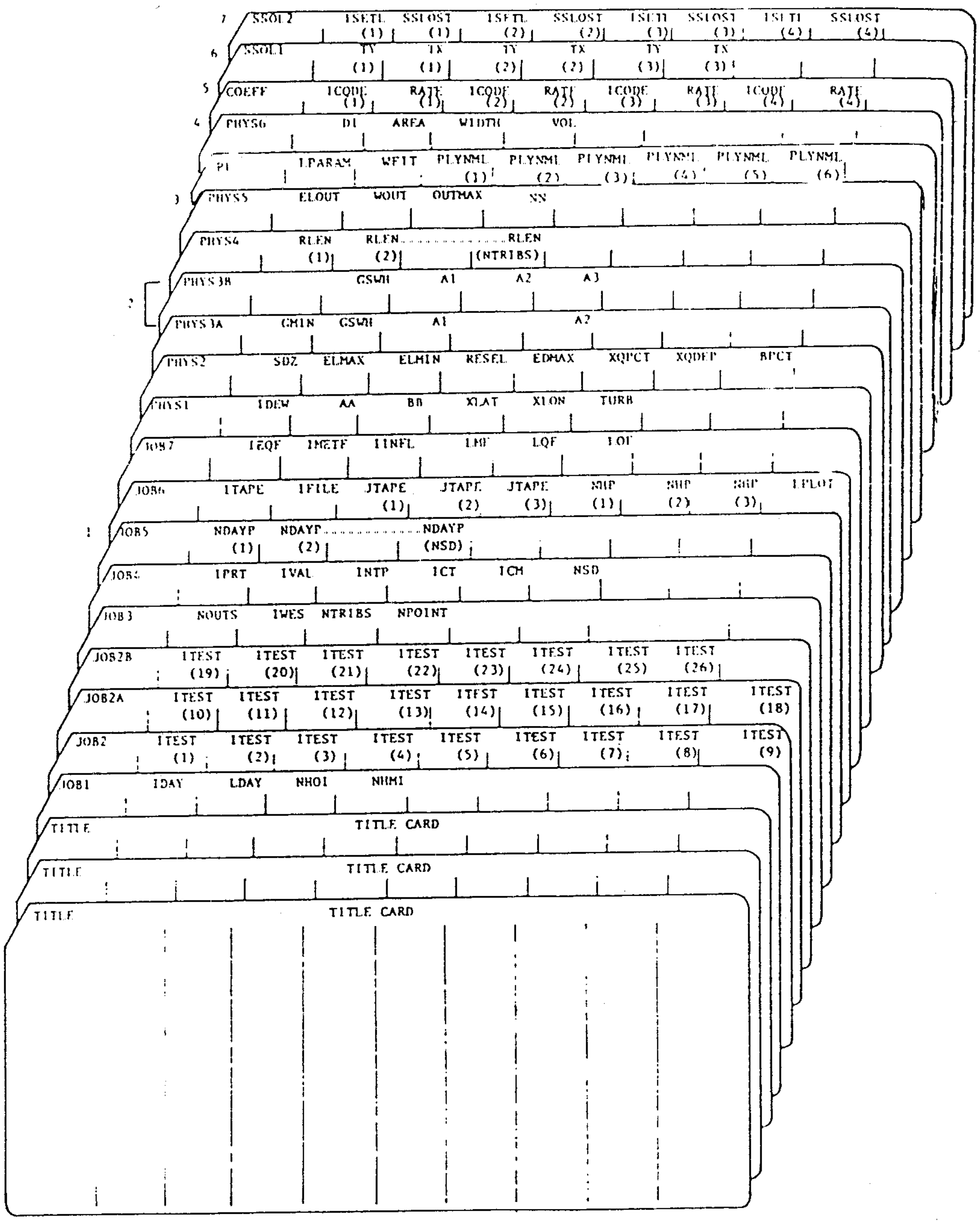
* Either OUTL1 or OUTL2 cards may be input at any interval.

** The time of the first observation must be on or before the first day of simulation (JOB1 card, field 2).

SUMMARY OF DATA CARDS

FOR

RESERVOIR QUALITY MODULE



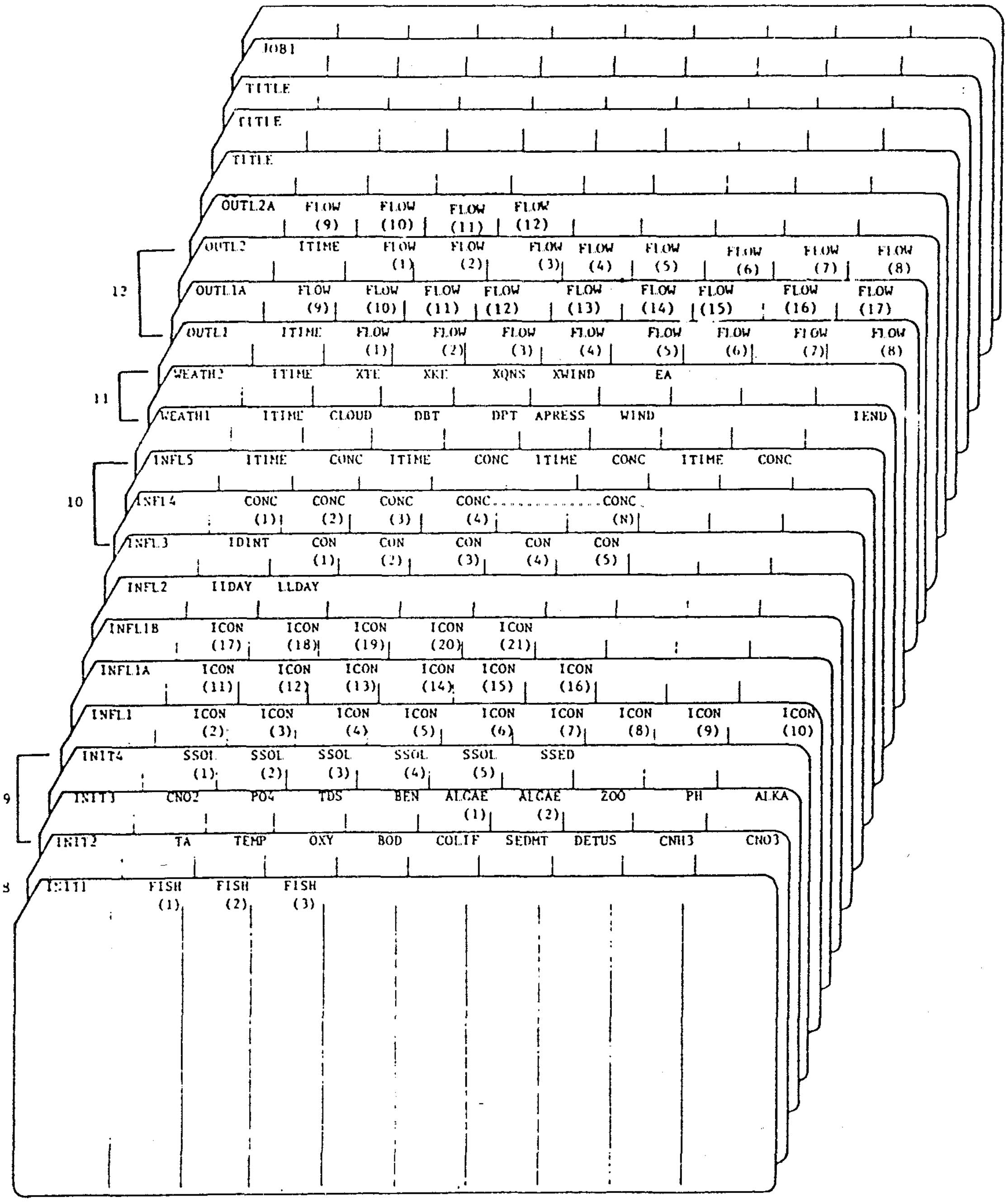
1. Include JOB5 cards only if NSD (JOB4 card, field 7) is positive.
2. Use either a PHYS3A or a PHYS3B card but not both.
3. One PHYS5 card is required for each outlet.
4. Repeat PHYS6 cards as necessary to define reservoir geometry between elevations ELMIN and ELMAX (PHYS2 card, fields 3 & 4).
5. Repeat COEFF cards as necessary to redefine as many coefficients as desired.
6. One SSOL1 card is required for each suspended solids group being modeled.
7. One SSOL2 card is required for each tributary inflow. Omit if no suspended solids groups are modeled

SUMMARY OF DATA CARDS

FOR

RESERVOIR QUALITY MODULE

(continued)



8. Omit INIT2 card if no fish types are being simulated.
9. Repeat INIT2, INIT3 and INIT4 cards, in that order, for NPOINT (JOB3 card, field 5) elevations.
10. Repeat sets of INFL3 and INFL4 cards, or sets of INFL3 and INFL5 cards for each quality constituent and each tributary (excluding those input via JTAPE, JOB6 card, fields 4-6).
11. Repeat sets of WEATH1 cards or sets of WEATH2 cards, but not both, as necessary to define meteorological conditions during the simulation period.
12. Repeat sets of OUTL1 and OUTL1A cards or OUTL2 cards as required to define the outflow conditions for entire study period.

STREAM HYDRAULICS MODULE

The input data requirements for the Stream Hydraulics Module can be separated into the following categories:

1. Job titles (TITLE cards).

2. Job controls (JOB cards) which include flow computation method selection, input and print controls, tape and file assignments and and other data which control operation of the module.

3. Tributary locations (TRIB cards).

4. STORM [22] generated hydrograph data (STORM cards) which includes length of record, quantity of inflow data and inflow rates.

5. Time variant inflow and withdrawal data (INFL cards) which includes the length of the flow record, description of flow data and flow rates.

6. Stream geometry data (GEOM cards) which includes reach and element lengths, intersection definitions and energy grade line elevations.

7a. Channel cross section coordinate data (CCC and all HEC-2 [23] format cards) which includes stage-flow relationships and sufficient data to generate all channel geometry data required by the module.

7b. Channel cross section geometry data (GEOM4 cards).

8. Boundary condition specifications (BOUND cards).

9a. Initial conditions (KW cards) for the kinematic wave flow computation method.

9b. St. Venant flow computation method specific data (STV cards) which includes variable time step controls and uniform or variable initial conditions.

9c. Control points (MR cards) for the Muskingum routing flow computation method.

9d. Modified Puls routing flow computation method specific data (MP cards) which includes control points and storage-outflow tables.

10. Downstream depth controls (DD cards).

11. Non-point inflow and withdrawal rates (NPF cards).

TITLE

All data categories are input via the card reader except for categories 4, 5 and 7, which may be input via tape or disk files at the users option. Categories 4 and 5 are processed and a continuous record of inflows and withdrawals written on a single file for later use during the simulation. At the users option, the file may be made permanent and used for subsequent simulations, thus eliminating the need to reread and reprocess this data.

Either data categories 7a or 7b may be used to define the channel cross section geometry. If 7a is used, the processed data may be punched or written on a permanent file and input as 7b cards in subsequent simulations.

A detailed description of the data card requirements are presented below and followed by a summary of input cards showing the sequential arrangement of the cards.

DATA CARD REQUIREMENTS

Job Title Cards - Three cards required

Field	Variable	Value	Description
1*		TITLE	Card identification
2-10	TITLE	alpha	Job title to be printed on the first page of printout.

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* Field 1 is always reserved for card identification, which must be left justified.

Job Control Card 1*

Field	Variable	Value	Description
1		JOB1	Card identification
2	IDAY	+	First day of simulation; year, month and day (e.g., 560701).
3	LDAY	+	Last day of simulation; year, month and day.
4	NL**	+	Number of inflow hydrographs.
5	NSLOAD	+	Number of STORM generated inflow hydrographs; maximum of 20. (Maximum of 10 if a quality simulation is planned).
		0	No STORM hydrographs.
6	NREM**	+	Number of withdrawals.
		0	No withdrawals.
7	IDAM	0	Not used
8	ICM	0	Input data is in metric units.
		1	Input data is in english units.
9	INTW	0	Non-point inflow and withdrawals will not be considered (omit NPF cards).
		1	Non-point inflow and withdrawals will be considered.

* These cards and all remaining cards in this description are required cards unless the specific card description defines it as being optional.

** A combined total of 30 inflows, flow boundary conditions and withdrawals (i.e., NL+NREM $\leq$ 30) are allowed in the hydraulics module, however, a maximum of 25 inflows and 5 withdrawals are allowed if a quality simulation is planned.

Job Control Card 2

Field	Variable	Value	Description
1		JOB2	Card identification
2	IHYDRO		Hydraulic computation method selector
		1	Steady state flow using stage vs. flow relationship.
		2	Steady state flow using backwater method.
		3	Dynamic flow using kinematic wave solution.
		4	Dynamic flow using St. Venant solution.
		5	Dynamic flow using Muskingum routing.
		6	Dynamic flow using modified Puls routing.
3	NREACH	+	Number of stream reaches.
4	INT	+	Number of stream reach intersections.
5	NBPP	+	Number of input channel cross sections; minimum of 2 per reach and maximum total of 41 over all reaches.*
6	NELEV	+	Number of elevations defining cross section geometric data; maximum of 21. (Must equal the number of elevations on ET cards if the channel geometry is defined using cross section coordinate data).
7	VWR	+	Scaling factor to adjust all channel cross section widths.
8	NCAL		Not used.
9	IPRT	+	Normal printout interval, output will be printed every IPRT days.
10	NSD	+	Number of additional print days shown on the JOB2A card other than those specified by the normal printout interval, IPRT (JOB2 card, field 9); maximum of 50.

* If more than 41 sections of input are desired, consideration should be given to running 2 or more separate jobs using the downstream interface options between jobs.

Job Control Card 2A*

Field	Variable	Value	Description
1		JOB2A	Card identification
2-10	NDAYP(I)	+	Print days other than those specified by the normal printout interval, IPRT (JOB2 card, field 9). Use year, month and day.

Job Control Card 3

Field	Variable	Value	Description
1		JOB3	Card identification
2	DELT	+	Computational time step in hours.
3	FREQ	+	Printout frequency for flow and stage in hours (not to exceed 24).
4	ICND	0	Read initial conditions for each node.
		1	Read only one value for initial conditions for each reach. This value will be assumed as a uniform condition throughout the reach.
5	IDST	0	Do not read downstream head cards.
		1	Read downstream head cards.
6	IALL	0	Do not print all steps and diagnostic information.
		1	Print all steps and diagnostic information for each time step.
7	IGEDA	-1	No cross-section data printed.
		0	Abbreviated channel cross section printout.
		1	Comprehensive channel cross section printout.

* Include only if NSD (JOB2 card, field 10) is positive. Use up to 9 numbers per card. Use as many cards as needed for all NSD values.

JOB4

Job Control Card 4* - Tape or file assignments

Field	Variable	Value	Description
1		JOB4	Card identification.
2	KTAPE	+	Any positive number will assign magnetic unit 10 for output of outflow hydrograph for input to subsequent simulations of downstream river reaches.
		0	Data will not be saved for further analysis.
3 4 5	LTAPE(1) LTAPE(2) LTAPE(3)	+ -	Positive numbers will assign magnetic units 11-13 for input of inflow hydrographs from previous simulation of upstream river reaches and reservoirs. One to 3 units may be assigned. A negative value allows the user to create an interface unit from card input during the simulation. The option should be used only to override mean daily reservoir releases with variable hydropower releases. A zero or blank will indicate no input unit from a previous analysis will be used.
6	IHYD	+	Any positive number will assign magnetic unit 14 for output of all hydraulic data required by the stream quality module.
		0	Data will not be saved for further analysis.
7	LSAVE	+	Any positive number will assign magnetic unit 15 for output of backwater results for use as initial conditions for the St. Venant method or St. Venant results for restarting a subsequent St. Venant simulation.
		-	Any negative number will assign magnetic unit 15 for input of initial conditions for the St. Venant method. (Only used for St. Venant method.)

*The numbers identified below may need to be assigned a magnetic tape or disk name using the specific job control language for the users computer system. No action is necessary for Harris 500 computer users.

Job Control Card 5* - Tape or file assignment

Field	Variable	Value	Description
1		JOB5	Card identification.
2	IINFL	+	Any positive number will assign magnetic unit 16 for output of processed tributary inflow and withdrawal rates generated from data on unit LQF (INHY cards).
		0	No withdrawals and all inflow data input via LTAPE (JOB4 card, field 3 through 5) files.
		-	Any negative number will assign magnetic unit 16 for input of a permanent record of processed tributary inflow and withdrawal rates generated by a previous simulation.
3	LQF	+	Any positive number will assign magnetic unit 17 for input of raw tributary inflow and withdrawal rates (INHY cards). Use a 5 for card input or it may be left blank if IINFL (JOB5 card, field 2) is positive.
4	INGEDA	+	Any positive number will assign magnetic unit 18 for input of cross section coordinate data using CCC1, CCC2, JP, ET, NC, SC, X1, X3, KL and GR cards. Use a 5 for card input.
		-	Any negative number will assign magnetic unit 18 for input of cross section geometry data GEOM4 cards. Use a -5 for card input.
5	LSF	+	Any positive number will assign magnetic unit 19 for input of STORM format inflow hydrographs (STORM3 cards). Use a 5 for card input.
6	JSFILE	+	Any positive number will assign a scratch unit 20 for processing STORM format inflow hydrograph data.
		0	No STORM format inflow hydrograph data (NSLOAD = 0, JOB1 card, field 5).

*The numbers identified below may need to be assigned a magnetic tape or disk name using the specific job control language for the users computer system. No action is necessary for Harris 500 computer users.

Tributary Location Card 1*

Field	Variable	Value	Description
1		TRIB	Card identification
2	IR	+	Reach number at tributary inflow or withdrawal location.
3	RMI	+	River mile location of tributary inflow or withdrawal.

STORM Generated Inflow Card 1**

Field	Variable	Value	Description
1		STORM1	Card identification
2	IIDAY	+	First day of STORM generated inflow rate and quality record; year, month and day.
3	LLDAY	+	Final day of STORM generated inflow rate and quality record; year, month and day.

STORM GEnerated Inflow Card 2**†

Field	Variable	Value	Description
1		STORM2	Card identification
2-10	NSS(I)	+	Number of STORM generated inflow points in time (STORM3 cards) for tributary I.

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* One card is required for each tributary inflow including headwater inflows and withdrawals (NL+NREM) cards, JOB1 cards, fields 4 and 6). The order of input must correspond to the order in which inflow data is read. The tributary inflow data input via the interface tapes, if any, must be input first; the base flow for STORM generated hydrographs, if any, input second; remaining inflows, if any, input third; flow boundary conditions at reach intersections (e.g., referring to Figure VII-1; flow specified at node 19, reach 5), if any, input fourth; and finally withdrawals.

** Omit all STORM cards if NSLOAD (JOB1 card, field 5) is zero or if IINFL (JOB5 card, field 2) is negative.

† One value of NSS (STORM2 cards, fields 2 through 10) is required for each STORM generated inflow. NSLOAD (JOB1 card, field 5) values required.

STORM Generated Inflow Card 3* - Input via unit LSF (JOB5 card, field 5)

Field	Variable	Value	Description
1		STORM3	Card identification
2	ITIME	+	Time of STORM generated inflow hydrograph data; year, month, day and hour.
3	TS(1)	+	STORM generated inflow in cfs or cms.
4	TS(2)	+	STORM generated suspended solids in mg/l.
5	TS(3)	+	STORM generated 5-day carbonaceous BOD in mg/l.
6	TS(4)	+	STORM generated total dissolved nitrogen in mg/l.
7	TS(5)	+	STORM generated total dissolved phosphorus in mg/l.
8	TS(6)	+	STORM generated coliform bacteria in MPN/100 ml.
9	TS(7)	+	STORM generated settleable solids in mg/l.

* NSS (STORM2 card, fields 2 through 10) cards are required for each tributary receiving STORM generated hydrographs. NSLOAD (JOB1 card, field 5) sets of cards are required. STORM3 cards are prepared automatically by STORM program [22]. STORM output card identification (i.e., field 1) will be a river mile instead of STORM3 and is acceptable to the module and need not be changed. Omit all STORM cards if NSLOAD is zero or if IINFL (JOB5 card, field 2) is negative. Note that certain pollutographs are also included. These are not used in the module, but they are incorporated because identical cards are required in the stream quality module.

INHY1-INHY2-INHY3

Inflow and Withdrawal Card 1* - Input via unit LQF (JOB5 card, field 3)

Field	Variable	Value	Description
1		INHY1	Card identification
2	IIDAY	+	First day of inflow record for all tributaries; year, month and day.
3	LLDAY	+	Last day of inflow record for all tributaries; year, month and day.

Inflow and Withdrawal Card 2*† - Input via unit LQF (JOB5 card, field 3)

Field	Variable	Value	Description
1		INHY2	Card identification
2	IDINT	+	Inflow hydrograph data update interval in hours. Hydrograph data is input using a series of INHY3 cards under this option.
		0	Hydrograph data is input at variable time intervals using a series of INHY4 cards under this option.
3-7	CON(I)	alpha	Description of inflow hydrograph.

Inflow and Withdrawal Card 3*†§ - Input via unit LQF (JOB5 card, field 3)

Field	Variable	Value	Description
1		INHY3	Card identification
2-10	CONC(I)	+	Inflow rate in cms or cfs.

---

* Omit all INHY cards if IINFL (JOB5 card, field 2) is negative.

† Repeat sets of INHY2 and INHY3 or sets of INHY2 and INHY4 card for each tributary. Omit this data for those tributaries input via tape interface units (i.e., positive values of LTAPE, JOB4 card, fields 3-5).

§ The number of INHY3 cards is determined by the length of the inflow hydrograph record (INHY1 cards, fields 2 and 3) and the inflow hydrograph update interval (INHY2 card, field 2). (e.g., 5 days of record with 2 hour update would require 5 x 24/2 = 60 values and a total of 7 cards).

Inflow and Withdrawal Card 4*†§ - Input via unit LQF (JOB5 card, field 3)

Field	Variable	Value	Description
1		INHY4	Card identification
2	ITIME**	+	Time of observation; month, day, hour and minute (e.g., 07010015)
		-1	Denotes the end of the data set.
3	CONC	+	Inflow rate in cms or cfs.
4	ITIME	+ -1	Pairs of time and corresponding inflow rates.
5	CONC		
6	ITIME		
7	CONC		
8	ITIME		
9	CONC		
10	IYB	+	Year of observation (e.g., 56)

* Omit all INHY cards if IINFL (JOB5 card, field 2) is negative.

† Repeat sets of INHY2 and INHY3 or sets of INHY2 and INHY4 card for each tributary. Omit this data for those tributaries input via tape interface units (i.e., positive values of LTAPE, JOB4 card, fields 3-5).

§ Use one or more INHY4 cards to input the inflow hydrograph data over the length of the inflow record.

** The first time of observation must be on or before hour zero of IIDAY (INHY1 card, field 2).

NPF1

Non-Point Inflow and Withdrawal Card 1*

Field	Variable	Value	Description
1		NPF1	Card identification
2	NZON	+	Number of non-point inflow and withdrawal zones; maximum of 5.
3	ITYPD	0	Non-point flows for days not specified on the NPF3 cards will be set to zero.
		1	Non-point flows will be held constant between days specified on NPF3 cards (e.g., the flow rates specified on the first NPF3 card will apply until overridden by the second NPF3 card).
4	IPNP	0	Print non-point flow data
		1	Do not print non-point flow data

* Omit all NPF cards if INTW (JOB1 card, field 9) equals zero, or if IINFL (JOB5 card, field 2) is negative.

Non-Point Inflow and Withdrawal Card 2*†

Field	Variable	Value	Description
1		NPF2	Card identification
2	ILIM1	+	Reach number at upstream limit of non-point inflow and withdrawal zone.
3	RMLIM1	+	River mile location at upstream limit of non-point inflow and withdrawal zone.
4	ILIM2	+	Reach number at downstream limit of non-point inflow and withdrawal zone.
5	RMLIM2	+	River mile location at downstream limit of non-point inflow and withdrawal zone.

Non-Point Inflow and Withdrawal Card 3*§

Field	Variable	Value	Description
1		NPF3	Card identification
2	IT1	+	Time of observation; year, month and day.
		-	Time of observation; year, month and day; however, a negative time denotes the final NPF3 card defining flows within the zone.
3	TQ1	+	Non-point inflow rate in cfs/mile or cms/km.
4	TQ2	+	Non-point withdrawal rate in cfs/mile or cms/km.

---

* Omit all NPF cards if INTW (JOB1 card, field 9) equals zero or if IINFL (JOB5 card, field 2) is negative.

† One NPF2 card is required for each non-point inflow zone (NZON, NPF1 card, field 2).

§ NZON (NPF1 card, field 2) sets of NPF3 cards are required.

GEOM1-GEOM2

Stream Geometry Card 1* - Reach definition

Field	Variable	Value	Description
1		GEOM1	Card identification.
2	RLEN	+	Reach length in miles or km.
3	ELEN	+	Element length in miles or km.
		-	For variable element lengths, number of different element sizes input on card GEOM2.

Stream Geometry Card 2* - Variable reach card. Omit if ELEN (GEOM1 card, field 3) is positive.

Field	Variable	Value	Description
1		GEOM 2	Card identification.
2	NTP	+	Number of elements of length ELN (GEOM2 card, field 3).
3	ELN	+	Length of element in miles or km.
4 5 6 7 8 9	NTP ELN NTP ELN NTP ELN	+	Number of elements and element lengths beginning at the upstream end of the reach and progressing downstream. ELEN (GEOM1 card, field 3) pairs are required, repeat GEOM2 cards as necessary. A maximum of eight element lengths may be specified per reach.

---

* Repeat GEOM1 card or sets of GEOM1 and GEOM2 cards for each stream reach beginning with the first and progressing sequentially to the last reach. An even number of elements and an odd number of nodes are required in each reach.

Stream Geometry Card 3* - Intersection definition

GEOM3

Field	Variable	Value	Description
1		GEOM3	Card identification
2	NCOM	+	Reach number upstream of the intersection.
		-	Reach number downstream of the intersection.
3	SHARE**	0	Reach is upstream of intersection.
		+	Fraction of the total flow through an intersection taken by the reach (the reach must be downstream of the intersection).
4	NCOM	+	Reach number upstream of the intersection.
		-	Reach number downstream of the intersection.
5	SHARE**	0	Reach is upstream of intersection.
		+	Fraction of the total flow through an intersection taken by the reach (the reach must be downstream of the intersection).
6	NCOM	+	Reach number upstream of the intersection.
		-	Reach number downstream of the intersection.
7	SHARE		For all computational methods except St. Venant
		0	Reach is upstream of intersection.
		+	Fraction of the total flow through an intersection taken by the reach (the reach must be downstream of the intersection).
			For St. Venant
		-1	Momentum transfer to the reach will be ignored. Only one non-momentum transfer case is allowed per intersection.
		0	Momentum from the tributary will be transferred to the main stem.

---

* One card is required for each intersection (INT, JOB2 card, field 4). A maximum of three reaches may enter a single intersection. (For definition of reach and intersections, see Figure VII-1).

** Must equal zero for St. Venant method.

CCC1–CCC2

Channel Cross Section Coordinate Card 1*

Field	Variable	Value	Description
1		CCC1	Card identification
2	NREACH	+	Reach number of first cross section.
3	RMT	+	River mile location of the first cross section.
4	QST	+	Discharge at first cross section elevation.
		-1	Discharge at all cross section elevations. will be computed by assuming normal depth in channel.
5-10	QST	+	Discharge at remaining cross section elevations in ascending order.

Channel Cross Section Coordinate Card 2*

Field	Variable	Value	Description
1		CCC2	Card identification
2-10	QST	+	Discharge at remaining cross section elevations in ascending order.

* One CCC1 card along with sufficient CCC2 cards to define NELEV (JOB2 card, field 5) values of QST are required for each channel cross section. NBPP (JOB2 card, field 5) sets are required. This data must be input in the same order as the following cross section coordinate cards. Omit all CCC2 cards if the first value of QST (GEDA1 card, field 3) is negative (i.e., normal depth will be assumed for stage flow relationship). Omit CCC1 and CCC2 cards if INGEDA (JOB5 card, field 4) is negative. This data is used to relate water depth to flow when using the stage-flow hydraulic computation method, the Muskingum or modified Puls hydrologic routing methods or where stage-flow boundary conditions are specified for other hydraulic computation methods.

Channel Cross Section Coordinate Card JP* - required card

Field**	Variable	Value	Description
0		JP	Card identification
1	AVGS	+	River mile location of the first channel cross section.
2	ASEL	+	Channel slope for projecting the elevation table upstream.
3			Not used
4			Not used
5			Not used
6			Not used
7	IFILE	+	Output tape of file unit identification number containing channel cross section data (GEOM4 cards) generated from the channel cross section coordinate cards.
		0	Channel cross section geometry card images will not be saved.
8			Not used
9	KSW(11)	0	Suppresses printout of subsection areas, wetted perimeters, conveyances, etc.
		1	Print the intermediate values of conveyance, area, hydraulic radius, n-value and reach length for each subsection in each cross section.

---

* Omit JP card if INGEDA (JOB5 card, field 4) is negative.

** The following field definition applies for channel cross section coordinate cards only: Field 0 is reserved for a two character card identification and must conform to the stated value. Field 1 utilizes card columns 3 through 8. Fields 2 through 10 are eight columns each.

Channel Cross Section Coordinate Card ET*†- Elevation Table, required card

Field	Variable	Value	Description
0		ET	Card identification
1-10	WS	+	Elevations in feet or meters.

Channel Cross Section Coordinate Card NC**†- required card for first cross section

Field	Variable	Value	Description
0		NC	Card identification
1	XNL	0	No change in Manning's "n" value for the left overbank.
		+	Manning's "n" value for the left overbank.
2	XNR	0	No change in Manning's "n" value for the right overbank.
		+	Manning's "n" value for the right overbank.
3	XNCH	0	No change in Manning's "n" value for the channel.
		+	Manning's "n" value for the channel.

---

* The table of geometric elements must contain NELEV (JOB2 card, field 6) values of elevation. The difference between two successive elevation values on this card is called the elevation interval. Up to three different intervals may be utilized. The elevation intervals should be chosen so that the elevation range (i.e., WS(NELEV)-WS(1)) divided by the lowest common denominator of the elevation intervals is less than 200. Values must be entered from lowest to highest elevation.

** Manning's "n" values are entered for starting each job, or for changing values previously specified. The values on this NC card apply to the cross section described on the following X1 card and apply until changed by a future NC card.

† Omit ET and NC cards if INGEDA (JOB5 card, field 4) is negative.

Channel Cross Section Card NV*† - Optional card

Field	Variable	Value	Description
0		NV	Card identification
1	NUMNV	+	Total number of Manning's "n" values entered on NV cards (maximum five). If NUMNV equals 5, a second NV card is required with ELN(5) input in field 1 of the second card.
2	VALN	+	Manning's "n" coefficient for area below ELN. The overbank "n" values specified on card NC will be used for the overbank roughness regardless of the values in this table.
3	ELN	+	Elevation of the water surface corresponding to VALN in increasing order.
4	VALN	+	Pairs of Manning's "n" coefficients and corresponding elevations.
5	ELN		
6	VALN		
7	ELN		
8	VALN		
9	ELN		
10	VALN		

Channel Cross Section Coordinate Card SC**† - Optional card

Field	Variable	Value	Description
0		SC	Card identification
1	AVGS	+	River mile location of first cross section where the new slope applies.
2	ASEL	-,0,+	Channel slope for projecting the elevation table upstream.

---

* NV cards are used to vary the Manning's n-values vertically. Straight line interpolation is used between points.

† Omit NV and SC cards if INGEDA (JOB5 card, field 4) is negative.

** The slope ASEL (JP card, field 2) is changed at any cross section with this card.

X1

Channel Cross Section Coordinate Card X1* - required card for each cross section

Field	Variable	Value	Description
0		X1	Card identification
1	SECNO	+	River mile location of channel cross section.
2	NUMST	0	Previous cross section is used for current section. Next GR cards are omitted.
		+	Total number of stations on the next GR cards.
3	STCHL	0	NUMST (X1 card, field 2) is zero.
		+	The station of the left bank of the channel.
4	STCHR	0	NUMST (X1 card, field 2) is zero.
		+	The station of the right bank of the channel must be equal to or greater than STCHL (X1 card, field 3).
5	XLOBL	+	Length of reach between current cross section and the previous cross section of the left overbank in feet.
6	XLOBR	+	Length of reach between current cross section and the previous cross section for the right oberbank in feet.
7	XLCH	+	Length of reach between current cross section and the previous cross section for the channel in feet.
8	PXSECR	0	Cross section stations will not be changed by the factor PXSECR.
		+	A ratio which will be multiplied times all cross section stations, except the first station, to increase or decrease cross section width. The ratio can apply to a repeated cross section or a current one (e.g., 1.1 would increase the width by 10%).

---

* This card is required for each cross section, and is used to specify the cross section geometry and program options applicable to that cross section. Omit X1 card if INGEDA (JOB5 card, field 4) is negative.

Channel Cross Section Coordinate Card X1*, (continued)

Field	Variable	Value	Description
9	PXSECE	0	Cross section elevations will not be changed.
		+ -	Constant to be added (+) or subtracted (-) from all cross section elevations. A repeated cross section is handled in the same manner as one just entered. Elevation changes are permanent; therefore, changes accumulate with successive, repeated sections.

* This card is required for each cross section, and is used to specify the cross section geometry and program options applicable to that cross section. Omit X1 card if INGEDA (JOB5 card, field 4) is negative.

X3

Channel Cross Section Coordinate Card X3* - optional card

Field	Variable	Value	Description
0		X3	Card identification
1	IEARA	0	Total area of cross section described on GR cards below the water surface elevation is used in the computations.
		10	Only the cross sectional area confined by levees below the water surface elevation is used in the computations. If the water surface elevation is above the top of levee (elevations corresponding to STCHL and STCHR (X1 card, fields 3 and 4) the flow areas outside the levee will be included.
2			Not used
3	ENCFP	0	Width between encroachments is not changed or is not specified.
		+	Width between encroachments is centered in the channel, midway between the left and right overbanks. Flow areas outside this width are not included in the computations. This width will be used for all cross sections unless changed by a positive ENCFP on card X3 of another cross section or unless overridden by the use of STENCL (X3 card, field 4).
4	STENCL	0	Encroachments by specifying stations and/or elevation will not be used on the left overbank.
		+	Station of the left encroachment. Flow areas to the left of (less than) this station and below ELENCL (X3 card, field 5) are not included in the computations. This option will override the option using ENCFP (X3 card, field 3) when both are used.
5	ELENCL	0	An encroachment elevation on the left side is not applicable.
		+	Elevation of the left encroachment. Flow areas below this elevation and less than STENCL (X3 card, field 4) are not included in the computations.

---

* Omit X3 card if INGEDA (JOB5 card, field 4) is negative.

Channel Cross Section Coordinate Card X3* (Continued)

Field	Variable	Value	Description
6	STENCR	0	An encroachment station on the right is not used.
		+	Station of the right encroachment. Flow areas to the right of (greater than) this station and below ELENCR (X3 card, field 7) are not included in the computations.
7	ELENCR	0	An encroachment elevation on the right side is not applicable.
		+	Elevation of the right encroachment. Flow areas below this elevation and greater than STENCR (X3 card, field 6) are not included in the computations.

Channel Cross Section Coordinate Card KL*† - optional card

Field	Variable	Value	Description
0		KL	Card identification
1	AVGS	+	River mile location of channel cross section where conveyance limits apply.
2	STST	0	The entire cross section is used for both volume and conveyance on the left overbank.
		+	The cross section station separating storage from conveyance on the left overbank.
3	ENST	0	The entire right overbank of the cross section is used to convey flow.
		+	The cross section station separating storage from conveyance on the right overbank.

* Omit X3 and KL cards if INGEDA (JOB5 card, field 4) is negative.

† The unsteady flow calculations must describe both volume and conveyance. Satisfying the volume requirement often causes cross sections to extend up tributaries. This is an area that does not contribute to conveyance of the mainstem discharge and conveyance limits should be established.

GR-EJ

Channel Cross Section Coordinate Card GR*† - optional card

Field	Variable	Value	Description
0		GR	Card identification
1	EL	+ -	Elevation of cross section in feet or meters at station STA (GR card, field 2). May be positive or negative.
2	STA	+	Station of cross section in feet or meters corresponding to elevation EL (GR card, field 1).
3	EL		
4	STA		
5	EL		
6	STA	+	Pairs of elevation of cross section and corresponding station location in feet or meters.
7	EL		
8	STA		
9	EL		
10	STA		

Channel Cross Section Coordinate Card EJ †- required card

Field	Variable	Value	Description
0		EJ	Card identification
1-10			Not used

---

* This card specifies the elevation and station of each point in a cross section used to describe the ground profile. It is required for each X1 card unless NUMST (X1 card, field 2) is zero. Repeat GR cards as necessary to input NUMST pairs of values.

† Omit GR and EJ cards if INGEDA (JOB5 card, field 4) is negative.

Stream Geometry Card 4*†- Cross Section Geometry - input via unit INGEDA (JOB5 card, field 4)

Field	Variable	Value	Description
1		GEOM4	Card identification
2	NR	+	Reach number
3	XMX	+	River mile location of cross section.
4	ELEV	+	Elevation in feet or meters.
5	A	+	Cross section area in square feet or square meters below elevation ELEV (GEOM6 card, field 5).
6	R23	+	Hydraulic radius to the 2/3 power at elevation ELEV.
7	WD	+	Surface width in feet or meters at elevation ELEV.
8	AMAN	+	Manning's n at elevation ELEV.
9			Not used
10	QST	+	Known discharge in cfs or cms at elevation ELEV. If QST is left blank, normal flow will be computed assuming normal depth. QST flows are used in the stage-flow hydraulic computation method, the Muskingum or modified Puls hydrologic routing methods or where stage-flow boundary conditions are specified for other hydraulic computation methods.

---

* NELEV (JOB2 card, field 6) cards are required for each cross section. These cards can be prepared automatically from channel cross section coordinate data by setting IFILE (JP card, field 7) equal to a punch unit or saved on file by setting IFILE equal to a permanent file unit number. Omit all GEOM4 cards if INGEDA (JOB5 card, field 4) is positive.

† The elevation increments (between layers) must be identical for all cross sections within a reach.

GEOM5-GEOM6

Stream Geometry Card 5*

Field	Variable	Value	Description
1		GEOM5	Card identification
2-10	ELEV	+	Actual channel bottom elevation (not necessarily the minimum elevation specified on the GEOM4 cards) in feet or meters for each cross section (NBPP sections, JOB2 card, field 5) from upstream to downstream. The order of input is identical to that of the GEOM4 card and the reverse of the channel cross section coordinate cards.

Stream Geometry Card 6**

Field	Variable	Value	Description
1		GEOM6	Card identification
2	ELEV	+	Actual channel bottom elevation in feet or meters.
3	EGL	+	Energy grade line elevation in feet or meters. These data must result in a positive energy slope and may be observed data or obtained from HEC-2 [23] or from any similar program for computing water surface profiles.
4	QEL	+	Flow corresponding to the energy grade line elevation (EGL, card 6, field 2) in cfs or cms. Normal depth flows computed from the cross section geometry and energy grade line data will be scaled such that the stage vs. flow table at elevation EGL will equal QEL.
		0	Stage vs. flow table will equal normal depth or user specified relationship.

---

* Repeat GEOM5 card as necessary to input NBPP values. Required for only the St. Venant and Backwater methods (i.e., IHYDRO, JOB2 card, field 2 = 2 or 4) and can represent negative or positive slopes.

** Repeat GEOM6 card as necessary to input NBPP cards. Required only if stage vs. flow, kinematic wave, Muskingum routing or modified Puls method is specified (i.e., IHYDRO = 1,3,5 or 6). The order of input is identical to that of the GEOM4 card and the reverse of the channel cross section coordinate cards.

Boundary Condition Card*

Field	Variable	Value	Description
1		BOUND	Card identification
2	NB	-1	A flow rate is specified at the downstream end of reach NRN (BOUND card, field 3).
		+1	A flow rate is specified at the upstream end of reach NRN.
		-2	The depth is specified at the downstream end of reach NRN.
		+2	The depth is specified at the upstream end of reach NRN.
		-3	A stage-flow relationship is specified at the downstream end of reach NRN.
		+3	A stage-flow relationship is specified at the upstream end of reach NRN.
3	NRN	+	Reach number where boundary conditions NB (BOUND card, field 2) applies.
4 5 6 7 8 9	NB NRN NB NRN NB NRN	– +	Pairs of boundary condition types and reach numbers where the bounday conditions apply.
10	IEND	0	Another boundary condition card will follow.
		1	Denotes the final boundary condition card.

* A maximum of ten boundary conditions of each type are allowed. Repeat BOUND cards as necessary to input all desired boundary conditions. The boundary conditions requirements for the various flow computational methods are presented in Table VIII-1.

Kinematic Wave Card 1* - Initial conditions

Field	Variable	Value	Description
1		KW1	Card identification
2	N	+	Reach number
3	Q	+	Uniform initial flow within the reach in cfs or cms.
4	YS	+	Initial guess at uniform normal depth within the reach in feet or meters.

Kinematic Wave Card 2* - Initial conditions

Field	Variable	Value	Description
1		KW2	Card identification
2	N	+	Node number
3	VEL2	+	Initial flow in cfs or cms.
4	VEL1	+	Initial depth in feet or meters.
5	DQDT	+	Not used
6	DYDT	+	Not used

* Either, but not both KW1 or KW2 cards must be used to define initial conditions when using the kinematic wave method. If ICND (JOB3 card, field 4) is 1, one KW1 card is required per reach. If ICND is zero, one KW2 card is required for each node. Omit all KW cards if IHYDRO (JOB2 card, field 2) is other than three.

St. Venant Card 1* - Time step control

Field	Variable	Value	Description
1		STV1	Card identification
2	TMAX	+	Maximum allowable time step in hours.
3	T1	+	Time in hours from the beginning of simulation after which the time step increment will be increased by a factor of 1.005 per time step.
		0	The time step will not be increased during the simulation unless increased by STV2 card data.
4	T2	+	Time in hours from the beginning of simulation after which the time step increment will be increased by a factor of 1.01 per time step.
5	T3	+	Time in hours from the beginning of simulation after which the time step increment will be increased by a factor of 1.02 per time step.

St. Venant Card 2* - Time step control

Field	Variable	Value	Description
1		STV2	Card identification
2	TSTIME	+	Time in hours from the beginning of simulation after which the time step increment will be set to TSNOW (STV2 card, field 3).
		0	The time step will not be changed during the simulation unless increased by STV1 card data.
3	TSNOW	+	Time step increment in hours used after time TSTIME (STV2 card, field 2).
4 5 6 7 8 9	TSTIME TSNOW TSTIME TSNOW TSTIME TSNOW	+	Pairs of times from the beginning of simulation and corresponding time step increments in hours.

* Omit all STV cards if IHYDRO (JOB2 card, field 2) is other than four.

St. Venant Card 3* - Initial conditions

Field	Variable	Value	Description
1		STV3	Card identification
2	N	+	Reach number
3	Q	+	Uniform initial flow within the reach in cfs or cms.
4	YS	+	Initial guess at uniform normal depth within the reach in feet or meters.

St. Venant Card 4*† - Initial Conditions

Field	Variable	Value	Description
1		STV4	Card identification
2	N	+	Node number
3	VEL1	+	Initial flow in cfs or cms.
4	VEL2	+	Initial depth in feet or meters.
5	DQDT	+	Initial rate of change of flow in cfs/sec or cms/sec. (Usually zero except for simulation restart.)
6	DYDT	+	Initial rate of change of depth in feet/sec or meters/sec. (Usually zero except for simulation restart.)

*Either, but not both STV3 or STV4 cards must be used to define initial conditions when using the St. Venant method. If ICND (JOB3 card, field 4) is 1, one STV3 card is required per reach. If ICND is zero, one STV4 card is required for each node. Omit all STV cards if IHYDRO (JOB2 card, field 2) is other than four.

†Omit STV4 cards if LSAVE(JOB4 card, field 7) was generated on last run of this job.

Muskingum Routing Card* - Control points

Field	Variable	Value	Description
1		MR	Card identification
2	NCP	+	Number of routing steps to control point
		-	Number of routing steps to control point, however, a negative value denotes the final MR card.
3	NR	+	Reach number location of control point.
4	CPMT	+	River mile or kilometer location of control point (downstream end of control section)
5	RCK	+	Muskingum K to control point in hours.
6	RCX	+	Muskingum X to control point.

* One MR card is required for each Muskingum routing reach beginning upstream and progressing downstream. Omit all MR cards if IHYDRO (JOB2 card, field 2) is other than five.

Modified Puls Routing Card 1* - Control points

Field	Variable	Value	Description
1		MP1	Card identification
2	NCP	+	Number of routing steps to control point.
		-	Number of routing steps to control point, however, a negative value denotes the final set of MP cards.
3	NR	+	Reach number location of control point.
4	CPMT	+	River mile or kilometer location of control point (downstream eand of control section).

Modified Puls Routing Card 2* - Storage cards

Field	Variable	Value	Description
1		MP2	Card identification
2	CPSX(1)	+	Storage volume in acre-feet or m^3 of first point in the storage-outflow table [e.g., storage volume corresponding to outflow rate CPSO(1), MP3 card, field 2].
3	CPSX(2)	+	Remaining storage volumes defining the storage-outflow table. A minimum of 2 and a maximum of 9 values may be used to define the table.
4	CPSX(3)		
5	CPSX(4)		
6	CPSX(5)		
7	CPSX(6)		
8	CPSX(7)		
9	CPSX(8)		
10	CPSX(9)		

* Repeat sets of MP cards for each reach where storage-outflow tables are defined; maximum of 10. Omit all MP cards if IHYDRO (JOB2 card, field 2) is other than six.

Modified Puls Routing Card 3* - Outflow cards

Field	Variable	Value	Description
1		MP3	Card identification
2	CPOX(1)	+	Outflow rate in cfs or cms of first point in the storage-outflow table (e.g., outflow rate corresponding to storage volume CPSX(1), MP2 card, field 2)
3	CPOX(2)	+	Remaining outflow rates defining the storage-outflow table. A minimum of 2 and maximum of 9 value may be used to define the table.
4	CPOX(3)		
5	CPOX(4)		
6	CPOX(5)		
7	CPOX(6)		
8	CPOX(7)		
9	CPOX(8)		
10	CPOX(9)		

* Repeat sets of MP cards for each reach where storage-outflow tables are defined; maximum of 10. Omit all MP cards if IHYDRO (JOB2 card, field 2) is other than six.

DD1-DD1A

Depth Card 1*

Field	Variable	Value	Description
1		DD1	Card identification
2	IIDAY	+	Julian date
3	NHY	+	Number of downstream depth-time point for reach.
4	TY	+	Time in hours.
5	YC	+	Downstream depth in feet or meters at time TY.
6	TY	+	Pairs of times and corresponding depths.
7	YC		
8	TY		
9	YC		

Depth Card 1A*

Field	Variable	Value	Description
1		DD1A	Card identification
2	TY	+	Pairs of times and corresponding depths
3	YC		
4	TY		
5	YC		
6	TY		
7	YC		
8	TY		
9	YC		

---

* DD1 and DD1A card are required only if a backwater (IHYDRO=2, JOB2 card, field 2) or a St. Venant (IHYDRO=4) method is specified and IDST (JOB3 card, field 5) is positive. One DD1 card along with sufficient DD1A cards to define NHY (DD1 card, field 3) pairs of time-depth points are required for each reach for which downstream depth boundary conditions have been specified (i.e., NB = ± 2, BOUND card, even numbered fields). The period of data used on the DD1 cards must be the same as the period used on the INHY cards.

End of Hydraulic Data Card

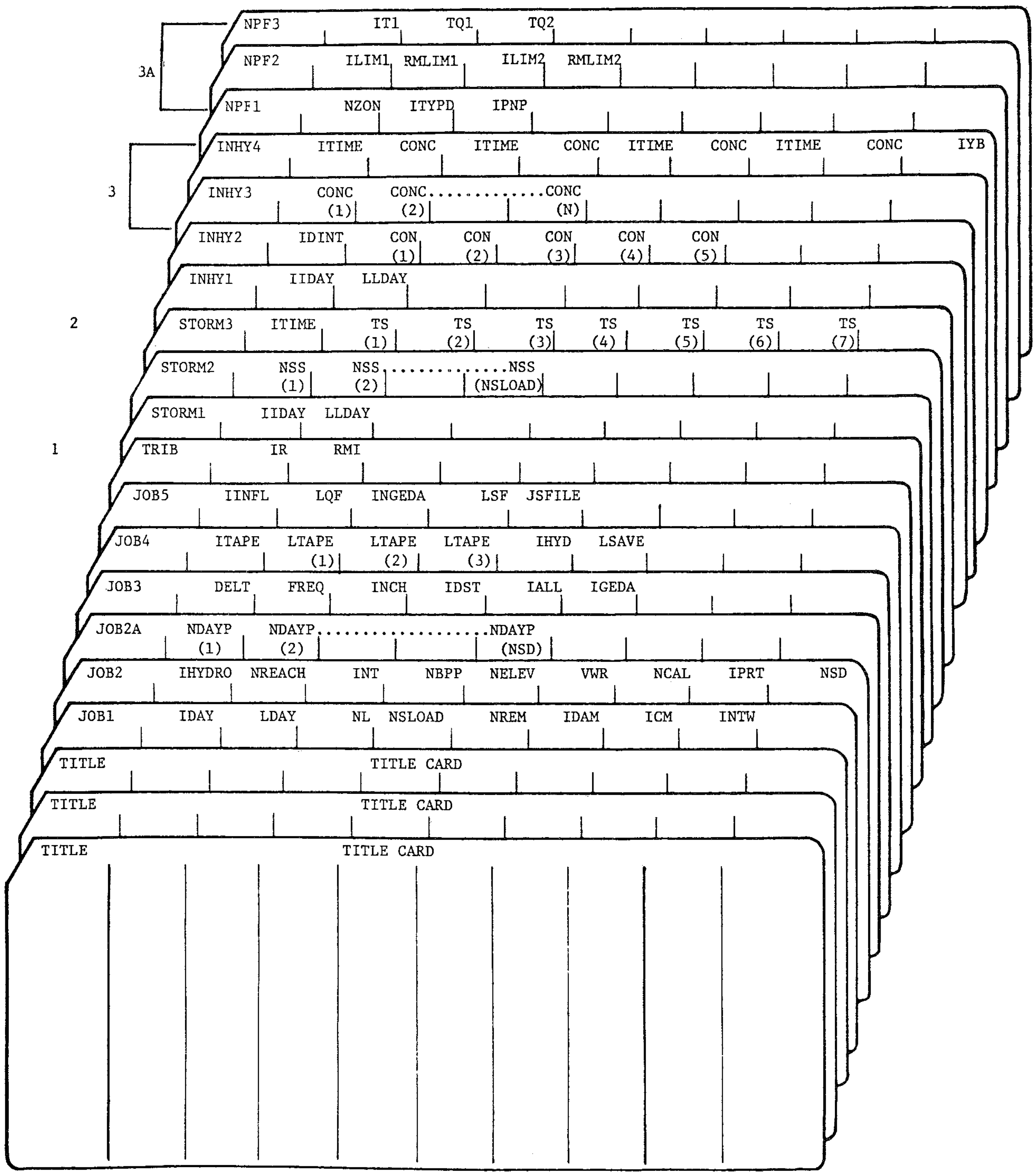
Field	Variable	Value	Description
1		END1	Card identification
2	TA	999	Signals the end of the hydraulic data.

NOTE: USE 4 BLANK CARDS AT THE END OF DATA DECK

SUMMARY OF DATA CARDS

FOR

STREAM HYDRAULICS MODULE

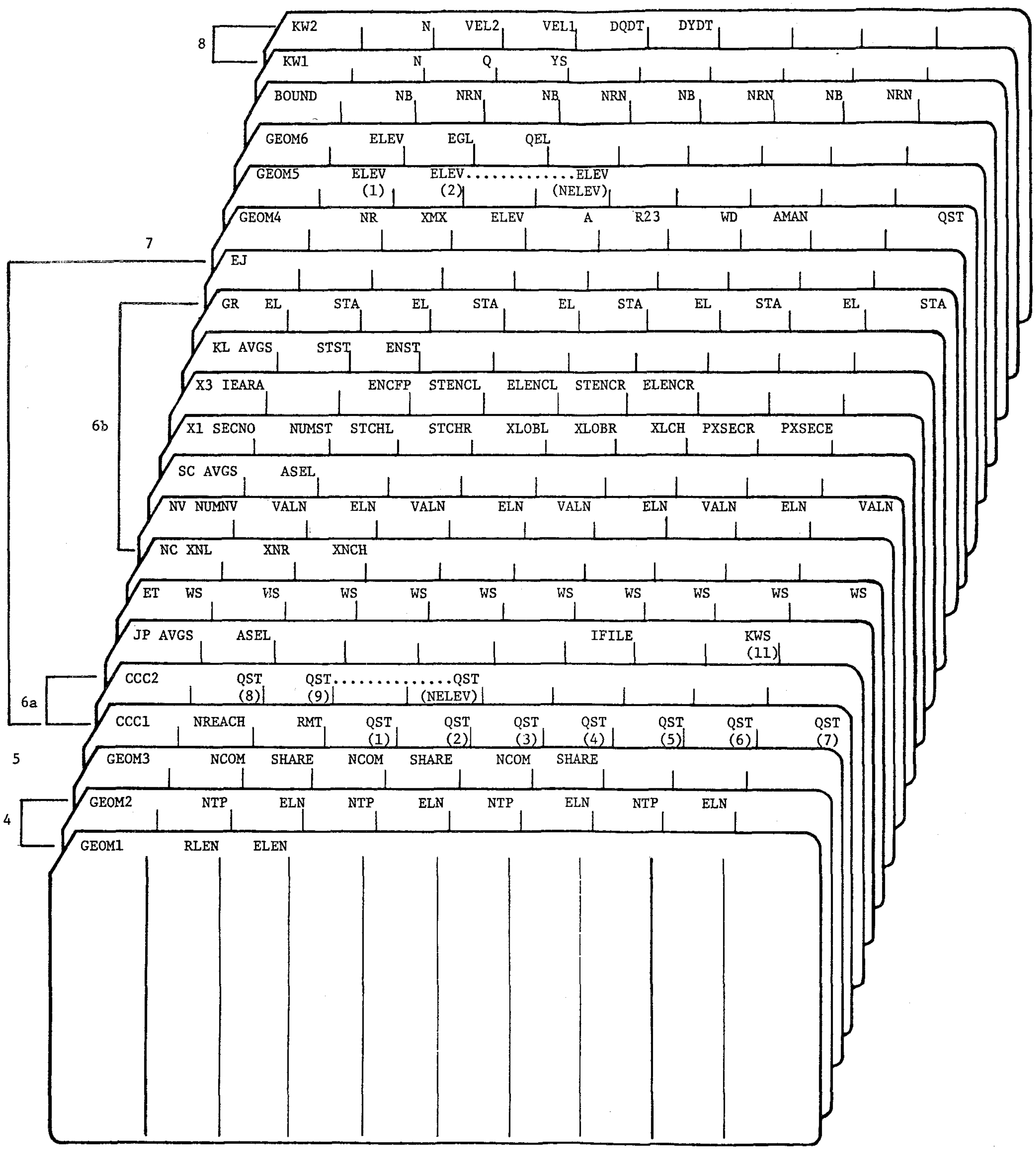


1. One TRIB card required for each tributary inflow and withdrawal (NL+NREM cards, JOB1 card, fields 4 and 6).
2. NSS (STORM2 cards, fields 2 through 10) cards are required for each tributary receiving STORM generated hydrographs.
3. Repeat sets of INHY2 and INHY3 cards or sets of INHY2 and INHY4 cards for each tributary and withdrawal (excluding those tributaries input via LTAPE, JOB4 card, fields 3-5).
3A. Repeat sets of NPF1 to NPF3 cards as required to define non-point inflow and withdrawal rates.

SUMMARY OF DATA CARDS

FOR

STREAM HYDRAULICS MODULE
(continued)

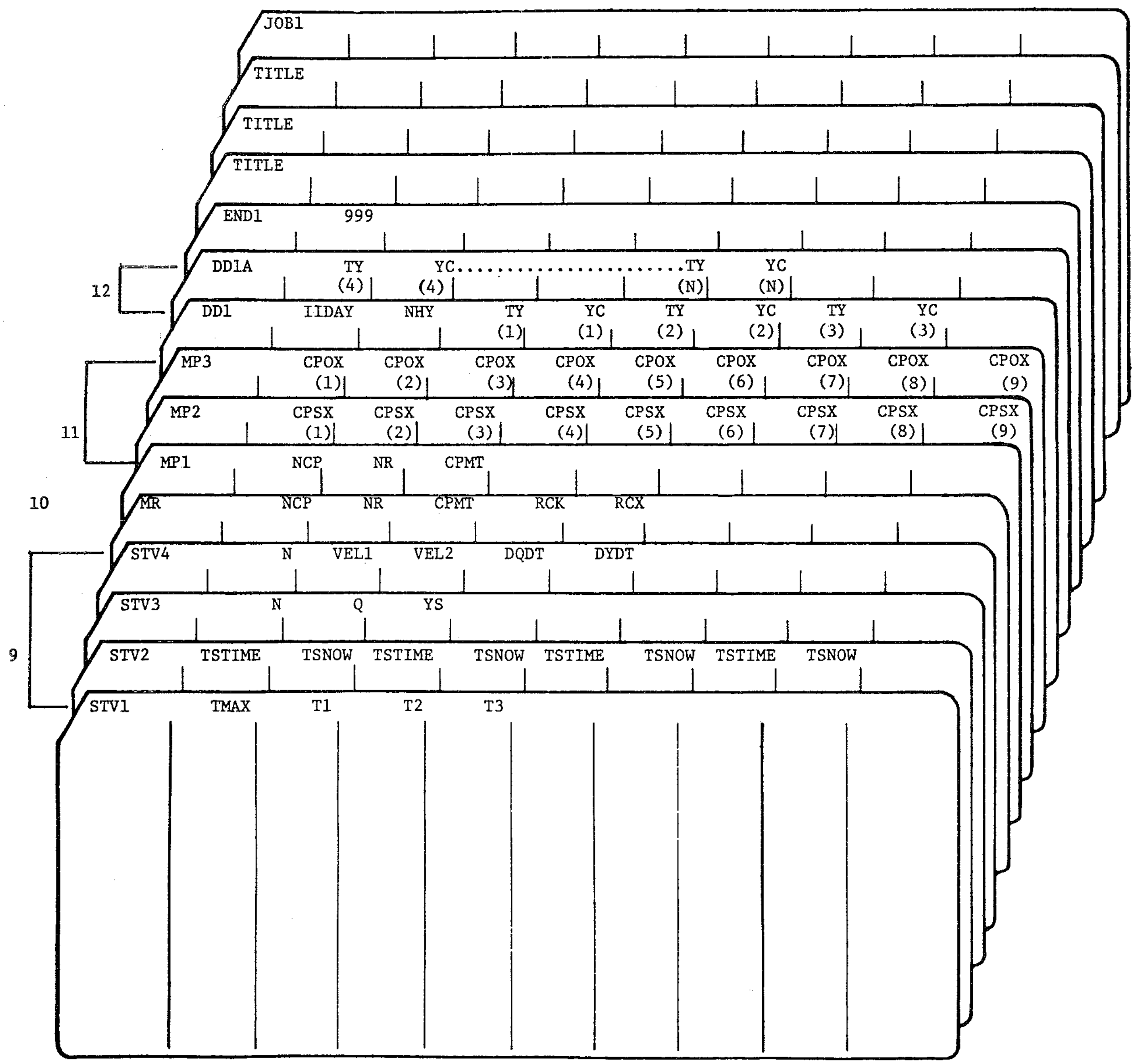


4. One GEOM1 or sets of GEOM1 and GEOM2 cards required for each reach.
5. One GEOM3 card is required for each intersection.
6. Omit all CCC1 through EJ cards if INGEDA (JOB5 card, field 4) is negative.
6a. One CCC1 card or sets of CCC1 and CCC2 cards is required for each channel cross section.
6b. Sets of NC through GR cards defines each cross section.
7. NELEV (JOB2 card, field 6) card is required for each channel cross section. Omit if INGEDA (JOB5 card, field 4) is positive.
8. Either sets of KW1 or sets of KW2 cards are required unless INHYDRO (JOB2 card, field 2) is other than three.

SUMMARY OF DATA CARDS

FOR

STREAM HYDRAULICS MODULE
(continued)



9. One STV1 and STV2 card followed by either sets of STV3 or sets of STV4 are required unless IHYDRO (JOB2 card, field 2) is other than four.
10. Repeat MR cards as necessary to define all Muskingum routing control points unless IHYDRO (JOB2 card, field 2) is other than five.
11. Repeat sets of MP1, MP2 and MP3 cards as necessary to define all modified Puls storage-outflow relationships unless IHYDRO (JOB2 card, field 2) is other than six.
12. Repeat sets of DD1 and DD1A cards as required to define downstream head controls.

STREAM QUALITY MODULE

The input data requirements for the Stream Quality Module can be separated into the following categories:

1. Job titles (TITLE cards).

2. Job controls (JOB cards) which include water quality constituent interaction modification specifications, input and print controls, tape and file assignments and other general data which control operation of the module.

3. Physical data (PHYS cards) such as tributary locations and invariant meteorological data.

4. Chemical, physical and biological coefficients (COEFF and SSOL cards).

5. STORM generated inflow rate and quality data (STORM cards) which includes pollutant correction factors, length of record and flow and quality data.

6. Time variant inflow quality data (INFL cards) which include the specification of which quality data are to be read, length and description of the quality record and the water quality constituent concentrations.

7. Time variant meteorological data (WEATH cards).

8. Initial quality conditions (INIT cards).

9. Non-point inflow quality data (NPQ cards).

All data categories are input via the card reader except for 5, 6 and 7. These three categories, which may be input via tape or disk files at the users option, are processed and written on files for later use during the simulation. At the users option, the files may be made permanent and also used during subsequent simulation, thus eliminating the need to reread and reprocess the data.

A detailed description of the data card requirements are presented below and followed by a summary of input cards showing the sequential arrangement of cards.

TITLE-JOB1

DATA CARD REQUIREMENTS

Job Title Cards - Three cards required

Field	Variable	Value	Description
1		TITLE*	Card identification
2-10	TITLE1	alpha	Job title to be printed on the first page of printout.

Job Control Card 1**

Field	Variable	Value	Description
1		JOB1	Card identification
2	IDAY	+	Date of first day of simulation; year, month and day (e.g., 560701).
3	LDAY	+	Date of last day of simulation; year, month and day.
4	NHOI	+	Simulation time interval in hours (usually between 1 and 4 hours).
5	NHMI	+	Meteorological data interval in hours (usually between 1 and 6 hours).
6	IFL	+	Stream hydraulics data input interval in days (usually 1)
7	INTW***	0	Non-point inflow quality will not be considered. (Omit all NPQ cards).
		1	Non-point inflow quality will be considered.

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* Field 1 is always reserved for card identification, which must be left justified.

** These cards and all remaining cards in this description are required cards unless the specific card description defines it as being optional.

*** The value of INTW must be equal to that specified in the stream hydraulics module (Stream Hydraulics Module JOB1 card, field 10).

Job Control Card 2 - Water Quality Constituent Interaction Modification Option

Field	Variable	Value	Description
1		JOB2	Card identification
2	ITEST(1)	*	Temperature option
3	ITEST(2)	*	Dissolved oxygen option
4	ITEST(3)	*	5-day carbonaceous BOD option
5	ITEST(4)	*	Coliform bacteria option
6	ITEST(5)	*	Organic detritus option
7	ITEST(6)	*	Amonnia option
8	ITEST(7)	*	Nitrate option
9	ITEST(8)	*	Nitrite option
10	ITEST(9)	*	Phosphate option

Job Control Card 2A - Water Quality Constituent Interaction Modification Option

Field	Variable	Value	Description
1		JOB2A	Card identification
2	ITEST(10)	*	Total dissolved solids option
3	ITEST(11)	*	Type 1 phytoplankton option
4	ITEST(12)	*	Type 2 phytoplankton option
5	ITEST(13)	*	Zooplankton option
6	ITEST(14)	*	Total inorganic carbon and pH option
7	ITEST(15)	*	Alkalinity option
8	ITEST(16)	*	Organic sediment option
9	ITEST(17)	*	Benthic animals option
10	ITEST(18)	*	Type 1 fish option

* -1 - specifies constituent to be held constant at its initial value in quality analysis.
0 - specifies constituent set to zero and ignored in quality analysis.
1 - specifies normal constituent treatment in quality analysis.

JOB2B-JOB2C

Job Control Card 2B - Water Quality Constituent Interaction Modification Option

Field	Variable	Value	Description
1		JOB2B	Card identification
2	ITEST(19)	*	Type 2 fish option
3	ITEST(20)	*	Type 3 fish option
4	ITEST(21)	*	Inorganic suspended solids groups 1 through 5 option
5	ITEST(22)		
6	ITEST(23)		
7	ITEST(24)		
8	ITEST(25)		
9	ITEST(26)	*	Inorganic sediment option

Job Control Card 2C - Water Quality Constituent Interaction Modification Option

Field	Variable	Value	Description
1		JOB2C	Card identification
2	ITEST(27)	*	Aquatic insects option
3	ITEST(28)	*	Type 1 benthic algae option
4	ITEST(29)	*	Type 2 benthic algae option
5	ITEST(30)	*	Unit toxicity option

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* -1 - specifies constituent to be held constant at its initial value in quality analysis.
  0 - specifies constituent set to zero and ignored in quality analysis.
  1 - specifies normal constituent treatment in quality analysis.

Job Control Card 3

Field	Variable	Value	Description
1		JOB3	Card identification
2	INTP1	+	Hydraulics summary printout interval in days.
3	INTP2	+	Printout interval in days for abbreviated summary of water quality simulation results.
4	INTP3	+	Printout interval in days for comprehensive summary of water quality simulation results.
5	INTH	+	Printout interval in hours. [e.g., output will be printed every INTH hours within each day specified by INTP1, INTP2 and INTP3 (JOB3 card, fields 2 through 4)]. INTH must be a multiple of NHOI (JOB1 card, field 4).
6	NPRTI	+	Element printout interval (e.g., a 1 will print results for each element, a 2 prints every other element, etc.).
7	NSD	+	Number of additional print days other than those specified by the printout intervals, INTP1, INTP2 and INTP3 (JOB3 card, fields 2 through 4); maximum of 45. All output options will be printed on these days.

Job Control Card 4*

Field	Variable	Value	Description
1		JOB4	Card identification
2-10	NDAYP(I)	+	Print days other than those specified by the normal printout interval, INTP1, INTP2 and INTP3 (JOB3 card, fields 2 through 4). Use year, month and day.

* Include only if NSD (JOB3 card, field 7) is positive. Use up to 9 dates per card. Use as many cards as needed for all NSD (JOB3 card, field 7) values.

JOB5

Job Control Card 5

Field	Variable	Value	Description
1		JOB5	Card identification
2	NPOINT	+	Number of initial water quality zones.
3	ICT	0	Index that specifies the input water temperature data is in degrees Celsius.
		1	Index that specifies the input water temperature data is in degrees Fahrenheit.
4	ICM	0	Index that specifies the input data other than meteorological (WEATH1 cards) is in metric units.
		1	Index that specifies the input data other than meteorological data (WEATH1 cards) is in English units.
5	NTL	+	Number of tributaries or other discharges to the stream system. Include tributary inflows input via quality interface tapes (JTAPE, JOB6 card, fields 4 through 6) and the base flow for STORM generated input. The maximum number is 25.
6	NREM	+	Number of withdrawals from the stream system. The maximum number is 5.
7	NSLOAD	+	Number of STORM generated tributary inflows.
		0	No STORM interface is required.
8	IRR	+	Reach number at the downstream end of the stream system.

Job Control Card 6* - Tape or file related data

Field	Variable	Value	Description
1		JOB6	Card identification.
2	IHYD	+	Any positive number will assign magnetic unit 14 for input of hydraulic data generated by stream hydraulics module.
3	ITAPE	+	Any positive number will assign magnetic unit 13 for output of the stream system discharge rate and quality data for input to subsequent simulations of downstream river reaches or reservoirs.
		0	Data will not be saved for further analysis.
4 5 6	JTAPE(1) JTAPE(2) JTAPE(3)	+	Positive numbers will assign magnetic units 10-12 for input of flow and quality data from previous simulation of upstream river reaches and reservoirs. Zero to 3 units may be assigned. A zero or blank will indicate no input unit from previous analysis will be used.
7 8 9	NHP(1) NHP(2) NHP(3)	+ -	Inflow rate and quality data interval on input units JTAPE (JOB6 card, fields 4-6). Set to zero if the corresponding JTAPE is zero. A negative value will cause the flow rate data on these files to be overridden by the flow rates input via the stream hydraulics interface IHYD (JOB6 card, field 2).
10	LPLOT	+	Any positive number will assign magnetic unit 17 for output of simulation results for use in post-processor graphics and statistics programs.
		0	Not interested in using post-processor.

*The numbers identified below may need to be assigned a magnetic tape or disk name using the specific job control language for the users computer system. No action is necessary for Harris 500 computer users.

JOB7

Job Control Card 7* - Tape or file related data

Field	Variable	Value	Description
1		JOB7	Card identification.
2	IEQF	+	Any positive number will assign magnetic unit 20 for input of meteorological data for use in calculating surface heat exchange rates using the equilibrium temperature approach. Cards can not be used.
		0	The heat budget approach to surface heat exchange will be used.
3	IMETF	+	Any positive number will assign magnetic unit 19 for output of processed meteorological data generated from data on unit LMF (WEATH1 cards).
		0	Used if IEQF (JOB7 card, field 2) is positive.
		-	Any negative number will assign magnetic unit 19 for input of processed meteorological data generated by a previous quality simulation.
4	IINFL	+	Any positive number will assign magnetic unit 18 for output of processed tributary inflow quality data generated from data on unit LQF (INFL and STORM cards).
		-	Any negative number will assign magnetic unit 18 for input of processed tributary inflow quality data generated by a previous quality simulation.
5	LMF	+	Any positive number will assign magnetic unit 20 for input of raw meteorological data (WEATH1 cards). Use a 5 for card input. May be left blank if IMETF (JOB7 card, field 3) is negative or IEQF (JOB7 card, field 2) is positive.
6	LQF	+	Any positive number will assign magnetic unit 21 for input of raw tributary inflow quality data (INFL cards). Use a 5 for card input. May be left blank if IINFL (JOB7 card, field 4) is negative.
7	LSI	+	Any positive number will assign magnetic unit 22 for input of STORM generated inflow quality data (STORM cards). Use a 5 for card input. May be left blank if IINFL (JOB7 card, field 3) is negative or NSLOAD (JOB5 card, field 7) is zero.
8 9	JSFILE(1) JSFILE(2)	+	Positive values will assign scratch units 15-16. One file is always required. Two files are required if both NSLOAD (JOB5 card, field 7) & IINFL (JOB7 card, field 4) are positive.

*The numbers identified below may need to be assigned a magnetic tape or disk name using the specific job control language for the users computer system. No action is necessary for Harris 500 computer users.

Physical Description Card 1* - Tributary and Withdrawal Location

Field	Variable	Value	Description
1		PHYS1	Card identification
2	IR	+	Reach number at tributary inflow location.
3	RMI	+	River mile location of tributary inflow.
4	REAR**	+	Reaeration coefficient to be applied to the dissolved oxygen deficit.
5	IRET	+	An optional capability defining an element number from which a withdrawal is made, to which water quality constituents are added and which is returned to the stream at RMI. A positive value causes the inflow quality defined on the INFL3 or INFL4 cards to be treated as incremental temperature or concentrations. Can be used for any tributary except those from quality interface tapes. This capability might be useful for a cooling water inflow which warms the water by an incremental temperature and then returns it to the stream.

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* One PHYS1 card is required for each tributary inflow and withdrawal (NTL+NREM card, JOB5 card, fields 5 and 6). The order of input must correspond to the order in which the inflow quality data is read. The tributary inflow quality data input via the quality interface tape, if any, must be input first; the base flow for STORM generated hydrographs, if any, input second; all remaining inflows, if any, input third; and finally all withdrawals. The order of input should be identical to the order used in the stream hydraulics simulation except that flow boundary conditions specified at reach intersections are not included.

** The reaeration coefficient is applied only to those tributary inflow input via quality interface tapes (JTAPE, JOB6 card, fields 4 through 6). This reaeration coefficient is applied to the oxygen deficit to account for oxygenation due to turbulent releases from impoundments.

PHYS2

Physical Description Card 2 - Invariant Meteorological Data

Field	Variable	Value	Description
1		PHYS2	Card identification
2	IDEW	1	Wet bulb temperature is required (WEATH1 card, field 5).
		0	Dew point temperature is required (WEATH1 card, field 5).
3	AA	+	Evaporation coefficient (usually zero).
4	BB	+	Evaporation coefficient (usually 1.5×10^{-9}*).
5	XLAT	+	North latitude of study area in degrees.
6	XLON	+	West longitude of study area in degrees.
		-	East longitude of study area in degrees.
7	TURB	+	Atmospheric turbidity factor (range from 2 for clear unpolluted atmosphere to 5 for highly polluted atmosphere).

* The most general way to code exponential numbers is $\pm$ xx.xxE+ee (e.g., 1.5E-09). Some computers can accept the example coded as 1.5-9.

Default Coefficient Override Card*

Field	Variable	Value	Description
1		COEFF	Card identification
2	ICODE(1)	+	Coefficient code number (see tables IV-1 through IV-4).
		-1	Denotes final default coefficient override value.
3	RATE(1)	+	New value for coefficient corresponding to ICODE(1).
4 5 6 7 8 9	ICODE(2) RATE(2) ICODE(3) RATE(3) ICODE(4) RATE(4)	+ -1	Coefficient code numbers and corresponding new values of coefficients.

* Repeat as necessary to redefine any or all of the chemical, physical and biological coefficients listed on Tables IV-1 through IV-4. The final card must have a -1 in one of the ICODE fields.

SSOL-K2

Inorganic Suspended Solids Card *

Field	Variable	Value	Description
1		SSOL	Card identification
2	TY(1)	+	Three pairs of settling velocity, cm/sec (TY) versus temperature, °C (TX) for inorganic suspended solids. These three points define the curve from which settling velocities will be calculated for a given water temperature.
3	TX(1)		
4	TY(2)		
5	TX(2)		
6	TY(3)		
7	TX(3)		
8	SIZE**	+	Suspended solids particle size in millimeters.
9	SSLIM	+	Critical flow velocity at which no deposition of suspended solids will take place in meters/sec.

Reaeration Coefficients ***

Field	Variable	Value	Description
1		K2	Card identification
2	SK2(1)	+	Reaeration coefficient for element number 1.
3-10	SK2	+	Reaeration coefficients for remaining elements.

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* One card is required for each suspended solids group being modeled. Controlled by ITEST (JOB2B card, fields 4 through 8).

** Two computational approaches are used. For particle sizes less than 0.065 millimeters, the solids are treated conservatively except for deposition at velocities below the critical flow velocity. No scour is allowed. For particle sizes greater than 0.065 millimeters, the stream power concept is used to determine the solids transport capacity of the stream.

*** Omit all K2 cards except when direct input of reaeration coefficients is desired (i.e., ICODE = 259, COEFF card, fields 2, 4, 6 or 8). Repeat cards as necessary to input a reaeration coefficient for each element.

STORM Generated Inflow Card 1*

Field	Variable	Value	Description
1		STORM1	Card identification
2	ISQ2	+1	STORM generated tributary inflow quality will override tributary base flow quality.
		-1	STORM generated tributary inflow quality load (i.e., concentration times flow) will be combined with the base flow quality load when the STORM hydrograph exceeds the base flow rate.
3	PQUAL(1)	+	Temperature of the STORM inflow.
		-	The STORM inflow temperature will be equal to the daily average dry bulb air temperature less PQUAL(1). This option cannot be used if ISQ2 (STORM1 card, field 2) is negative.
4	PQUAL(2)	+	Dissolved oxygen concentration in the STORM inflow.
		-	The STORM inflow dissolved oxygen concentration will be determined as a PQUAL(2) fraction of saturation. This option cannot be used if ISQ2 (STORM1 card, field 2) is negative.
5	PQUAL(3)	+	Fraction of the STORM generated BOD. Usually one.
6	PQUAL(4)	+	Fraction of the STORM generated coliform bacteria. Usually one.
7	PQUAL(5)	+	Organic detritus fraction of the STORM generated suspended solids. Usually 0-.25.
8	PQUAL(6)	+	Suspended solids group 1 fraction of the STORM generated suspended solids. Usually .75-1.0.
9	PQUAL(7)**	+	Ammonia nitrogen fraction of STORM generated total nitrogen. Usually about .5.
10	PQUAL(8)**	+	Nitrate nitrogen fraction of STORM generated total nitrogen. Usually about .5.

* Omit all STORM generated inflow cards if NSLOAD (JOB5 card, field 7) is zero or if IINFL (JOB7 card, field 4) is negative.

** The sum of the fraction for ammonia and nitrate should usually equal one or less.

STORM1A-STORM2

STORM Generated Inflow Card 1A*

Field	Variable	Value	Description
1		STORM1A	Card identification
2	PQUAL(9)	+	Orthophosphate phosphorus fraction of STORM generated total phosphorus.
3	PQUAL(10)	+	Suspended solids group 2 fraction of the STORM generated settleable solids.
4	PQUAL(11)	+	Suspended solids group 3 fraction of the STORM generated settleable solids.

STORM Generated Inflow Card 2*

Field	Variable	Value	Description
1		STORM2	Card identification
2	IIDAY	+	First day of STORM generated inflow rate and quality record; year, month and day.
3	LLDAY	+	Final day of STORM generated inflow rate and quality record; year, month and day.

* Omit all STORM generated inflow cards if NSLOAD (JOB5 card, field 7) is zero or if IINFL (JOB7 card, field 4) is negative.

STORM Generated Inflow Card 3*†

Field	Variable	Value	Description
1		STORM3	Card identification
2-10	NSS(I)	+	Number of STORM generated inflow and quality points in time (STORM4 cards) for tributary I.

STORM Generated Inflow Card 4**†

Field	Variable	Value	Description
1		STORM4	Card identification
2	ITIME	+	Time of STORM generated inflow and quality data; year, month, day and hour.
3	TS(1)	+	STORM generated inflow in cfs or cms.
4	TS(2)	+	STORM generated suspended solids in mg/l.
5	TS(3)	+	STORM generated 5-day carbonaceous BOD in mg/l.
6	TS(4)	+	STORM generated total dissolved nitrogen in mg/l.
7	TS(5)	+	STORM generated total dissolved phosphorus in mg/l.
8	TS(6)	+	STORM generated coliform bacteria in MPN/100 ml.
9	TS(7)	+	STORM generated settleable solids in mg/l.

---

* NSLOAD (JOB5 card, field 7) values are required. One value of NSS (STORM3 cards, fields 2 through 10) is required for each STORM generated inflow.

† Omit all STORM cards if NSLOAD (JOB5 card, field 7) is zero or if IINFL (JOB7 card, field 4) is negative.

** NSS (STORM3 cards, fields 2 through 10) cards are required for each tributary receiving STORM generated hydrographs. NSLOAD (JOB5 card, field 7) sets of cards are required. STORM4 cards are prepared automatically by the STORM program [22]. STORM output card identification (i.e., field 1) will be a river mile instead of STORM4 and is acceptable to the module and need not be changed.

INFL1

Inflow Quality Card 1* - Input via unit LQF (JOB7 card, field 6)

Field	Variable	Value	Description
1		INFL1	Card identification
2	ICON(1)	**	Temperature in °C or °F.
3	ICON(2)	**	Dissolved oxygen in mg/l
4	ICON(3)	**	5-day carbonaceous BOD in mg/l
5	ICON(4)	**	Coliform bacteria in MPN/100 ml.
6	ICON(5)	**	Organic detritus in mg/l
7	ICON(6)	**	Ammonia as nitrogen as mg/l
8	ICON(7)	**	Nitrate as nitrogen in mg/l
9	ICON(8)	**	Nitrite as nitrogen in mg/l
10	ICON(9)	**	Phosphate as phosphorus in mg/l

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* INFL1 cards determine which inflow quality parameters will be input via sets of INFL3 and INFL4 cards or sets of INFL3 and INFL5 cards. One set is required for each non-zero value of ICON(I) for each tributary inflow. Omit all INFL cards if IINFL (JOB7 card, field 4) is negative.

** -1 - Inflow quality data will be read but not printed.
 0 - Inflow quality data will not be read.
 +1 - Inflow quality data will be read and printed.

Inflow Quality Card 1A* - Input via unit LQF (JOB7 card, field 6)

Field	Variable	Value	Description
1		INFL1A	Card identification
2	ICON(10)	**	Total dissolved solids in mg/l
3	ICON(11)	**	Type 1 phytoplankton in mg/l
4	ICON(12)	**	Type 2 phytoplankton in mg/l
5	ICON(13)	**	Zooplankton in mg/l
6	ICON(14)	**	pH in pH units
7	ICON(15)	**	Alkalinity as $CaCO_3$ in mg/l

Inflow Rate and Quality Card 1B* - Input via unit LQF (JOB7 card, field 6)

Field	Variable	Value	Description
1		INFL1B	Card identification
2 3 4 5 6	ICON(16) ICON(17) ICON(18) ICON(19) ICON(20)	**	Suspended solids groups 1 through 5 in mg/l
7	ICON(21)	**	Unit toxicity in mg/l.

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* INFL1 cards determine which inflow quality parameters will be input via sets of INFL3 and INFL4 cards or sets of INFL3 and INFL5 cards. One set is required for each non-zero value of ICON(I) for each tributary inflow. Omit all INFL cards if IINFL (JOB7 card, field 4) is negative.

** -1 - Inflow quality data will be read but not printed.
 0 - Inflow quality data will not be read.
 +1 - Inflow quality data will be read and printed.

Inflow Quality Card 2* - Input via unit LQF (JOB7 card, field 6)

Field	Variable	Value	Description
1		INFL2	Card identification
2	IIDAY	+	First day of inflow quality record for all tributaries; year, month and day.
3	LLDAY	+	Last day of inflow quality record for all tributaries; year, month and day.

Inflow Quality Card 3*† - Input via unit LQF (JOB7 card, field 6)

Field	Variable	Value	Description
1		INFL3	Card identification
2	IDINT	+	Inflow quality data update interval in hours. Inflow data is input using a series of INFL4 cards under this option (should not exceed 24).
		0	Inflow data is input at variable time intervals using a series of INFL5 cards under this option.
3-7	CON(I)	alpha	Description of inflow data

* Omit all INFL cards if IINFL (JOB7 card, field 4) is negative.

† Repeat sets of INFL3 and INFL4 or sets of INFL3 and INFL5 cards for each parameter and each tributary (excluding those input via JTAPE, JOB6 card, field 4-6). Controlled by INFL1, INFL1A and INFL1B cards.

Inflow Quality Card 4*† - Input via unit LQF (JOB7 card, field 6)

Field	Variable	Value	Description
1		INFL4	Card identification
2-10	CONC(I)**	+	Inflow quality in appropriate units.

* Repeat sets of INFL3 and INFL4 or sets of INFL3 and INFL5 cards for each parameter and each tributary (excluding those input via JTAPE, JOB6 card, field 4-6). Controlled by INFL1, INFL1A and INFL1B cards. Omit all INFL cards if IINFL (JOB7 card, field 4) is negative.

† The number of INFL4 cards is determined by the length of inflow data record (INFL2 cards, fields 2 and 3) and the inflow data update interval (INFL3 card, field 2). (e.g., 60 day of record with 4 hour update interval would require 60 x 24/4 = 360 values and a total of 40 cards).

** A negative value for temperature will result in an inflow temperature equal to the daily average dry bulb air temperature less the input temperature value.

A negative value for oxygen signifies a fraction of saturation.

A negative value of BOD denotes BOD values which include the oxygen demands of ammonia, nitrite and detritus. These BOD values will be reduced commensurated with the concentration of the other constituents.

INFL5

Inflow Rate and Quality Card 5*† - Input via unit LQF (JOB7 card, field 6)

Field	Variable	Value	Description
1		INFL5	Card identification
2	ITIME**	+	Time of observation; year, month, day and hour (e.g., 56070100).
		-1	Denotes the end of the data set.
3	CONC***	+	Inflow quality in appropriate units.
4	ITIME		
5	CONC		
6	ITIME	+	Pairs of time and corresponding inflow
7	CONC	-1	quality.
8	ITIME		
9	CONC		

---

* Repeat sets of INFL3 and INFL4 or sets of INFL3 and INFL5 cards for each parameter and each tributary (excluding those input via JTAPE, JOB6 card, field 4-6). Controlled by INFL1, INFL1A and INFL1B cards. Omit all INFL cards if IINFL (JOB7 card, field 4) is negative.

† Use one or more INFL5 cards to input inflow quality over the length of the inflow data record.

** The first time of observation must be on or before hour zero of IIDAY (INFL2 card, field 2).

*** A negative value for temperature will result in an inflow temperature equal to the daily average dry bulb air temperature less the input temperature value.

A negative value for oxygen signifies a fraction of saturation.

A negative value of BOD denotes BOD values which include the oxygen demands of ammonia, nitrite and detritus. These BOD values will be reduced commensurated with the concentration of the other constituents.

Weather Data Card 1*

Field	Variable	Value	Description
1		WEATH1	Card identification
2	ITIME**	+	Time of observation; year, month, day and hour.
3	CLOUD	+	Fraction of sky that is cloud covered.
4	DBT	+	Dry bulb air temperature in °F.
5	DPT	+	Wet bulb or dew point air temperature in °F. Controlled by IDEW (PHYS2 card, field 3).
6	APRESS	+	Barometric pressure in inches of mercury.
7	WIND	+	Wind speed in mph.
8		0	Not used
9		0	Not used
10	IEND	0	Denotes other than last day of weather data.
		-1	Denotes last day of weather data. The minus one must be included on all cards for the last day.

* The WEATH1 card is repeated at NHMI (JOB1 card, field 5) intervals during a day. [24/NHMI] WEATH1 cards are required for each day (i.e., if NHMI =3, 8 WEATH1 cards would be required per day). This data would define the meteorological conditions at hours 0, 3, 6,...18 and 21. The meteorological conditions at hour 24 would be set equal to hour 0 of the next day if data were input at daily intervals. If other than daily data, hour 24 would be set equal to hour 0 of the same day. Sets of WEATH1 cards can be input at any interval. Omit if IEQF (JOB1 card, field 2) is positive or if IMETF (JOB7 card, field 3) is negative.

** The time of the first observation must be on or before the first day of simulation (JOB1 card, field 2).

WEATH2

Weather Data Card 2* - Input via unit IEQF (JOB7 card, field 2)

Field	Variable	Value	Description
1		WEATH2	Card identification
2	ITIME**	+	Time of observation; year, month and day
3	XTE	+	Equilibrium temperature in degrees C.
4	XKE	+	Coefficient of surface heat exchange in kcal/m^2/sec/C.
5	XQNS	+	Short wave solar radiation in kcal/m^2/sec.
6	XWIND	+	Wind speed in meters/sec.
7	EA	+	Vapor pressure in millibars.

Note: Fields 6 and 7 are not used for stream analysis. These fields are only shown so the users knows the same set of cards can be used for both river and reservoir analysis.

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* One card representing average meteorological conditions is required for each day of simulation. These cards can be obtained directly from the "Thermal Simulation of Lakes" computer program available at the HEC. Omit if IEQF(JOB7 card, field 2) is zero.

** The first time of the first observation must be on or before the first day of simulation (JOB1 card, field 2).

Initial Conditions Card 1*

Field	Variable	Value	Description
1		INIT1	Card identification
2	NFZONE	+	Number of fish zones; maximum of 10.
3	IDIST	+	Redistribute fish population within each fish zone at the end of each time step.
		0	Do not redistribute fish population.

Initial Conditions Card 2**

Field	Variable	Value	Description
1		INIT2	Card identification
2	IR1	+	Reach number at upstream limit of fish zone.
3	RM1	+	River mile location of upstream limit of fish zone.
4	IR2	+	Reach number at downstream limit of fish zone.
5	RM2	+	River mile location of downstream limit of fish zone.
6	FISH(1)	+	Type 1 fish density in kg/km.
7	FISH(2)	+	Type 2 fish density in kg/km.
8	FISH(3)	+	Type 3 fish density in kg/km.

* Omit INIT1 card if ITEST 18, 19 and 20 (JOB2A card, field 10 and JOB2B card, fields 2 and 3) are all zero.

** NFZONE (INIT1 card, field 2) cards are required. Omit all INIT2 cards if ITEST 18, 19 and 20 are zero.

INIT3

Initial Conditions Card 3*

Field	Variable	Value	Description
1		INIT3	Card identification
2	IR1	+	Reach number at upstream limit of initial quality zone.
3	RM1	+	River mile location at upstream limit of initial quality zone.
4	IR2	+	Reach number at downstream limit of initial quality zone.
5	RM2	+	River mile location at downstream limit of initial quality zone.
6	TEMP	+	Temperature in °C or °F.
7	OXY	+	Dissolved oxygen in mg/l.
8	BOD	+	5-day carbonaceous BOD in mg/l.
9	COLIF	+	Coliform bacteria in MPN/100 ml.
10	SEDMT	+	Organic sediment (settled detritus) in mg/m^2.

---

* The cards, INIT3, INIT4, INIT5 and INIT6, in that order, are repeated for NPOINT (JOB5 card, field 2) quality zones. Initial conditions must be defined at all elements. Any parameter on this card can be left blank if the corresponding ITEST(JOB2, JOB2A, JOB2B and JOB2C card) value equals zero.

Initial Conditions Card 4*

Field	Variable	Value	Description
1		INIT4	Card identification
2	DETUS	+	Organic detritus in mg/l.
3	CNH3	+	Ammonia as nitrogen in mg/l.
4	CNO3	+	Nitrate as nitrogen in mg/l.
5	CNO2	+	Nitrite as nitrogen in mg/l.
6	PO4	+	Phosphate as phosphorus in mg/l.
7	TDS	+	Total dissolved solids in mg/l.
8	BEN	+	Benthic animals in mg/m^2.
9	ALGAE(1)	+	Type 1 phytoplankton in mg/l.
10	ALGAE(2)	+	Type 2 phytoplankton in mg/l.

Initial Conditions Card 5*

Field	Variable	Value	Description
1		INIT5	Card identification
2	ZOO	+	Zooplankton in mg/l
3	PH	+	pH in pH units
4	ALKA	+	Alkalinity as calcium carbonate in mg/l.
5 6 7 8 9	SSOL(1) SSOL(2) SSOL(3) SSOL(4) SSOL(5)	+	Inorganic suspended solids groups 1 through 5 in mg/l.
10	SSED		Inorganic sediment in mg/m^2.

* The cards, INIT3, INIT4, INIT5 and INIT6, in that order, are repeated for NPOINT (JOB5 card, field 2) quality zones. Initial conditions must be defined at all elements. Any parameter on this card can be left blank if the corresponding ITEST (JOB2, JOB2A, JOB2B and JOB2C card) value equals zero.

Initial Condition Card 6*

Field	Variable	Value	Description
1		INIT6	Card identification
2	TOX	+	Unit toxicity in mg/l.
3	YNSECT	+	Aquatic insects in mg/m^2.
4	BALGAE(1)	+	Type 1 benthic algae in mg/m^2.
5	BALGAE(2)	+	Type 2 benthic algae in mg/m^2.
6	CMUD	+	Thermal conductance coefficient of the stream bed in $kcal/m^2/sec/C$ (usually between 0.025 and 0.075).
7	DMUD	+	Effective thermal capacity of stream bed expressed as meters of water (usually between 0.5 and 1.0).
8	EXCO	+	Secchi disk reading in feet or meters. The effects of all particulate materials being modeled or held constant should be excluded.

Non-Point Inflow Quality Card 1**

Field	Variable	Value	Description
1		NPQ1	Card identification
2	IT1***	+	Time of observation; year, month and day.
		-	Time of observation; year, month and day: however, a negative time denotes the final set of NPQ cards.
3	NZON	+	Number of non-point quality zones (maximum of 20).

---

* The cards, INIT3, INIT4, INIT5 and INIT6, in that order, are repeated for NPOINT (JOB5 card, field 2) quality zones. Initial conditions must be defined at all elements. Any parameter on this card can be left blank if the corresponding ITEST (JOB2, JOB2A, JOB2B and JOB2C card) value equals zero.

** Input set of NPQ cards at any time interval. Omit all NPQ cards if INTW (JOB1 card, field 7) equals zero.

*** The time of the first observation must be on or before the first day of simulation (JOB1 card, field 2).

Non-Point Inflow Quality Card 2*

Field	Variable	Value	Description
1		NPQ2	Card identification
2	ILIM(1)	+	Reach number at upstream limit of non-point inflow quality zone.
3	RMLIM(1)	+	River mile location at upstream limit of non-point inflow quality zone.
4	ILIM(2)	+	Reach number at downstream limit of non-point inflow quality zone.
5	RMLIM(1)	+	River mile location at downstream limit of non-point inflow quality zone.
6	DA(1)	+	Temperature in °C or °F.
		-	A negative value for temperature will result in an inflow temperature equal to the daily average dry bulb air temperature less the input temperature value.
7	DA(2)	+	Dissolved oxygen in mg/l.
		-	A negative value for oxygen signifies a fraction of saturation.
8	DA(3)	+	5-day carbonaceous BOD
		-	A negative value of BOD denotes BOD values which include the oxygen demands of ammonia, nitrite and detritus. These BOD values will be reduced commensurated with the concentration of the other constituents.
9	DA(13)	+	Coliform bacteria in MPN/100 ml.
10	DA(7)	+	Organic detritus in mg/l.

* Input set of NPQ cards at any time interval. Omit all NPQ cards if INTW (JOB1 card, field 7) equals one.

NPQ2A-NPQ2B

Non-Point Quality Card 2A*

Field	Variable	Value	Description
1		NPQ2A	Card identification
2	DA(8)	+	Ammonia nitrogen in mg/l.
3	DA(9)	+	Nitrate nitrogen in mg/l.
4	DA(10)	+	Nitrite nitrogen in mg/l.
5	DA(11)	+	Phosphate phosphorus in mg/l.
6	DA(14)	+	Total dissolved solids in mg/l.
7	DA(5)	+	Type 1 phytoplankton in mg/l.
8	DA(6)	+	Type 2 phytoplankton in mg/l.
9	DA(4)	+	Zooplankton in mg/l.
10	DA(23)	+	pH in pH units.

Non-Point Quality Card 2B*

Field	Variable	Value	Description
1		NPQ2B	Card identification
2	DA(12)	+	Alkalinity as calcium carbonate in mg/l.
3 4 5 6 7	DA(16) DA(17) DA(18) DA(19) DA(20)	+	Suspended solids groups 1 through 5 in mg/l.
8	DA(21)	+	Unit toxicity in mg/l.

NOTE: USE 4 BLANK CARDS AT THE END OF DATA DECK

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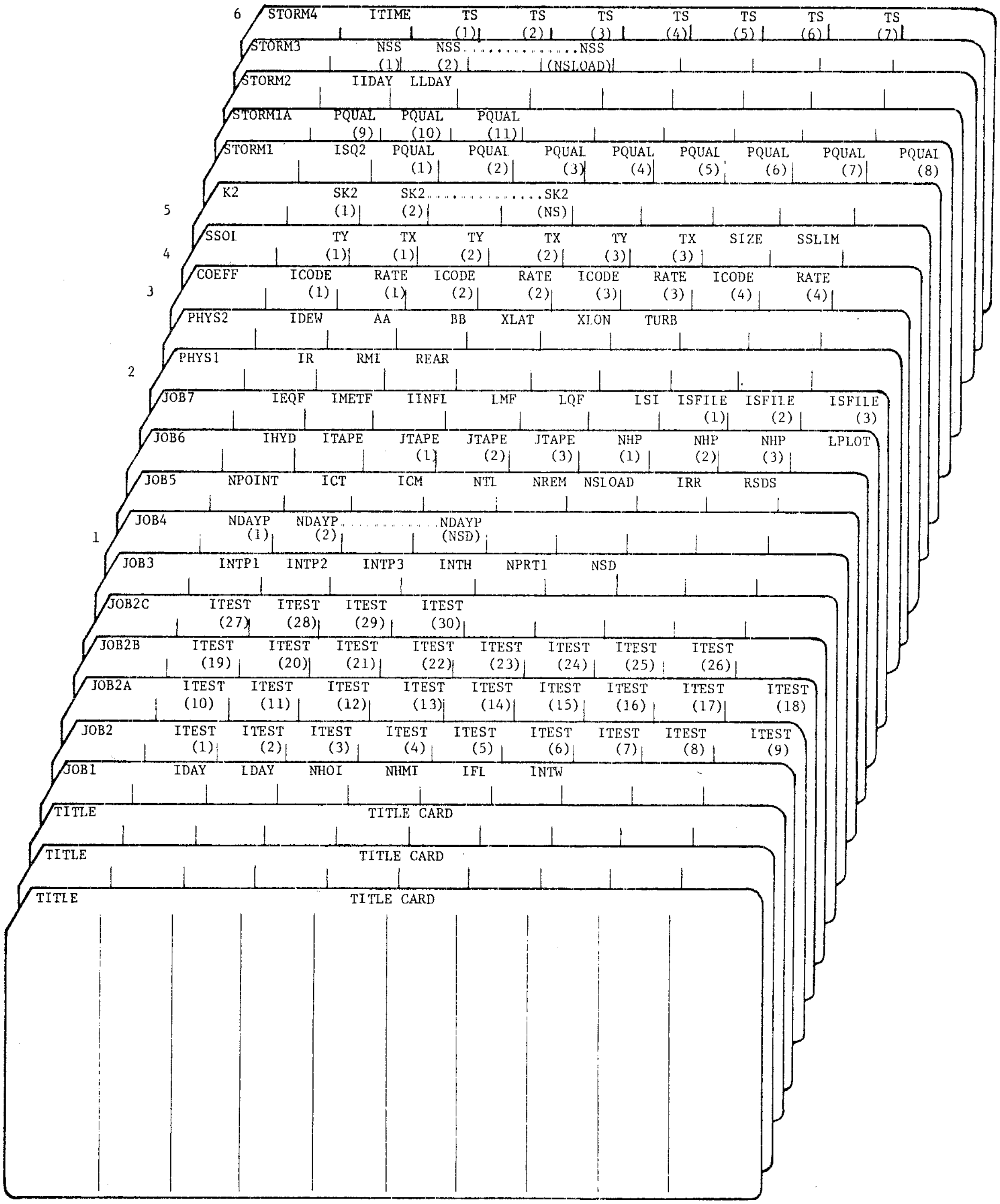
* Input set of NPQ cards at any time interval. Omit all NPQ cards if INTW (JOB1 card, field 7) equals one.

SUMMARY OF DATA CARDS

FOR

STREAM QUALITY MODULE



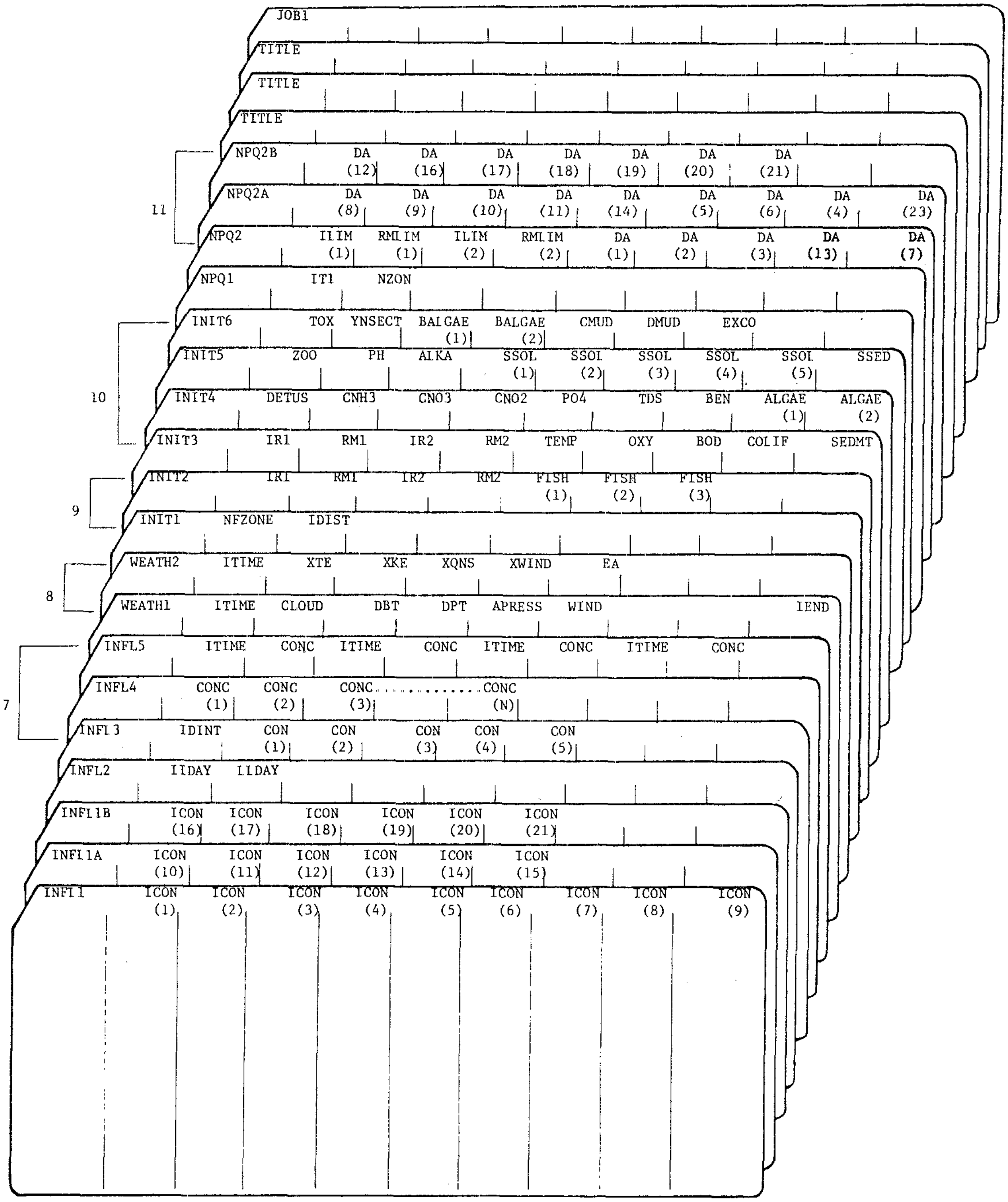
1. Include JOB5 cards only if NSD (JOB3 card, field 7) is positive.
2. One PHYS1 card is required for each tributary inflow and withdrawal (NIL+NREM cards, JOB5 card, fields 5 and 6).
3. Repeat COEFF cards as necessary to redefine as many coefficients as desired.
4. One SSOL card is required for each suspended solids group being modeled.
5. Omit K2 cards unless direct input of reaeration coefficients is specified.
6. NSS (STORM3 cards, fields 2 through 10) cards are required for each tributary receiving STORM generated data.

SUMMARY OF DATA CARDS

FOR

STREAM QUALITY MODULE

(continued)



7. Repeat sets of INFL3 and INFL4 cards or sets of INFL3 and INFL5 cards for each quality constituent and each tributary (excluding those input via JTAPE, JOB6 card, fields 4-6).
8. Repeat sets of WEATH1 cards or sets of WEATH2 cards, but not both, as necessary to define meteorological conditions during the simulation period.
9. Omit INIT1 and INIT2 cards if no fish types are being simulated.
10. Repeat sets of INIT3 through INIT6 for NPOINT (JOB5 card, field 2) initial water quality zones.
11. Repeat sets of NPQ2, NPQ2A and NPQ2B for NZON (NQP1 card, field 3) non-point inflow quality zones.

IX. MODEL APPLICATION

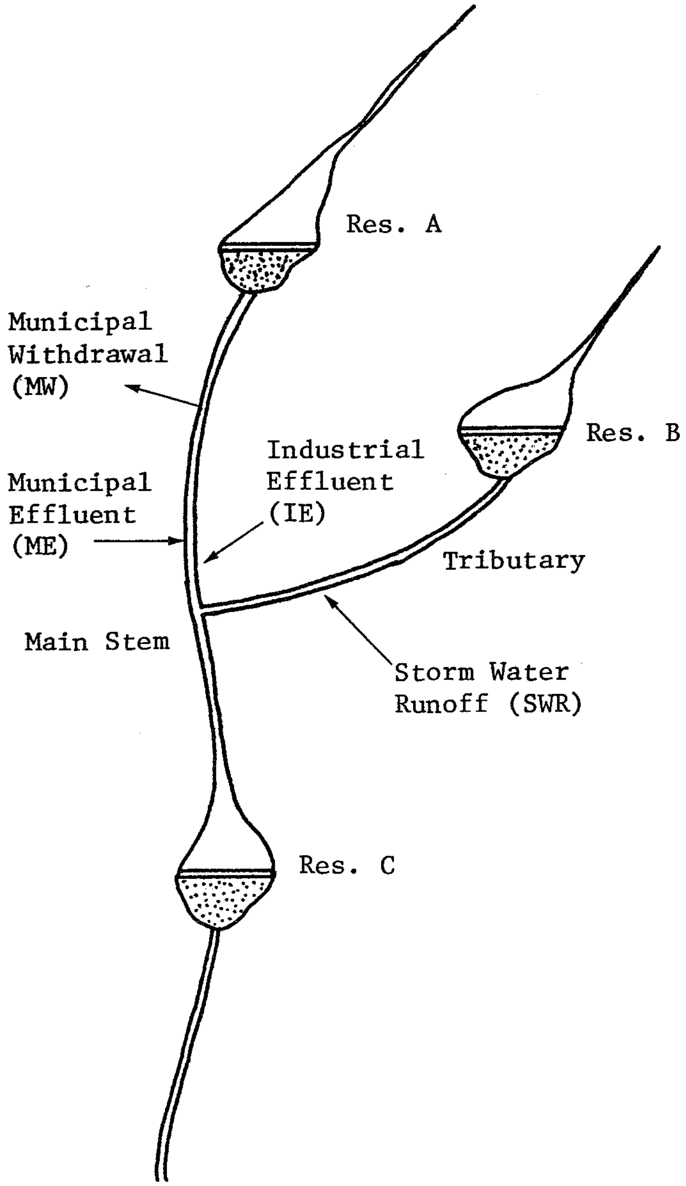
TOTAL SYSTEM REPRESENTATION

The first stage in utilization of the model is reduction of the prototype situation into a model representation. The reservoir module is capable of analyzing a single reservoir and the stream modules are capable of analyzing a branched stream system. The size of the stream system is limited by one of the following constraints.

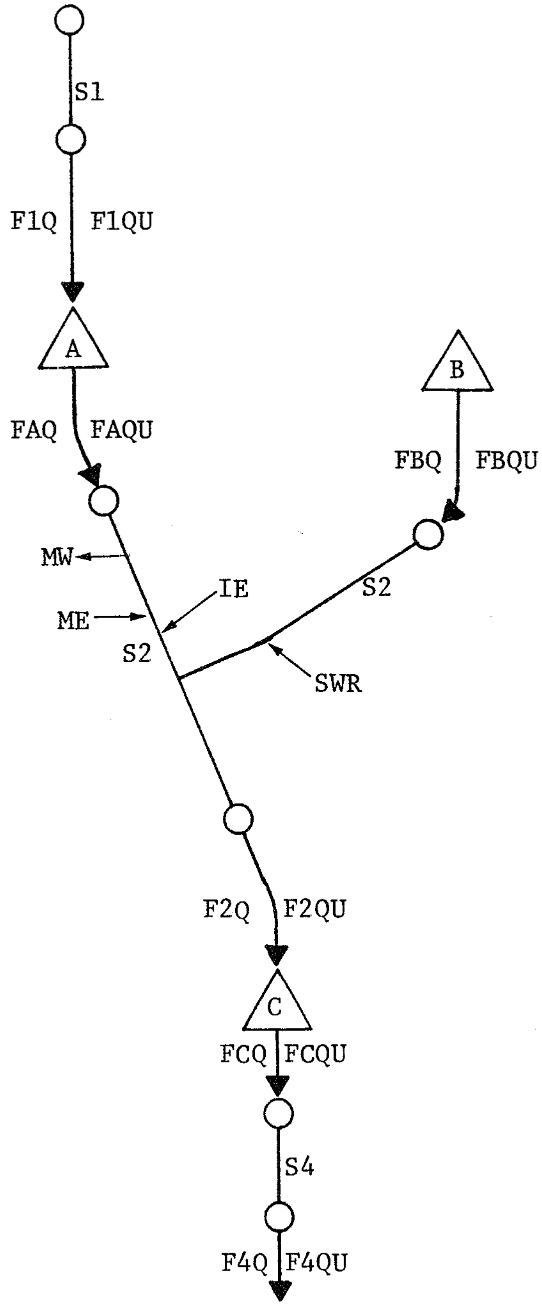
- Maximum of 10 reaches.
- Maximum of 100 volume elements.
- Maximum of 105 nodes.
- Maximum of 10 inflows and 5 withdrawals.

The prototype must be reduced to a series of reservoirs and stream systems for simulation. Individual modules of the WQRRS model are linked by storage on magnetic files of downstream river flow and quality or reservoir discharge flow and quality. These files are input as inflows to the stream or reservoir. The operation of the total system is best demonstrated by an example.

The sample stream-reservoir system is shown in Figure IX-1a. It consists of two rivers, three reservoirs and known inflows and withdrawals. This system must be broken into a series of subsystems, each consisting either of a reservoir or a stream system. Figure IX-1b shows a schematic representation in which there are three stream systems. Note that stream system S2 contains three stream reaches, the tributary and the main stem above and below its confluence with the tributary. The required analysis process may be listed in the following steps:



(a) prototype



(b) schematic

FIGURE IX-1

Typical Stream-Reservoir System

1. Simulate stream S1 hydraulics and generate downstream flows F1Q.

2. Simulate stream S1 quality and generate downstream flows F1QU.

3. Simulate Reservoir A using inflows F1Q and F1QU and generate outflows FAQ and FAQU.

4. Simulate Reservoir B and generate discharge flow and quality FBQ and FBQU.

5. Simulate stream system S2 hydraulics using upstream inflows FAQ and FBQ, inflows ME, IE and SWR and withdrawal MW and generate downstream flows F2Q.

6. Simulate stream S2 quality using upstream inflow quality FAQU and FBQU, inflow quality ME, IE and SWR, and generate downstream quality F2QU.

7. Simulate Reservoir C using inflow F2Q and F2QU and generate outflows FCQ and FCQU.

8. Simulate stream S4 hydraulics using upstream flows FCQ and generate final downstream flows F4Q.

9. Simulate stream S4 quality using upstream quality FCQU and generate final downstream quality F4QU.

The model is structured to operate such a problem by processing the 9 steps above as semi-independent steps. Each step may have up to three inputs from previous steps (e.g., stream system receiving inflow from three reservoirs).

To demonstrate the use of the system approach, an example utilizing a fictitious reservoir-stream system has been prepared. Because of need for a simplified example data set, a short simulation period has been selected with a minimum of inflow, meteorological and channel cross section data. In an actual application, a longer simulation period should be used (e.g., a typical simulation period for a reservoir simulation is one year) and all data input in sufficient detail to accurately describe prototype conditions. A discussion of the input and the output follows.

EXAMPLE OF A RIVER-RESERVOIR WATER QUALITY ANALYSIS

The example problem utilizes a fictitious river system (see Figure IX-2) which includes the California River between river miles 340 and 366 and Sutter Creek between river miles 100 and 108.

A water quality analysis is required to evaluate the impact of Smith Reservoir, a proposed impoundment, on downstream sport fishing. The downstream fishery is principally a cold water type (e.g., trout, steelhead, etc.). One aspect of the analysis is to determine the required number and elevation of ports for a multilevel intake structure to provide for the release of water with a constant temperature of 55 degrees Fahrenheit (i.e., 12.8°C). In addition to temperature, other water quality parameters are being analyzed in the channel between the dam and Station 3 so that a comparison of project and preproject water quality conditions can be made.

The historical drought period of 1 June 1956 through 30 September 1956 is being used for analysis. This period does not contain the lowest flows of record, but it is a low-flow period for which a substantial amount of inflow quality data is available. Water quality data are also available in the stream channel during this period and have been used to calibrate the model.

Reservoir Example

The reservoir example consists of a four month simulation beginning on June 1. If this were an actual application the reservoir should be simulated for the entire year. A reservoir simulation beginning at mid-year should be avoided since the initial conditions within the reservoir may dominate the results during critical periods. This is particularly true for preimpoundment studies where initial conditions cannot be known.

All water quality constituents have been modeled except for coliform bacteria, four classes of inorganic suspended solids and inorganic sediment.

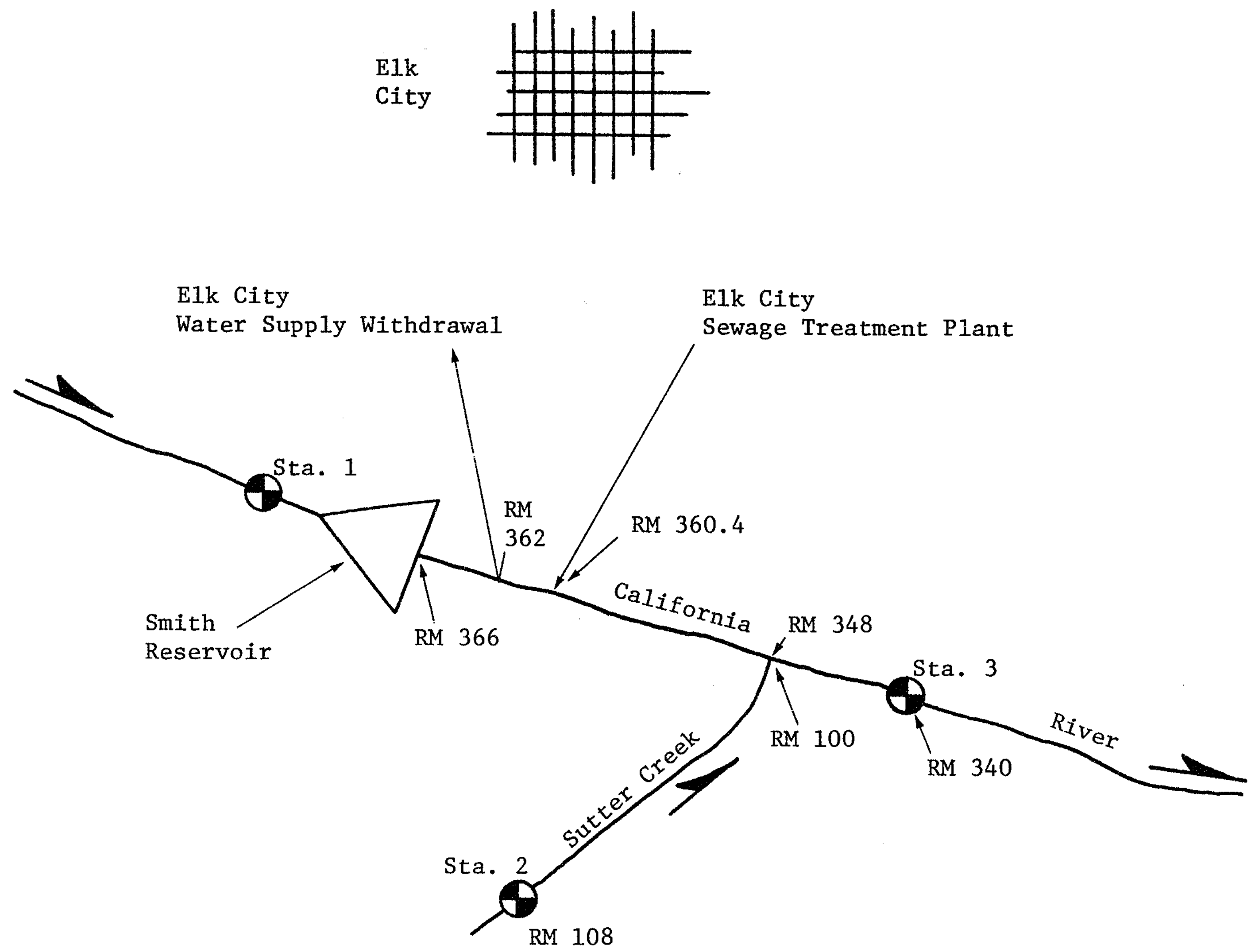


FIGURE IX-2

Schematic of the California River

A description of the physical characteristics of the reservoir are given in Tables IX-1 and IX-2. Determination of the best number of withdrawal ports and their location is a trial and error process. For the sample problem, seven ports distributed with depth as shown in Table IX-3 have been used. The assumed initial quality conditions for the reservoir are given in Table IX-4. Initial fish densities of 10 kg/hectare have been assumed for each fish type. The hydrological, meteorological and inflow quality data for the simulation period are given in Tables IX-5 and IX-6.

Assume that only minor changes to default physical, chemical and biological coefficients were required during separate calibration studies not described herein.

The coded input data for the reservoir module representing the data referenced above is shown in Figure IX-3. A portion of the output generated by the simulation is shown in Figure IX-4. The first twelve pages of the output are a summary of all input data which are processed prior to the beginning of the quality simulation. The remaining pages are an example of the simulation results. The complete output would include simulation results at ten day intervals plus two special print days. To reduce the volume of output presented herein, only the simulation results for Julian days 212 and 257 have been included.

Stream Example

The stream example consists of a two day simulation for the period of September 13 through September 14. All water quality constituents have been modeled except for four classes of inorganic suspended solids, inorganic sediment and unit toxicity.

The general physical characteristics of the stream system are given in Table IX-7 and the channel cross sections are shown in Figure IX-5.

The assumed initial conditions for the stream system are given in Table IX-8.

Inflows to the stream system include the Sutter Creek headwater, Elk City STP and the power releases from the reservoir. The inflow rate and quality of the Sutter Creek headwater and Elk City STP are given in Table IX-9. The Elk City withdrawal rate was a constant 22 cfs.

For the reservoir simulation, average monthly outflow were used. For the stream simulation, however, a dynamic flow condition typical of power generation releases was used. In the stream quality simulation, the reservoir outflow quality combined with the dynamic outflow results in dynamic loading at the upstream end of the river system. The reservoir outflow hydrograph is shown in Figure IX-6. Meteorological data for the simulation period is shown in Table IX-10.

The actual input data for the stream hydraulics module and the stream quality module representing the data referenced above is shown in Figures IX-7 and IX-9 respectively. Portions of the output generated by the stream hydraulic and stream quality simulations is shown in Figures IX-8 and IX-10. The first nine pages of the stream hydraulics output and the first eleven pages of the stream quality output are a summary of all input data which are processed prior to the beginning of the simulation. The remaining pages are samples of the simulation results. The complete stream hydraulic and quality output includes simulation results at four hour intervals for each day of simulation. To reduce the volume of output, only the hydraulic simulation results for all of the second day and the quality simulation results for hour 0400 of the second day have been included.

Summary

The input and output for the reservoir and the stream quality module have many similarities as do the stream hydraulic and the stream quality modules. This similarity will benefit the user once any one of the three modules has been run and an understanding of the input and output has been accomplished.

The documented example was completed by executing each module independently. In theory, all three modules could be linked together and executed in a single computer job. This use of the model is not encouraged. The output from each module should normally be carefully examined before proceeding to the next step.

The approximate computer time required to solve the example problems on the Control Data Corporation 7600 are:

- Reservoir Module (122 day simulation) — 4 seconds
- Stream Hydraulic Module (2 day simulation) — 37 seconds
- Stream Quality Module (2 day simulation) — 7 seconds

TABLE IX-1

Miscellaneous Physical Data

<u>Meteorological</u>	
Evaporation Coefficient "A"	0
Evaporation Coefficient "B"	1.5×10^{-9}
Latitude in degrees north	41
Longitude in degrees west	121
Atmospheric turbidity	3
<u>Reservoir</u>	
Layer thickness in feet	5
Maximum pool elevation in feet	560
Bottom elevation in feet	400
Initial (1 June 1956) elevation in feet	536
Secchi disk depth in feet	6
Fraction of solar radiation absorbed in top foot	.4
Maximum fraction of outflow through bottom outlet	.20
Water column stability in Kg/m^3/meter	.001
Water column critical stability in 1/meter	2×10^{-6}
Maximum effective diffusion coefficient in m^2/sec	3×10^{-5}
Emperical diffusion constant A_3	-0.7
Effective length at the tributary inflow location in feet	15000
Desired discharge temperature in °F	55

TABLE IX-2

Outlet Characteristics

Elevation (feet)	Virtual Width (feet)	Maximum Outflow Rate (cfs)
405	10	500
425	10	500
450	10	500
475	10	500
500	15	500
525	15	500
550	15	500

TABLE IX-3

Reservoir Elevation-Area-Width Table

Elevation (feet)	Area (acres)	Width at Dam (feet)
400	10	50
430	36	150
440	80	200
450	190	240
470	500	300
490	1180	380
530	3400	530
560	9000	650

TABLE IX-4

Initial Reservoir Quality

Constituent	Elevation (feet) 400	515	530	560
Temperature in °F	42	48	70	75
DO in mg/l	5	7	8	8
Carbonaceous BOD in mg/l	.1	.1	.1	.1
Coliform in MPN/100 ml	0	0	0	0
Sediment in mg/m^2	100000	50000	50000	50000
Detritus in mg/l	1	1	2	2
NH_3 in mg/l	.02	.02	.01	.01
NO_3 in mg/l	.10	.10	.05	.05
NO_2 in mg/l	.002	.002	.005	.005
PO_4 in mg/l	.01	.01	.01	.01
TDS in mg/l	300	300	300	300
Benthic animals in mg/m^2	500	500	500	500
Phytoplankton 1 in mg/l	.10	.10	1.2	1.5
Phytoplankton 2 in mg/l	.10	.10	.3	.4
Zooplankton in mg/l	.01	.01	.015	.02
pH	7.2	7.2	7.6	7.6
Alkalinity in mg/l	50	50	50	50
Suspended Solids in mg/l	1	1	1	1

TABLE IX-5

Time Varient Hydrological and Meteorological Data

	1Jun	11Jun	21Jun	1Jul	11Jul	21Jul	1Aug	11Aug	21Aug	1Sep	11Sep	21Sep
Cloudiness	.3	.3	.2	.3	.1	.1	.4	.6	.7	.5	.2	.2
Dry Bulb Temperature in °F	66	68	70	72	77	75	74	74	74	76	78	78
Wet Bulb Temperature in °F	53	55	54	56	58	58	63	66	67	62	62	62
Barometric Pressure in Hg	30	30	30	30	30	30	30	30	30	30	30	30
Wind Speed in mph	5	7	6	6	7	7	5	4	4	6	7	7
Reservoir Inflow in cfs	1000	700	500	300	100	100	100	100	200	200	200	200
Reservoir Outflow in cfs	600	600	600	400	400	400	200	200	200	300	300	300

TABLE IX-6

Tributary Inflow Quality

Temperature in °F below air temp.	5
Fraction of DO saturation	.9
Carbonaceous BOD in mg/l	.5
Coliform in MPN/100 ml	0
Detritus in mg/l	5
NH_3 in mg/l	.008
NO_3 in mg/l	.020
NO_2 in mg/l	0
PO_4 in mg/l	.005
TDS in mg/l	300
Phytoplankton 1 in mg/l	0
Phytoplankton 2 in mg/l	0
Zooplankton in mg/l	0
pH	7.4
Alkalinity in mg/l	40
Suspended Solids in mg/l	10

FIGURE IX-3

RESERVOIR MODULE INPUT DATA

TITLE	EXAMPLE PROBLEM - RESERVOIR QUALITY								
TITLE	FICTITIOUS CALIFORNIA RIVER SYSTEM								
TITLE	SMITH RESERVOIR								
JOB1	560601	560930	24	24					
JOB2	1	1	1	0	1	1	1	1	1
JOB2A	1	1	1	1	1	1	1	1	1
JOB2B	1	1	1	0	0	0	0	0	
JOB3	7	1	1	4					
JOB4	10	24	1	1	1	2			
JOB5	560913	560916							
JOB6	1	0	0	0	0	0	0	0	0
JOB7	0	1	1	0	0	0			
PHYS1	1	0	0	41	121	3			
PHYS2	5	560	400	536	6	.4	1	.20	
PHYS3A	.0010	2.-6	.3-4		-.7				
PHYS4	15000								
PHYS5	405	10	500	1					
PHYS5	425	10	500	2					
PHYS5	450	10	500	1					
PHYS5	475	10	500	2					
PHYS5	500	15	500	1					
PHYS5	525	15	500	2					
PHYS5	550	15	500	1					
PHYS6	400	10	50	50					
PHYS6	430	36	150						
PHYS6	440	80	200						
PHYS6	450	190	240						
PHYS6	470	500	300						
PHYS6	490	1180	380						
PHYS6	530	3400	530						
PHYS6	560	9000	650						
COEFF	74	.2	75	.1	76	.1	77	.1	
COEFF	122	.1	39	.03	28	.25			
COEFF	86	.05	87	.1	88	.15	89	.15	
COEFF	89	.15	-1						
SSOL1	.001	10	.0012	22	.0014	30			
SSOL2	-1	.1							
INIT1	10	10	10	2000					
INIT2	400	42	5	.1	0	100000	1	.02	.1
INIT3	.002	.01	300	500	.100	.100	.010	7.2	50
INIT4	1	0	0	0	0	0			
INIT2	515	48	7	.1	0	50000	1	.02	.1
INIT3	.002	.01	300	500	.100	.100	.010	7.2	50
INIT4	1	0	0	0	0	0			

```
INIT2         530       70        8        .1        0     50000        2       .01      .05
INIT3        .005      .01      300       500      1.2      .300     .015       7.6       50
INIT4           1        0        0         0        0         0
INIT2         560       75        8        .1        0     50000        2       .01      .05
INIT3        .005      .01      300       500      1.5      .400     .020       7.6       50
INIT4           1        0        0         0        0         0
INFL1           1        1        1         0        1         1        1         0        1
INFL1A          1        0        0         0        1         1
INFL1B          1        0        0         0        0
INFL2      560601   561001
INFL3           0 INFLOW RATE
INFL5    56060100 1000.   56061100 700.    56062100 500.    56070100 300.
INFL5    56071100 100.    56082100 200.          -1
INFL3           0 TEMPERATURE
INFL5    56060100       -5       -1
INFL3           0 DISSOLVED OXYGEN
INFL5    56060100      -.9       -1
INFL3           0 BOD
INFL5    56060100       .5       -1
INFL3           0 DETRITUS
INFL5    56060100        5       -1
INFL3           0 AMMONIA
INFL5    56060100     .008       -1
INFL3           0 NITRATE
INFL5    56060100     .020       -1
INFL3           0 PHOSPHATE
INFL5    56060100     .005       -1
INFL3           0 TDS
INFL5    56060100      300       -1
INFL3           0 PH
INFL5    56060100      7.4       -1
INFL3           0 ALKALINITY
INFL5    56060100       40       -1
INFL3           0 SSOL NO 1
INFL5    56060100      10.       -1
WEATH1   56060100       .3       66        53       30         5
WEATH1   56061100       .3       68        55       30         7
WEATH1   56062100       .2       70        54       30         6
WEATH1   56070100       .3       72        56       30         6
WEATH1   56071100       .1       77        58       30         7
WEATH1   56072100       .1       75        58       30         7
WEATH1   56080100       .4       74        63       30         5
WEATH1   56081100       .6       74        66       30         4
WEATH1   56082100       .7       74        67       30         4
WEATH1   56090100       .5       76        62       30         6
WEATH1   56091100       .2       78        62       30         7
WEATH1   56092100       .2       78        62       30         7                           -1
OUTL1      560601       -1      600        55
OUTL1      560701       -1      400        55
OUTL1      560801       -1      200        55
OUTL1     -560901       -1      300        55
TITLE
TITLE
TITLE
JOB1
```

```
****************************************************      **************************************
*  WATER QUALITY FOR RIVER-RESERVOIR SYSTEMS       *      *  U.S. ARMY CORPS OF ENGINEERS      *
*  RESERVOIR MODEL                                 *      *  THE HYDROLOGIC ENGINEERING CENTER *
*  DECEMBER 1978 UPDATED DECEMBER 1984             *      *  609 SECOND STREET, SUITE D        *
*  ERROR CORRECTION 014                            *      *  DAVIS, CALIFORNIA 95616           *
*  RUN DATE 15 JAN 85  TIME   9:42:29              *      *  (916) 440-2105 (FTS) 448-2105     *
****************************************************      **************************************
```

```
X     X    XXX    XXXXXX  XXXXXX   XXXXX  XXXXXX
X     X   X   X   X     X X     X X     X X     X
X     X  X     X  X     X X     X X       X     X
X  X  X  X     X  XXXXXX  XXXXXX   XXXXX  XXXXXX
X X X X  X   X X  X   X   X   X         X X   X
XX   XX   X   X   X    X  X    X  X     X X    X
X     X    XXX X  X     X X     X  XXXXX  X     X
```

FIGURE IX-4

RESERVOIR MODULE OUTPUT

EXAMPLE PROBLEM - RESERVOIR QUALITY
FICTITIOUS CALIFORNIA RIVER SYSTEM
SMITH RESERVOIR

DAYS OF SIMULATION	122
FIRST DAY OF SIMULATION	153 (56/ 6/ 1)
FINAL DAY OF SIMULATION	274 (56/ 9/30)
COMPUTATIONAL TIME STEP, HOURS	24
METEOROLOGICAL DATA INTERVAL, HOURS	24
NUMBER OF OUTLETS	7
WITHDRAWAL METHOD (WES=0/DEBLER=1)	1
NUMBER OF INFLOW POINTS	1
NUMBER OF POINTS DEFINING INITIAL QUALITY PROFILE	4
PRINTOUT INTERVAL, DAYS	10
PRINTOUT INTERVAL, HOURS	24
VERTICAL LAYER PRINTOUT INTERVAL	1
INPUT WATER TEMPERATURE UNITS (F=1/C=0)	1
INPUT UNITS (ENGLISH=1/METRIC=0)	1
ADDITIONAL PRINTOUT DAYS	257 (56/ 9/13) 260 (56/ 9/16)

STATUS OF WATER QUALITY CONSTITUENTS

NUMBER	CONSTITUENT	SIMULATE	HOLD CONSTANT	SET TO ZERO
1	TEMPERATURE	****		
2	DISSOLVED OXYGEN	****		
3	CARBONACEOUS BOD	****		
4	COLIFORM BACTERIA			****
5	ORGANIC DETRITUS	****		
6	AMMONIA AS N	****		
7	NITRATE AS N	****		
8	NITRITE AS N	****		
9	PHOSPHATE AS P	****		
10	TOTAL DISSOLVED SOLIDS	****		
11	PHYTOPLANKTON NO. 1	****		
12	PHYTOPLANKTON NO. 2	****		
13	ZOOPLANKTON	****		
14	TOTAL INORGANIC CARBON	****		
15	ALKALINITY AS CACO3	****		
16	ORGANIC SEDIMENT	****		
17	BENTHIC ANIMALS	****		
18	FISH NO. 1	****		
19	FISH NO. 2	****		
20	FISH NO. 3	****		
21	SUSPENDED SOLIDS NO. 1	****		
22	SUSPENDED SOLIDS NO. 2			****
23	SUSPENDED SOLIDS NO. 3			****

24	SUSPENDED SOLIDS NO. 4	****
25	SUSPENDED SOLIDS NO. 5	****
26	INORGANIC SEDIMENT	****

TAPE OR FILE RELATED DATA

OUTFLOW RATE AND QUALITY INTERFACE	10
OUTFLOW HYDROGRAPH INTERFACE	0
U/S FLOW AND QUALITY INTERFACE UNIT NO. 1	0
DATA INTERVAL, HOURS, U/S INTERFACE NO. 1	0
U/S FLOW AND QUALITY INTERFACE UNIT NO. 2	0
DATA INTERVAL, HOURS, U/S INTERFACE NO. 2	0
U/S FLOW AND QUALITY INTERFACE UNIT NO. 3	0
DATA INTERVAL, HOURS, U/S INTERFACE NO. 3	0
SIMULATION RESULTS FOR HEC PLOT PACKAGE	0
EQUILIBRIUM TEMPERATURE AND EXCHANGE RATES	0
PROCESSED METEOROLOGICAL DATA **	15
PROCESSED INFLOW RATES AND QUALITY DATA **	16
UNPROCESSED METEOROLOGICAL DATA *	5
UNPROCESSED INFLOW RATES AND QUALITY DATA *	5
UNPROCESSED WITHDRAWAL DATA *	5

* DATA WILL BE READ FROM CARDS IF UNIT = 5

** A NEGATIVE NUMBER INDICATES A PERMANENT RECORD, NO CARD INPUT REQUIRED

INVARIENT METEOROLOGICAL DATA

TYPE OF HEAT EXCHANGE (HEAT BUDGET=0/EQ TEMP=1)	0
TEMPERATURE (DEW POINT=0/WET BULB=1)	1
EVAPORATION CONSTANT A	0.00E+01
EVAPORATION CONSTANT B	0.15E-08
LATITUDE OF RESERVOIR, DEG	41.0
LONGITUDE OF RESERVOIR, DEG	121.0
LONGITUDE (WEST=+1/EAST=-1))	1.0
ATMOSPHERIC TURBIDITY	3.0

INVARIENT PHYSICAL DATA

LAYER THICKNESS, METERS	1.5
MAXIMUM WATER SURFACE ELEVATION, METERS	170.7
BOTTOM ELEVATION, METERS	121.9
STARTING WATER SURFACE ELEVATION, METERS	163.4
SECCHI DISK DEPTH, METERS	1.8
DEPTH OF INITIAL SOLAR ENERGY ABSORPTION, METERS	0.30
FRACTION OF SOLAR ENERGY ABSORBED	0.40
MAXIMUM FRACTION OF OUTFLOW THROUGH BOTTOM GATE	0.20
WATER COLUMN MINIMUM STABILITY, KG/M3/M	0.10E-02
WATER COLUMN CRITICAL STABILITY (GSWH), KG/M3/M	0.20E-05
MAXIMUM ALLOWABLE DISPERSION (A1), M2/SEC	0.30E-04
COEFFICIENT RELATION GRADIENT TO DISPERSION (A3)	-0.70E+00

EFFECTIVE RESERVOIR LENGTH AT TRIBUTARY INFLOW POINT

INFLOW NUMBER	RESERVOIR LENGTH, M
1	4572.

OUTLET CHARACTERISTICS

OUTLET NUMBER	ELEV (USER DATUM) FT OR METERS	ELEV (FROM ZERO DATUM) METERS	VIRTUAL WIDTH METERS	MAXIMUM FLOW RATE CMS	OUTLET TYPE
1	405.0	1.5	3.0	14.16	WET WELL 1
2	425.0	7.6	3.0	14.16	WET WELL 2
3	450.0	15.2	3.0	14.16	WET WELL 1
4	475.0	22.9	3.0	14.16	WET WELL 2
5	500.0	30.5	4.6	14.16	WET WELL 1
6	525.0	38.1	4.6	14.16	WET WELL 2
7	550.0	45.7	4.6	14.16	WET WELL 1

1/85

RESERVOIR GEOMETRY DATA

	INPUT DATA (USER DATUM AND UNITS)			*I*		GENERATED DATA (ZERO DATUM)				
ELEM	ELEVATION FT OR M	AREA AC OR M2	WIDTH AT DAM FT OR M	*I* *I*	ELEVATION METERS	AREA M2	BOTTOM AREA M2	VOLUME M3	ELEM VOLUME M3	WIDTH AT DAM METERS
1	400.0	10.0	50.0		0.0	0.0000E+01	0.5800E+05	0.0000E+01	0.1367E+06	15.
2					1.5	0.5800E+05	0.1754E+05	0.1367E+06	0.1018E+06	20.
3					3.0	0.7554E+05	0.1754E+05	0.2385E+06	0.1285E+06	25.
4					4.6	0.9308E+05	0.1754E+05	0.3670E+06	0.1552E+06	30.
5					6.1	0.1106E+06	0.1754E+05	0.5222E+06	0.1819E+06	36.
6					7.6	0.1282E+06	0.1754E+05	0.7041E+06	0.2087E+06	41.
7	430.0	36.0	150.0		9.1	0.1457E+06	0.8903E+05	0.9128E+06	0.2899E+06	46.
8					10.7	0.2347E+06	0.8903E+05	0.1203E+07	0.4256E+06	53.
9	440.0	80.0	200.0		12.2	0.3237E+06	0.2226E+06	0.1628E+07	0.6630E+06	61.
10					13.7	0.5463E+06	0.2226E+06	0.2291E+07	0.1002E+07	67.
11	450.0	190.0	240.0		15.2	0.7689E+06	0.3136E+06	0.3293E+07	0.1411E+07	73.
12					16.8	0.1083E+07	0.3136E+06	0.4704E+07	0.1889E+07	78.
13					18.3	0.1396E+07	0.3136E+06	0.6593E+07	0.2367E+07	82.
14					19.8	0.1710E+07	0.3136E+06	0.8960E+07	0.2845E+07	87.
15	470.0	500.0	300.0		21.3	0.2023E+07	0.6880E+06	0.1180E+08	0.3608E+07	91.
16					22.9	0.2711E+07	0.6880E+06	0.1541E+08	0.4656E+07	98.
17					24.4	0.3399E+07	0.6880E+06	0.2007E+08	0.5705E+07	104.
18					25.9	0.4087E+07	0.6880E+06	0.2577E+08	0.6753E+07	110.
19	490.0	1180.0	380.0		27.4	0.4775E+07	0.1123E+07	0.3253E+08	0.8133E+07	116.
20					29.0	0.5898E+07	0.1123E+07	0.4066E+08	0.9845E+07	122.
21					30.5	0.7021E+07	0.1123E+07	0.5050E+08	0.1156E+08	127.
22					32.0	0.8144E+07	0.1123E+07	0.6206E+08	0.1327E+08	133.
23					33.5	0.9267E+07	0.1123E+07	0.7533E+08	0.1498E+08	139.
24					35.1	0.1039E+08	0.1123E+07	0.9031E+08	0.1669E+08	144.
25					36.6	0.1151E+08	0.1123E+07	0.1070E+09	0.1840E+08	150.
26					38.1	0.1264E+08	0.1123E+07	0.1254E+09	0.2011E+08	156.
27	530.0	3400.0	530.0		39.6	0.1376E+08	0.3777E+07	0.1455E+09	0.2385E+08	162.
28					41.1	0.1754E+08	0.3777E+07	0.1694E+09	0.2960E+08	168.
29					42.7	0.2131E+08	0.3777E+07	0.1990E+09	0.3536E+08	174.
30					44.2	0.2509E+08	0.3777E+07	0.2343E+09	0.4112E+08	180.
31					45.7	0.2887E+08	0.3777E+07	0.2754E+09	0.4687E+08	186.
32					47.2	0.3264E+08	0.3777E+07	0.3223E+09	0.5263E+08	192.
33	560.0	9000.0	650.0		48.8	0.3642E+08	0.0000E+01	0.3749E+09	0.0000E+01	198.

CHEMICAL COMPOSITION

	CARBON	NITROGEN	PHOSPHORUS
ALGAE	0.400	0.080	0.012
ZOOPLANKTON	0.400	0.080	0.012
BENTHOS	0.400	0.080	0.012
FISH	0.400	0.080	0.012
DETR / SED	0.400	0.080	0.012

BIOLOGICAL COEFFICIENTS

	GROWTH 1/DAY	RESPIRATION 1/DAY	MORTALITY 1/DAY	HALF SATURATION CONSTANTS LIGHT KCAL/M2/SEC	PO4-P MG/L	NH3+NO3-N MG/L	CO2-C MG/L	SINKING VEL M/DAY
PHYTOPLANKTON 1	2.00	0.150		0.003	0.030	0.060	0.025	0.250 *
PHYTOPLANKTON 2	2.50	0.200		0.004	0.030	0.060	0.025	0.100

	GROWTH	RESPIRATION	MORTALITY	HALF SATURATION	GRAZING PREFFERENCE NO 1	NO 2	NO 3	ASSIM. EFF	PARTICULATE EXCREATA
ZOOPLANKTON	0.150	0.015	0.010	0.300	0.500	0.200		0.60	0.60
BENTHOS	0.030 *	0.008	0.004	2000.000				0.60	0.60
FISH NO. 1	0.020	0.003	0.002	0.200	0.005			0.50	0.60
FISH NO. 2	0.025	0.003	0.002	0.200	0.005			0.50	0.60
FISH NO. 3	0.020	0.003	0.002	500.000	0.001			0.50	0.60

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
FISH NO. 1 HARVEST, 1/MONTH	0.00	0.00	0.00	0.00	0.00	0.20 *	0.10 *	0.10 *	0.10 *	0.00	0.00	0.00
FISH NO. 2 HARVEST, 1/MONTH	0.00	0.00	0.00	0.00	0.00	0.05 *	0.10 *	0.15 *	0.15 *	0.00	0.00	0.00
FISH NO. 3 HARVEST, 1/MONTH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

* INDICATES COEFFICIENT DEFAULT VALUE HAS BEEN OVERRIDDEN BY USER

MISCELLANEOUS COEFFICIENTS

	DECAY RATE, 1/DAY	OXYGEN CONSUMED	CARBON RELEASED
BOD	0.30		0.20
AMMONIA	0.20	3.50	
NITRITE	0.50	1.20	
COLIFORMS	1.00		
DETRITUS	0.020	1.60	
SEDIMENTS	0.005	1.60	
BIOMASS RESPIRATION		1.60	
ALGAL GROWTH		1.60	(PRODUCED)

DETRITUS SETTLING VELOCITY, METERS/DAY 0.500

	ALG 1	ALG 2	ZOO	DETRITUS	SS 1	SS 2	SS 3	SS 4	SS 5
SHADING FACTOR, 1/(MG/L)/M	0.20	0.20	0.02	0.10	0.10 *	0.00	0.00	0.00	0.00

COEFFICIENT TEMPERATURE ADJUSTMENT PARAMETER

	CALIBRATION MAGNITUDE				CALIBRATION TEMPERATURE			
	K1	K2	K3	K4	T1	T2	T3	T4
ALGAE 1	0.10	0.98	0.98	0.10	5.	22.	25.	34.
ALGAE 2	0.10	0.98	0.98	0.10	10.	28.	30.	40.
ZOOPLANKTON	0.10	0.98	0.98	0.10	5.	28.	30.	38.
BENTHOS	0.10	0.98	0.98	0.10	5.	22.	25.	38.
FISH 1	0.10	0.98	0.98	0.10	5.	20.	20.	25.
FISH 2	0.10	0.98	0.98	0.10	10.	27.	30.	38.
FISH 3	0.10	0.98	0.98	0.10	5.	22.	30.	36.
BOD	0.10	0.98			4.	30.		
AMMONIA	0.10	0.98			4.	30.		
NITRITE	0.10	0.98			4.	30.		
DETRITUS/SED	0.10	0.98			4.	30.		

Q10 TEMPERATURE ADJUSTMENT FACTOR

COLIFORM DIEOFF	1.040
BOD DECAY	0.000
AMMONIA DECAY	0.000
NITRITE DECAY	0.000
DETRITUS DECAY	0.000
NON GROWTH BIOLOGICAL ACTIVITY	0.000

* INDICATES COEFFICIENT DEFAULT VALUE HAS BEEN OVERRIDDEN BY USER

COEFFICIENT TEMPERATURE ADJUSTMENT

	TEMPERATURE, C																			
	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38
BOD	0.10	0.10	0.10	0.15	0.22	0.31	0.42	0.54	0.65	0.75	0.82	0.88	0.92	0.95	0.97	0.98	0.99	0.99	1.00	1.00
NH3	0.10	0.10	0.10	0.15	0.22	0.31	0.42	0.54	0.65	0.75	0.82	0.88	0.92	0.95	0.97	0.98	0.99	0.99	1.00	1.00
NO2	0.10	0.10	0.10	0.15	0.22	0.31	0.42	0.54	0.65	0.75	0.82	0.88	0.92	0.95	0.97	0.98	0.99	0.99	1.00	1.00
DET	0.10	0.10	0.10	0.15	0.22	0.31	0.42	0.54	0.65	0.75	0.82	0.88	0.92	0.95	0.97	0.98	0.99	0.99	1.00	1.00
COLIF	0.46	0.49	0.53	0.58	0.62	0.68	0.73	0.79	0.85	0.92	1.00	1.08	1.17	1.27	1.37	1.48	1.60	1.73	1.87	2.03
ALG 1, R/M	0.10	0.10	0.10	0.14	0.25	0.40	0.58	0.74	0.85	0.92	0.96	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ALG 2, R/M	0.10	0.10	0.10	0.10	0.10	0.10	0.18	0.30	0.46	0.62	0.77	0.87	0.93	0.96	0.98	0.99	0.99	1.00	1.00	1.00
ALG 1, G	0.10	0.10	0.10	0.14	0.25	0.40	0.58	0.74	0.85	0.92	0.96	0.98	0.98	0.96	0.86	0.62	0.30	0.10	0.00	0.00
ALG 2, G	0.10	0.10	0.10	0.10	0.10	0.10	0.18	0.30	0.46	0.62	0.77	0.87	0.93	0.96	0.97	0.97	0.93	0.81	0.56	0.27
ZOO, R/M	0.10	0.10	0.10	0.13	0.20	0.29	0.41	0.55	0.67	0.78	0.85	0.91	0.94	0.97	0.98	0.99	0.99	1.00	1.00	1.00
ZOO, G	0.10	0.10	0.10	0.13	0.20	0.29	0.41	0.55	0.67	0.78	0.85	0.91	0.94	0.97	0.98	0.97	0.91	0.70	0.34	0.10
BEN, R/M	0.10	0.10	0.10	0.14	0.25	0.40	0.58	0.74	0.85	0.92	0.96	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
BEN, G	0.10	0.10	0.10	0.14	0.25	0.40	0.58	0.74	0.85	0.92	0.96	0.98	0.98	0.96	0.92	0.82	0.65	0.42	0.22	0.10
FISH 1, R/M	0.10	0.10	0.10	0.14	0.27	0.46	0.66	0.81	0.91	0.96	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
FISH 2, R/M	0.10	0.10	0.10	0.10	0.10	0.10	0.19	0.32	0.49	0.66	0.80	0.89	0.94	0.97	0.99	0.99	1.00	1.00	1.00	1.00
FISH 3, R/M	0.10	0.10	0.10	0.14	0.25	0.40	0.58	0.74	0.85	0.92	0.96	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
FISH 1, G	0.10	0.10	0.10	0.14	0.27	0.46	0.66	0.81	0.91	0.95	0.96	0.80	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FISH 2, G	0.10	0.10	0.10	0.10	0.10	0.10	0.19	0.32	0.49	0.66	0.80	0.89	0.94	0.97	0.98	0.97	0.91	0.70	0.34	0.10
FISH 3, G	0.10	0.10	0.10	0.14	0.25	0.40	0.58	0.74	0.85	0.92	0.96	0.98	0.99	0.99	0.99	0.98	0.87	0.46	0.10	0.00

INORGANIC SUSPENDED SOLIDS

NUMBER	FALL VELOCITY, CM/SEC AT THREE TEMPERATURES, C					
1	0.001	10.	0.001	22.	0.001	30.

INITIAL SUSPENDED SOLIDS DEPOSITION AT TRIBUTARY DISCHARGE POINT

TRIBUTARY	SUSPENDED SOLIDS GROUP	NUMBER OF ELEMENTS	FRACTION DEPOSITED
1	1	-1	0.100

INITIAL RESERVOIR QUALITY CONDITIONS

FISH STATUS

	DENSITY KG/HA	TOTAL BIOMASS KG	GROWTH RATE KG/HA/MO	HARVEST RATE KG/HA/MO
FISH 1	10.00	20000.0	0.00	0.00
FISH 2	10.00	20000.0	0.00	0.00
FISH 3	10.00	20000.0	0.00	0.00

ELEM	GATE	DEPTH M	TEMP C	OXYGEN MG/L	BOD MG/L	COLIFORMS MPN/100	INORGANIC SUSPENDED SOLIDS NO 1 MG/L	NO 2 MG/L	NO 3 MG/L	NO 4 MG/L	NO 5 MG/L	DETRITUS MG/L	LIGHT EXT 1/M	SHORT WAVE KCAL/M2/SEC	SEDIMENTS INORG G/M2	ORG G/M2
27		0.8	21.3	8.0	0.1	0.00E+01	1.00	0.00	0.00	0.00	0.00	2.00	0.00	0.000E+01	0.	50.
26	6	2.3	19.1	7.8	0.1	0.00E+01	1.00	0.00	0.00	0.00	0.00	1.83	0.00	0.000E+01	0.	50.
25		3.8	15.0	7.5	0.1	0.00E+01	1.00	0.00	0.00	0.00	0.00	1.50	0.00	0.000E+01	0.	50.
24		5.3	10.9	7.2	0.1	0.00E+01	1.00	0.00	0.00	0.00	0.00	1.17	0.00	0.000E+01	0.	50.
23		6.9	8.8	7.0	0.1	0.00E+01	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.000E+01	0.	51.
22		8.4	8.7	6.9	0.1	0.00E+01	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.000E+01	0.	53.
21	5	9.9	8.5	6.8	0.1	0.00E+01	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.000E+01	0.	55.
20		11.4	8.4	6.7	0.1	0.00E+01	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.000E+01	0.	58.
19		13.0	8.2	6.6	0.1	0.00E+01	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.000E+01	0.	60.
18		14.5	8.1	6.5	0.1	0.00E+01	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.000E+01	0.	62.
17		16.0	7.9	6.4	0.1	0.00E+01	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.000E+01	0.	64.
16	4	17.5	7.8	6.3	0.1	0.00E+01	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.000E+01	0.	66.
15		19.0	7.7	6.3	0.1	0.00E+01	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.000E+01	0.	68.
14		20.6	7.5	6.2	0.1	0.00E+01	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.000E+01	0.	71.
13		22.1	7.4	6.1	0.1	0.00E+01	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.000E+01	0.	73.
12		23.6	7.2	6.0	0.1	0.00E+01	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.000E+01	0.	75.
11	3	25.1	7.1	5.9	0.1	0.00E+01	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.000E+01	0.	77.
10		26.7	6.9	5.8	0.1	0.00E+01	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.000E+01	0.	79.
9		28.2	6.8	5.7	0.1	0.00E+01	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.000E+01	0.	82.
8		29.7	6.6	5.7	0.1	0.00E+01	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.000E+01	0.	84.
7		31.2	6.5	5.6	0.1	0.00E+01	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.000E+01	0.	86.
6	2	32.8	6.4	5.5	0.1	0.00E+01	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.000E+01	0.	88.
5		34.3	6.2	5.4	0.1	0.00E+01	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.000E+01	0.	90.
4		35.8	6.1	5.3	0.1	0.00E+01	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.000E+01	0.	92.
3		37.3	5.9	5.2	0.1	0.00E+01	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.000E+01	0.	95.
2	1	38.9	5.8	5.1	0.1	0.00E+01	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.000E+01	0.	97.
1		40.4	5.6	5.0	0.1	0.00E+01	1.00	0.00	0.00	0.00	0.00	1.00	0.00	0.000E+01	0.	100.

RESERVOIR QUALITY, CONTINUED

ELEMENT	DEPTH M	TDS MG/L	ALKA MG/L	PH UNITS	CO2-C MG/L	TIC MG/L	NH3-N MG/L	NO3-N MG/L	NO2-N MG/L	PO4-P MG/L	ALGAE 1 MG/L	ALGAE 2 MG/L	ZOOPLANKTON MG/L	BENTHIC ANIMALS MG/M2
27	0.8	300.	50.	7.6	0.653	12.6	0.010	0.050	0.005	0.010	1.225	0.308	0.015	500.
26	2.3	300.	50.	7.5	0.790	12.8	0.012	0.058	0.004	0.010	1.017	0.267	0.014	500.
25	3.8	300.	50.	7.4	1.155	13.1	0.015	0.075	0.003	0.010	0.650	0.200	0.012	500.
24	5.3	300.	50.	7.3	1.707	13.7	0.018	0.092	0.002	0.010	0.283	0.133	0.011	500.
23	6.9	300.	50.	7.2	2.094	14.1	0.020	0.100	0.002	0.010	0.100	0.100	0.010	500.
22	8.4	300.	50.	7.2	2.094	14.1	0.020	0.100	0.002	0.010	0.100	0.100	0.010	500.
21	9.9	300.	50.	7.2	2.145	14.1	0.020	0.100	0.002	0.010	0.100	0.100	0.010	500.
20	11.4	300.	50.	7.2	2.145	14.1	0.020	0.100	0.002	0.010	0.100	0.100	0.010	500.
19	13.0	300.	50.	7.2	2.145	14.1	0.020	0.100	0.002	0.010	0.100	0.100	0.010	500.
18	14.5	300.	50.	7.2	2.145	14.1	0.020	0.100	0.002	0.010	0.100	0.100	0.010	500.
17	16.0	300.	50.	7.2	2.145	14.1	0.020	0.100	0.002	0.010	0.100	0.100	0.010	500.
16	17.5	300.	50.	7.2	2.145	14.1	0.020	0.100	0.002	0.010	0.100	0.100	0.010	500.
15	19.0	300.	50.	7.2	2.145	14.1	0.020	0.100	0.002	0.010	0.100	0.100	0.010	500.
14	20.6	300.	50.	7.2	2.198	14.2	0.020	0.100	0.002	0.010	0.100	0.100	0.010	500.
13	22.1	300.	50.	7.2	2.198	14.2	0.020	0.100	0.002	0.010	0.100	0.100	0.010	500.
12	23.6	300.	50.	7.2	2.198	14.2	0.020	0.100	0.002	0.010	0.100	0.100	0.010	500.
11	25.1	300.	50.	7.2	2.198	14.2	0.020	0.100	0.002	0.010	0.100	0.100	0.010	500.
10	26.7	300.	50.	7.2	2.198	14.2	0.020	0.100	0.002	0.010	0.100	0.100	0.010	500.
9	28.2	300.	50.	7.2	2.198	14.2	0.020	0.100	0.002	0.010	0.100	0.100	0.010	500.
8	29.7	300.	50.	7.2	2.198	14.2	0.020	0.100	0.002	0.010	0.100	0.100	0.010	500.
7	31.2	300.	50.	7.2	2.259	14.3	0.020	0.100	0.002	0.010	0.100	0.100	0.010	500.
6	32.8	300.	50.	7.2	2.259	14.3	0.020	0.100	0.002	0.010	0.100	0.100	0.010	500.
5	34.3	300.	50.	7.2	2.259	14.3	0.020	0.100	0.002	0.010	0.100	0.100	0.010	500.
4	35.8	300.	50.	7.2	2.259	14.3	0.020	0.100	0.002	0.010	0.100	0.100	0.010	500.
3	37.3	300.	50.	7.2	2.259	14.3	0.020	0.100	0.002	0.010	0.100	0.100	0.010	500.
2	38.9	300.	50.	7.2	2.259	14.3	0.020	0.100	0.002	0.010	0.100	0.100	0.010	500.
1	40.4	300.	50.	7.2	2.259	14.3	0.020	0.100	0.002	0.010	0.100	0.100	0.010	500.

FIRST DAY OF INFLOW QUALITY RECORD	560601
LAST DAY OF INFLOW QUALITY RECORD	561001
TOTAL NUMBER OF DAYS	123

2 CARDS READ FOR	INFLOW RATE	(FLOW)
1 CARDS READ FOR	TEMPERATURE	(TEMP)
1 CARDS READ FOR	DISSOLVED OXYGEN	(OXY)
1 CARDS READ FOR	BOD	(BOD)
1 CARDS READ FOR	DETRITUS	(DET)
1 CARDS READ FOR	AMMONIA	(NH3)
1 CARDS READ FOR	NITRATE	(NO3)
1 CARDS READ FOR	PHOSPHATE	(PO4)
1 CARDS READ FOR	TDS	(TDS)
1 CARDS READ FOR	PH	(PH)
1 CARDS READ FOR	ALKALINITY	(ALK)
1 CARDS READ FOR	SSOL NO 1	(SS 1)

TIME (MONTH/DAY) VS. DAILY AVERAGE INFLOW RATE OR CONCENTRATION IN APPROPRIATE UNITS

PARAMETER	TRIB NO.	TIME	FLOW/CONC	TIME	FLOW/CONC	TIME	FLOW/CONC	TIME	FLOW/CONC	TIME	FLOW/CONC
FLOW	1	6/ 1	1000.0	6/11	700.0	6/21	500.0	7/ 1	300.0	7/11	100.0
FLOW	1	8/21	200.0								
TEMP	1	6/ 1	-5.00								
OXY	1	6/ 1	-0.90								
BOD	1	6/ 1	0.50								
DET	1	6/ 1	5.00								
NH3	1	6/ 1	0.008								
NO3	1	6/ 1	0.020								
PO4	1	6/ 1	0.005								
TDS	1	6/ 1	300.								
PH	1	6/ 1	7.4								
ALK	1	6/ 1	40.0								
SS 1	1	6/ 1	10.0								

METEOROLOGICAL DATA

DATE	TIME	CLOUD COVER	DRY BULB TEMP, F	DEW / WET TEMP, F	PRESSURE IN HG	WIND SPEED MPH
56/ 6/ 1	0	0.30	66.00	53.00	30.00	5.00
56/ 6/11	0	0.30	68.00	55.00	30.00	7.00
56/ 6/21	0	0.20	70.00	54.00	30.00	6.00
56/ 7/ 1	0	0.30	72.00	56.00	30.00	6.00
56/ 7/11	0	0.10	77.00	58.00	30.00	7.00
56/ 7/21	0	0.10	75.00	58.00	30.00	7.00
56/ 8/ 1	0	0.40	74.00	63.00	30.00	5.00
56/ 8/11	0	0.60	74.00	66.00	30.00	4.00
56/ 8/21	0	0.70	74.00	67.00	30.00	4.00
56/ 9/ 1	0	0.50	76.00	62.00	30.00	6.00
56/ 9/11	0	0.20	78.00	62.00	30.00	7.00
56/ 9/21	0	0.20	78.00	62.00	30.00	7.00

SIMULATION RESULTS FOR DAY 212, HOUR 24

METEOROLOGICAL DATA

SHORTWAVE SOLAR RAD, KCAL/M2/SEC	0.0632
LONGWAVE ATMOS RAD, KCAL/M2/SEC	0.0844
WIND SPEED, METERS/SEC	3.1
DRY BULB TEMPERATURE, C	23.9
WET BULB TEMPERATURE, C	14.4
EVAPORATION RATE, METERS/MONTH	0.226
ACCUMULATIVE EVAPORATION, METERS	0.388

GENERAL INFORMATION

WATER SURFACE ELEV, METERS	40.6
SURFACE AREA, MIL M2	17.536
TOTAL VOLUME, MIL M3	161.7
MIN ELEMENT RESIDENT TIME, DAYS	0.09
LAKE RESIDENT TIME, DAYS	165.3
ALGAL PRODUCTION RATE, G/M2/DAY	-0.054
SUSPENDED INORGANIC SOLIDS, KG	25788.
SETTLED INORGANIC SOLIDS, KG	0.

INFLOW AND OUTFLOW QUALITIES

	FLOW CMS	TEMP C	OXYGEN MG/L	BOD MG/L	COLIFORMS MPN/100ML	INORGANIC SUSPENDED SOLIDS NO 1 MG/L	NO 2 MG/L	NO 3 MG/L	NO 4 MG/L	NO 5 MG/L	DETRITUS MG/L
TRIB 1	2.83	21.1	8.1	0.5	0.000E+01	9.0	0.0	0.0	0.0	0.0	5.0
OUTFLOW	11.33	12.6	5.7	0.0	0.000E+01	0.3	0.0	0.0	0.0	0.0	0.4

	TDS MG/L	ALKALINITY MG/L-CACO3	PH UNITS	TIC MG/L	NH3-N MG/L	NO3-N MG/L	NO2-N MG/L	PO4-P MG/L	ALGAE 1 MG/L	ALGAE 2 MG/L	ZOOPLANKTON MG/L
TRIB 1	300.	40.	7.4	10.4	0.008	0.020	0.000	0.005	0.000	0.000	0.000
OUTFLOW	301.	47.	7.2	13.3	0.035	0.100	0.013	0.017	0.149	0.044	0.006

OUTFLOW DISTRIBUTION FROM TOP TO BOTTOM (SELECTIVE WITHDRAWAL, TEMPERATURE OBJECTIVE = 12.8 C)

GATE	1	2	3	4	5	6	7
FLOW, CMS	0.00	0.00	0.00	5.43	5.90	0.00	0.00

FISH STATUS

	DENSITY KG/HA	TOTAL BIOMASS KG	GROWTH RATE KG/HA/MO	HARVEST RATE KG/HA/MO
FISH 1	8.12	16246.7	-1.17	0.81
FISH 2	9.12	18245.5	-1.03	0.91
FISH 3	10.10	20203.0	-0.09	0.00

RESERVOIR QUALITY

ELEM	GATE	DEPTH M	TEMP C	OXYGEN MG/L	BOD MG/L	COLIFORMS MPN/100	INORGANIC SUSPENDED SOLIDS NO 1 MG/L	NO 2 MG/L	NO 3 MG/L	NO 4 MG/L	NO 5 MG/L	DETRITUS MG/L	LIGHT EXT 1/M	SHORT WAVE KCAL/M2/SEC	SEDIMENTS INORG G/M2	ORG G/M2
27		0.8	23.1	8.7	0.0	0.00E+01	0.00	0.00	0.00	0.00	0.00	0.01	0.95	0.119E-01	0.	55.
26	6	2.3	23.1	8.7	0.0	0.00E+01	0.00	0.00	0.00	0.00	0.00	0.01	0.95	0.282E-02	0.	66.
25		3.8	23.1	8.7	0.0	0.00E+01	0.00	0.00	0.00	0.00	0.00	0.01	0.95	0.663E-03	0.	74.
24		5.3	21.7	7.9	0.0	0.00E+01	0.02	0.00	0.00	0.00	0.00	0.06	0.96	0.154E-03	0.	80.
23		6.9	19.8	7.2	0.0	0.00E+01	0.24	0.00	0.00	0.00	0.00	0.27	0.99	0.338E-04	0.	82.
22		8.4	17.8	6.7	0.0	0.00E+01	0.25	0.00	0.00	0.00	0.00	0.26	0.99	0.744E-05	0.	85.
21	5	9.9	15.4	6.2	0.0	0.00E+01	0.25	0.00	0.00	0.00	0.00	0.26	0.99	0.164E-05	0.	88.
20		11.4	12.9	5.8	0.0	0.00E+01	0.24	0.00	0.00	0.00	0.00	0.27	0.99	0.361E-06	0.	91.
19		13.0	11.1	5.4	0.0	0.00E+01	0.23	0.00	0.00	0.00	0.00	0.32	0.00	0.000E+01	0.	94.
18		14.5	10.0	5.3	0.0	0.00E+01	0.23	0.00	0.00	0.00	0.00	0.40	0.00	0.000E+01	0.	97.
17		16.0	9.4	5.2	0.0	0.00E+01	0.25	0.00	0.00	0.00	0.00	0.49	0.00	0.000E+01	0.	99.
16	4	17.5	9.1	5.1	0.0	0.00E+01	0.28	0.00	0.00	0.00	0.00	0.58	0.00	0.000E+01	0.	101.
15		19.0	8.8	5.0	0.0	0.00E+01	0.32	0.00	0.00	0.00	0.00	0.67	0.00	0.000E+01	0.	104.
14		20.6	8.6	4.9	0.0	0.00E+01	0.37	0.00	0.00	0.00	0.00	0.76	0.00	0.000E+01	0.	106.
13		22.1	8.5	4.9	0.0	0.00E+01	0.43	0.00	0.00	0.00	0.00	0.84	0.00	0.000E+01	0.	108.
12		23.6	8.4	4.8	0.0	0.00E+01	0.48	0.00	0.00	0.00	0.00	0.90	0.00	0.000E+01	0.	109.
11	3	25.1	8.3	4.8	0.0	0.00E+01	0.52	0.00	0.00	0.00	0.00	0.94	0.00	0.000E+01	0.	111.
10		26.7	8.3	4.8	0.0	0.00E+01	0.56	0.00	0.00	0.00	0.00	0.98	0.00	0.000E+01	0.	113.
9		28.2	8.2	4.7	0.0	0.00E+01	0.60	0.00	0.00	0.00	0.00	1.01	0.00	0.000E+01	0.	115.
8		29.7	8.1	4.7	0.0	0.00E+01	0.65	0.00	0.00	0.00	0.00	1.06	0.00	0.000E+01	0.	117.
7		31.2	8.0	4.6	0.0	0.00E+01	0.70	0.00	0.00	0.00	0.00	1.09	0.00	0.000E+01	0.	118.
6	2	32.8	7.8	4.5	0.0	0.00E+01	0.78	0.00	0.00	0.00	0.00	1.15	0.00	0.000E+01	0.	118.
5		34.3	7.6	4.4	0.0	0.00E+01	0.85	0.00	0.00	0.00	0.00	1.18	0.00	0.000E+01	0.	119.
4		35.8	7.6	4.3	0.0	0.00E+01	0.90	0.00	0.00	0.00	0.00	1.21	0.00	0.000E+01	0.	121.
3		37.3	7.5	4.2	0.0	0.00E+01	0.94	0.00	0.00	0.00	0.00	1.22	0.00	0.000E+01	0.	123.
2	1	38.9	7.5	4.2	0.0	0.00E+01	0.98	0.00	0.00	0.00	0.00	1.24	0.00	0.000E+01	0.	124.
1		40.4	7.4	4.1	0.0	0.00E+01	1.00	0.00	0.00	0.00	0.00	1.24	0.00	0.000E+01	0.	129.

1/85

RESERVOIR QUALITY, CONTINUED

ELEMENT	DEPTH M	TDS MG/L	ALKA MG/L	PH UNITS	CO2-C MG/L	TIC MG/L	NH3-N MG/L	NO3-N MG/L	NO2-N MG/L	PO4-P MG/L	ALGAE 1 MG/L	ALGAE 2 MG/L	ZOOPLANKTON MG/L	BENTHIC ANIMALS MG/M2
27	0.8	333.	51.	8.1	0.214	12.4	0.018	0.028	0.007	0.007	0.153	0.066	0.023	0.
26	2.3	333.	51.	8.1	0.212	12.4	0.018	0.028	0.007	0.007	0.153	0.066	0.023	0.
25	3.8	333.	51.	8.1	0.214	12.4	0.018	0.028	0.007	0.007	0.153	0.066	0.023	0.
24	5.3	317.	47.	7.6	0.621	12.0	0.020	0.035	0.008	0.009	0.167	0.065	0.016	0.
23	6.9	308.	45.	7.4	1.007	11.8	0.023	0.048	0.009	0.011	0.145	0.058	0.011	0.
22	8.4	304.	45.	7.3	1.305	12.1	0.027	0.064	0.011	0.014	0.139	0.055	0.009	0.
21	9.9	302.	46.	7.2	1.623	12.6	0.031	0.082	0.012	0.016	0.139	0.050	0.008	0.
20	11.4	301.	47.	7.2	1.920	13.2	0.035	0.099	0.013	0.017	0.144	0.045	0.007	0.
19	13.0	300.	48.	7.2	2.142	13.7	0.037	0.111	0.014	0.018	0.152	0.041	0.006	0.
18	14.5	300.	49.	7.2	2.270	13.9	0.039	0.118	0.014	0.019	0.158	0.038	0.005	0.
17	16.0	300.	49.	7.2	2.319	14.1	0.040	0.121	0.015	0.019	0.160	0.037	0.004	0.
16	17.5	300.	49.	7.2	2.381	14.2	0.041	0.123	0.015	0.019	0.161	0.036	0.004	0.
15	19.0	300.	50.	7.2	2.391	14.3	0.042	0.124	0.015	0.020	0.159	0.035	0.003	0.
14	20.6	300.	50.	7.1	2.447	14.3	0.043	0.125	0.015	0.020	0.156	0.034	0.002	0.
13	22.1	300.	50.	7.1	2.453	14.4	0.044	0.125	0.015	0.020	0.153	0.034	0.002	0.
12	23.6	300.	50.	7.2	2.461	14.4	0.045	0.126	0.015	0.020	0.150	0.034	0.001	0.
11	25.1	300.	50.	7.2	2.465	14.4	0.046	0.126	0.015	0.020	0.148	0.033	0.001	0.
10	26.7	300.	50.	7.1	2.515	14.4	0.047	0.126	0.016	0.020	0.145	0.033	0.001	0.
9	28.2	300.	50.	7.1	2.518	14.4	0.048	0.126	0.016	0.021	0.143	0.033	0.001	0.
8	29.7	300.	50.	7.1	2.522	14.5	0.049	0.127	0.016	0.021	0.138	0.033	0.000	0.
7	31.2	300.	50.	7.1	2.526	14.5	0.050	0.127	0.016	0.021	0.132	0.032	0.000	0.
6	32.8	300.	50.	7.1	2.580	14.5	0.050	0.128	0.017	0.021	0.120	0.032	0.000	0.
5	34.3	300.	50.	7.1	2.584	14.5	0.051	0.129	0.017	0.021	0.112	0.032	0.000	0.
4	35.8	300.	50.	7.1	2.587	14.6	0.052	0.129	0.017	0.022	0.106	0.031	0.000	0.
3	37.3	300.	50.	7.1	2.589	14.6	0.053	0.129	0.017	0.022	0.102	0.031	0.000	0.
2	38.9	300.	50.	7.1	2.641	14.6	0.055	0.129	0.017	0.022	0.098	0.031	0.000	0.
1	40.4	300.	50.	7.1	2.644	14.6	0.057	0.129	0.018	0.022	0.096	0.031	0.000	0.

SIMULATION RESULTS FOR DAY 257, HOUR 24

METEOROLOGICAL DATA

SHORTWAVE SOLAR RAD, KCAL/M2/SEC	0.0407
LONGWAVE ATMOS RAD, KCAL/M2/SEC	0.0877
WIND SPEED, METERS/SEC	3.1
DRY BULB TEMPERATURE, C	25.6
WET BULB TEMPERATURE, C	16.7
EVAPORATION RATE, METERS/MONTH	0.192
ACCUMULATIVE EVAPORATION, METERS	0.580

GENERAL INFORMATION

WATER SURFACE ELEV, METERS	39.9
SURFACE AREA, MIL M2	13.759
TOTAL VOLUME, MIL M3	150.1
MIN ELEMENT RESIDENT TIME, DAYS	0.17
LAKE RESIDENT TIME, DAYS	204.5
ALGAL PRODUCTION RATE, G/M2/DAY	0.001
SUSPENDED INORGANIC SOLIDS, KG	34630.
SETTLED INORGANIC SOLIDS, KG	0.

INFLOW AND OUTFLOW QUALITIES

	FLOW CMS	TEMP C	OXYGEN MG/L	BOD MG/L	COLIFORMS MPN/100ML	INORGANIC SUSPENDED SOLIDS NO 1 MG/L	NO 2 MG/L	NO 3 MG/L	NO 4 MG/L	NO 5 MG/L	DETRITUS MG/L
TRIB 1	5.66	22.8	7.8	0.5	0.000E+01	9.0	0.0	0.0	0.0	0.0	5.0
OUTFLOW	8.50	12.7	4.4	0.0	0.000E+01	0.4	0.0	0.0	0.0	0.0	0.4

	TDS MG/L	ALKALINITY MG/L-CACO3	PH UNITS	TIC MG/L	NH3-N MG/L	NO3-N MG/L	NO2-N MG/L	PO4-P MG/L	ALGAE 1 MG/L	ALGAE 2 MG/L	ZOOPLANKTON MG/L
TRIB 1	300.	40.	7.4	10.4	0.008	0.020	0.000	0.005	0.000	0.000	0.000
OUTFLOW	302.	48.	7.1	13.6	0.039	0.146	0.015	0.025	0.060	0.021	0.001

OUTFLOW DISTRIBUTION FROM TOP TO BOTTOM (SELECTIVE WITHDRAWAL, TEMPERATURE OBJECTIVE = 12.8 C)

GATE	1	2	3	4	5	6	7
FLOW, CMS	0.00	0.00	2.27	6.22	0.00	0.00	0.00

FISH STATUS

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	DENSITY KG/HA	TOTAL BIOMASS KG	GROWTH RATE KG/HA/MO	HARVEST RATE KG/HA/MO
FISH 1	6.45	12901.2	-1.02	0.65
FISH 2	7.16	14326.5	-1.17	1.07
FISH 3	9.95	19906.3	-0.10	0.00

RESERVOIR QUALITY

ELEM	GATE	DEPTH M	TEMP C	OXYGEN MG/L	BOD MG/L	COLIFORMS MPN/100	INORGANIC SUSPENDED SOLIDS NO 1 MG/L	NO 2 MG/L	NO 3 MG/L	NO 4 MG/L	NO 5 MG/L	DETRITUS MG/L	LIGHT EXT i/M	SHORT WAVE KCAL/M2/SEC	SEDIMENTS INORG G/M2	ORG G/M2
26	6	0.8	23.0	8.4	0.0	0.00E+01	0.01	0.00	0.00	0.00	0.00	0.02	0.96	0.760E-02	0.	62.
25		2.3	23.0	8.4	0.0	0.00E+01	0.01	0.00	0.00	0.00	0.00	0.02	0.96	0.176E-02	0.	70.
24		3.8	23.0	8.4	0.0	0.00E+01	0.01	0.00	0.00	0.00	0.00	0.02	0.96	0.409E-03	0.	76.
23		5.3	23.1	8.3	0.0	0.00E+01	0.02	0.00	0.00	0.00	0.00	0.02	0.96	0.949E-04	0.	79.
22		6.9	22.0	6.9	0.1	0.00E+01	0.45	0.00	0.00	0.00	0.00	0.45	1.03	0.198E-04	0.	85.
21	5	8.4	20.9	6.2	0.0	0.00E+01	0.46	0.00	0.00	0.00	0.00	0.44	1.02	0.420E-05	0.	91.
20		9.9	19.6	5.8	0.0	0.00E+01	0.46	0.00	0.00	0.00	0.00	0.42	1.01	0.897E-06	0.	95.
19		11.4	18.3	5.4	0.0	0.00E+01	0.46	0.00	0.00	0.00	0.00	0.40	0.00	0.000E+01	0.	98.
18		13.0	16.8	5.1	0.0	0.00E+01	0.45	0.00	0.00	0.00	0.00	0.40	0.00	0.000E+01	0.	102.
17		14.5	15.3	4.9	0.0	0.00E+01	0.44	0.00	0.00	0.00	0.00	0.40	0.00	0.000E+01	0.	105.
16	4	16.0	13.5	4.6	0.0	0.00E+01	0.44	0.00	0.00	0.00	0.00	0.40	0.00	0.000E+01	0.	107.
15		17.5	11.9	4.3	0.0	0.00E+01	0.44	0.00	0.00	0.00	0.00	0.41	0.00	0.000E+01	0.	110.
14		19.0	10.6	4.1	0.0	0.00E+01	0.44	0.00	0.00	0.00	0.00	0.40	0.00	0.000E+01	0.	113.
13		20.6	9.9	3.9	0.0	0.00E+01	0.45	0.00	0.00	0.00	0.00	0.39	0.00	0.000E+01	0.	116.
12		22.1	9.6	3.8	0.0	0.00E+01	0.46	0.00	0.00	0.00	0.00	0.37	0.00	0.000E+01	0.	118.
11	3	23.6	9.4	3.7	0.0	0.00E+01	0.46	0.00	0.00	0.00	0.00	0.36	0.00	0.000E+01	0.	120.
10		25.1	9.3	3.7	0.0	0.00E+01	0.46	0.00	0.00	0.00	0.00	0.35	0.00	0.000E+01	0.	123.
9		26.7	9.2	3.6	0.0	0.00E+01	0.45	0.00	0.00	0.00	0.00	0.34	0.00	0.000E+01	0.	125.
8		28.2	9.0	3.5	0.0	0.00E+01	0.44	0.00	0.00	0.00	0.00	0.33	0.00	0.000E+01	0.	127.
7		29.7	8.9	3.5	0.0	0.00E+01	0.43	0.00	0.00	0.00	0.00	0.33	0.00	0.000E+01	0.	129.
6	2	31.2	8.7	3.4	0.0	0.00E+01	0.40	0.00	0.00	0.00	0.00	0.33	0.00	0.000E+01	0.	128.
5		32.8	8.5	3.3	0.0	0.00E+01	0.38	0.00	0.00	0.00	0.00	0.34	0.00	0.000E+01	0.	130.
4		34.3	8.5	3.2	0.0	0.00E+01	0.36	0.00	0.00	0.00	0.00	0.35	0.00	0.000E+01	0.	132.
3		35.8	8.4	3.2	0.0	0.00E+01	0.35	0.00	0.00	0.00	0.00	0.36	0.00	0.000E+01	0.	135.
2	1	37.3	8.4	3.1	0.0	0.00E+01	0.34	0.00	0.00	0.00	0.00	0.37	0.00	0.000E+01	0.	137.
1		38.9	8.4	3.1	0.0	0.00E+01	0.33	0.00	0.00	0.00	0.00	0.37	0.00	0.000E+01	0.	144.

RESERVOIR QUALITY, CONTINUED

ELEMENT	DEPTH M	TDS MG/L	ALKA MG/L	PH UNITS	CO2-C MG/L	TIC MG/L	NH3-N MG/L	NO3-N MG/L	NO2-N MG/L	PO4-P MG/L	ALGAE 1 MG/L	ALGAE 2 MG/L	ZOOPLANKTON MG/L	BENTHIC ANIMALS MG/M2
26	0.8	341.	52.	8.1	0.210	12.6	0.018	0.032	0.007	0.008	0.218	0.051	0.020	0.
25	2.3	341.	52.	8.1	0.212	12.6	0.018	0.032	0.007	0.008	0.218	0.051	0.020	0.
24	3.8	341.	52.	8.1	0.214	12.6	0.018	0.032	0.007	0.008	0.218	0.051	0.020	0.
23	5.3	340.	52.	8.1	0.227	12.6	0.018	0.033	0.007	0.008	0.217	0.050	0.020	0.
22	6.9	317.	46.	7.5	0.846	11.9	0.023	0.062	0.008	0.013	0.140	0.034	0.009	0.
21	8.4	312.	46.	7.3	1.119	12.0	0.026	0.082	0.010	0.017	0.108	0.030	0.007	0.
20	9.9	309.	45.	7.3	1.307	12.2	0.029	0.096	0.011	0.019	0.087	0.028	0.005	0.
19	11.4	307.	46.	7.2	1.504	12.4	0.031	0.109	0.012	0.021	0.074	0.026	0.004	0.
18	13.0	305.	46.	7.2	1.702	12.7	0.031	0.121	0.012	0.022	0.066	0.024	0.003	0.
17	14.5	304.	47.	7.2	1.859	13.0	0.033	0.132	0.013	0.023	0.061	0.023	0.002	0.
16	16.0	303.	47.	7.1	2.091	13.4	0.036	0.143	0.014	0.024	0.058	0.022	0.001	0.
15	17.5	302.	48.	7.1	2.296	13.8	0.040	0.151	0.016	0.025	0.058	0.020	0.001	0.
14	19.0	301.	49.	7.1	2.450	14.1	0.042	0.158	0.017	0.026	0.059	0.019	0.000	0.
13	20.6	300.	49.	7.1	2.531	14.2	0.044	0.161	0.018	0.027	0.061	0.018	0.000	0.
12	22.1	300.	49.	7.1	2.596	14.3	0.047	0.162	0.018	0.027	0.063	0.017	0.000	0.
11	23.6	300.	49.	7.1	2.606	14.4	0.049	0.163	0.019	0.027	0.065	0.017	0.000	0.
10	25.1	300.	49.	7.1	2.667	14.4	0.051	0.164	0.019	0.028	0.066	0.016	0.000	0.
9	26.7	300.	49.	7.1	2.674	14.5	0.053	0.165	0.019	0.028	0.067	0.016	0.000	0.
8	28.2	300.	49.	7.1	2.682	14.5	0.054	0.166	0.020	0.029	0.068	0.016	0.000	0.
7	29.7	300.	49.	7.1	2.740	14.6	0.056	0.166	0.020	0.029	0.069	0.015	0.000	0.
6	31.2	300.	50.	7.1	2.751	14.6	0.057	0.168	0.021	0.029	0.070	0.015	0.000	0.
5	32.8	300.	50.	7.1	2.758	14.7	0.058	0.169	0.022	0.030	0.071	0.015	0.000	0.
4	34.3	300.	50.	7.1	2.815	14.7	0.060	0.169	0.022	0.030	0.072	0.014	0.000	0.
3	35.8	300.	50.	7.1	2.819	14.7	0.061	0.170	0.022	0.030	0.072	0.014	0.000	0.
2	37.3	300.	50.	7.1	2.823	14.7	0.063	0.170	0.023	0.030	0.072	0.014	0.000	0.
1	38.9	300.	50.	7.1	2.826	14.7	0.065	0.170	0.023	0.031	0.073	0.014	0.000	0.

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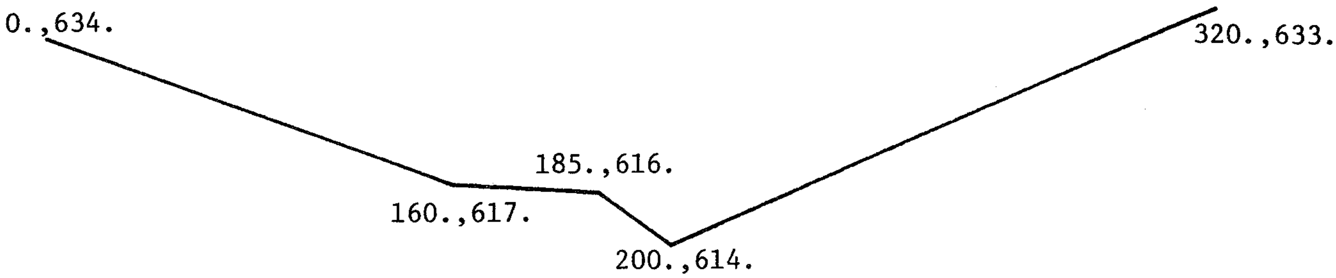
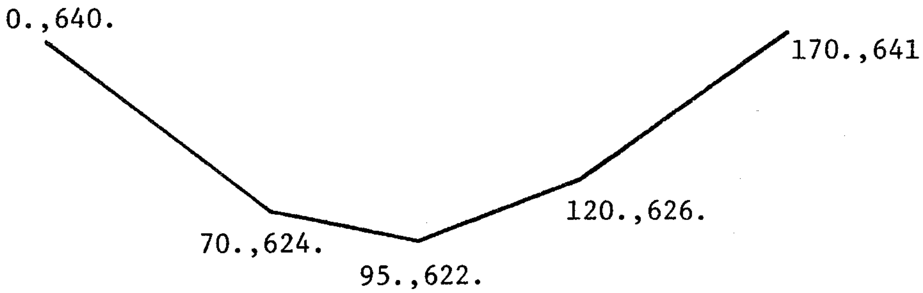
TABLE IX-7

Miscellaneous Physical Data for STREAM System

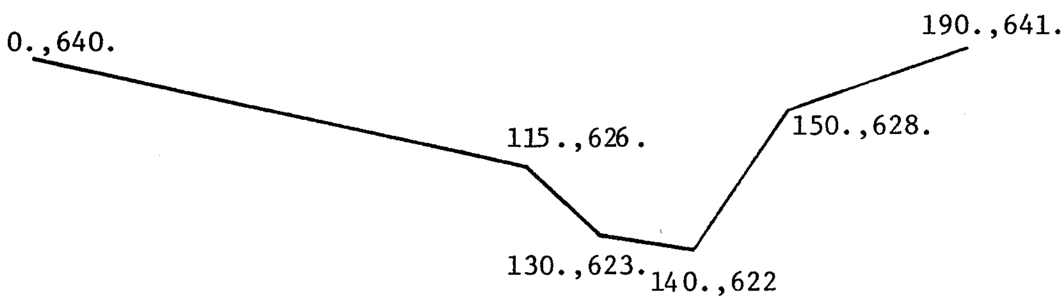
Meteorological	
Evaporation Coefficient "A"	0
Evaporation Coefficient "B"	1.5×10^{-9}
Latitude in degrees north	41
Longitude in degrees west	121
Atmospheric turbidity	3
Stream	
Location of dam in river miles	366
Location of Elk City water supply withdrawal in river miles	362
Location of Elk City sewage treatment plant in river miles	360.4
Location of Sutter Creek inflow in river miles	348
Location of Station 3 in river miles	340
Location of Station 2 in river miles	108
Downstream end of Sutter Creek in river miles	100
Element length in miles	1
Reaeration applied to reservoir release	.33



California River - RM 340



California River - RM 348



Sutter Creek - RM 100

FIGURE IX-5

Typical Cross Sections for the
California River and Sutter Creek

TABLE IX-8

Initial Stream Conditions

Initial Fish

River Mile Limits	Fish Densities in Kg/Km Type 1	Type 2	Type 3
360 to 366	30	5	10
348 to 360	20	10	10
100 to 108	5	10	10
340 to 348	10	20	10

Quality Conditions

Constituents		Constituents	
Temperature in °F	68	Benthic animals in mg/m^2	200
DO in mg/l	9	Phytoplankton 1 in mg/l	.1
Carbonaceous BOD in mg/l	1	Phytoplankton 2 in mg/l	.1
Coliform in MPN/100 ml	2	Zooplankton in mg/l	.001
Sediment in mg/m^2	10000	pH	7.5
Detritus in mg/l	4	Alkalinity in mg/l	50
NH_3 in mg/l as N	.05	Suspended solids in mg/l	5
NO_3 in mg/l as N	.20	Aquatic Insects in mg/m^2	400
NO_2 in mg/l as N	.01	Benthic Algae 1 in mg/m^2	500
PO_4 in mg/l as P	.02	Benthic Algae 2 in mg/m^2	1000
TDS in mg/l	500		

Physical Conditions

Parameters	Reach Number 1	2	3
Bottom condition in $kcal/m^2/sec/C$	.001	.001	.001
Bottom thermal capacity in feet	2	2	2
Secchi disk in feet	3	3	3

TABLE IX-9

Inflow Rate and Quality

Constituent	Elk City STP	Sutter Creek
Inflow Q in cfs	18	80
Inflow Temperature in °F	78	*
DO	6 mg/1	95% saturation
BOD in mg/1	8	2
Coliform in MPN/100 ml	500	100
Detritus in mg/1	5	1
NH_3 in mg/1	.5	.02
NO_3 in mg/1	.5	.20
NO_2 in mg/1	0	0
PO_4 in mg/1	.25	.03
TDS in mg/1	1500	500
Phytoplankton 1 in mg/1	0	0
Phytoplankton 2 in mg/1	0	0
Zooplankton in mg/1	0	0
pH	7	7.6
Alkalinity in mg/1	100	60
Suspended Solids in mg/1	20	2

* Sutter Creek Temperature in °F

Date	Time of Day (Hour)					
	0	4	8	12	16	20
Sept 13	66	65	68	71	70	68
Sept 14	65	64	67	71	70	67
Sept 15	66	64	67	70	69	68
Sept 16	66	65	68	71	70	68

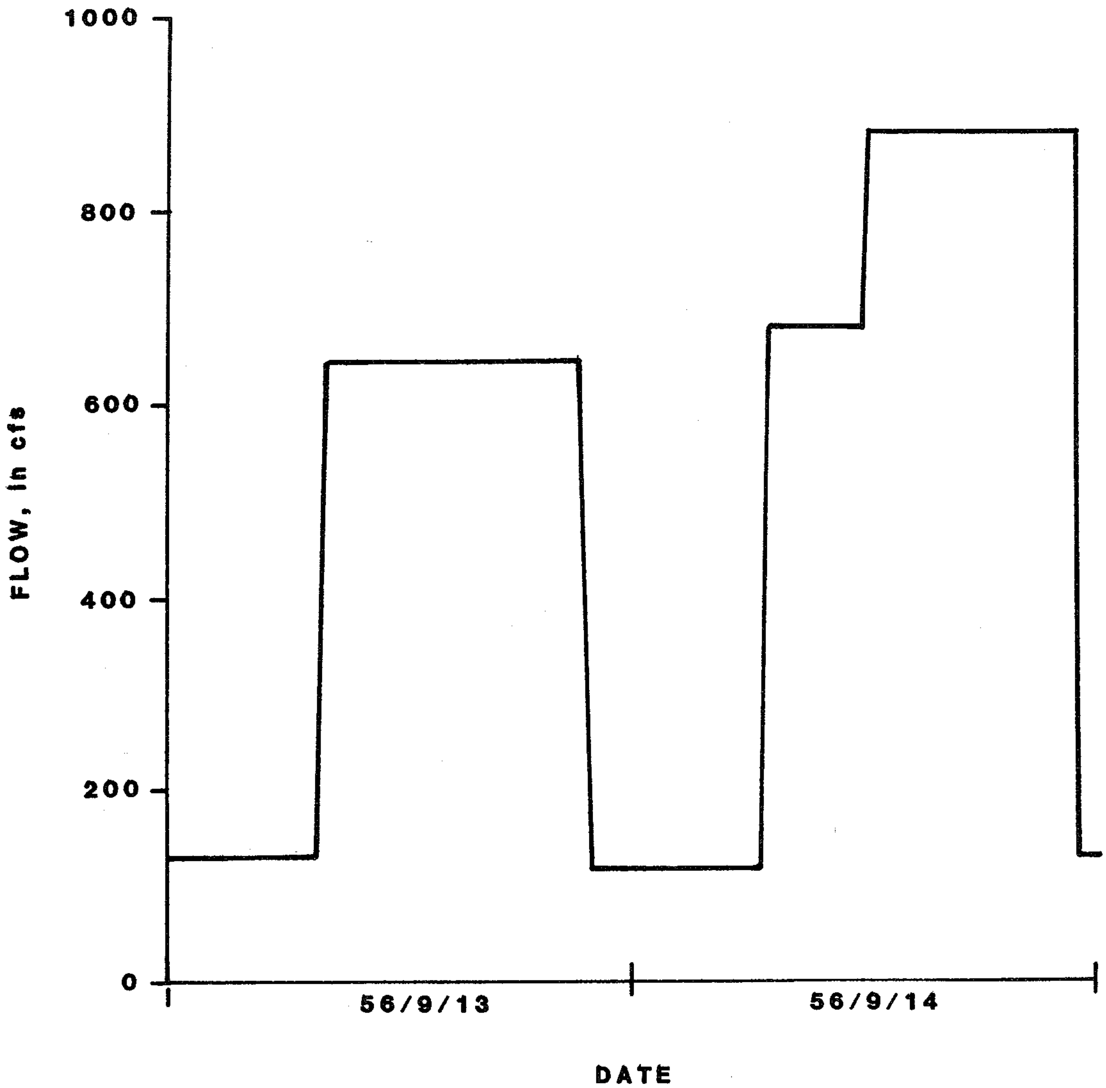


FIGURE IX-6

Reservoir Outflow Hydrograph

TABLE IX-10

Meteorological Condition

Sept 13, 1956 through Sept 16, 1956

	Time in hours					
	0	4	8	12	16	20
Cloudiness	.3	.3	.2	.1	.1	.2
Dry Bulb Temperature in °F	70	66	78	92	88	74
Wet Bulb Temperature in °F	61	60	62	63	64	62
Barometric Pressure in inches of Hg	30	30	30	30	30	30
Wind speed in mph	3	3	6	6	9	9

FIGURE IX-7

STREAM HYDRAULICS MODULE INPUT DATA

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TITLE     EXAMPLE PROBLEM 1 - MUSKINGUM ROUTING
TITLE     FICTITIOUS CALIFORNIA RIVER SYSTEM
TITLE     CALIFORNIA RIVER BELOW SMITH RESERVOIR INCLUDING SUTTER CREEK
JOB1      560913  560914       3       0       1       0       1       0       0
JOB2           5       3       1       7      20       1       0       1       0
JOB3           4       1       0       0       0       0
JOB4           0      -1       0       0       1       0
JOB5           1       5       5       5       0       0       0
TRIB           1     366
TRIB           1   360.4
TRIB           2     108
TRIB           1     362
INHY1     560913  560916
INHY2          0 RESERVOIR RELEASES
INHY4    9130000 130.    9130730 130.    9130800 640.    9132130 640.         56
INHY4    9132200 120.    9140630 120.    9140700 680.    9141400 680.         56
INHY4    9141415 880.    9142300 880.    9142315 130.         -1              56
INHY2          0 ELK CITY STP
INHY4    9130000 18.          -1
INHY2          0 SUTTER CREEK HEADWATER
INHY4    9130000 120.         -1
INHY2          0 ELK CITY WATER SUPPLY
INHY4    9130000 22.          -1
GEOM1         18      -2
GEOM2          8      .5      14      1.
GEOM1          8       1
GEOM1          8       1
GEOM3          1       0      -3       0       2      -1
CCC1           3     340       0       2       4       8      20      35      60
CC2           90     130     225     380     580     820    1100    1400    1725
CC2         2100    2530    3000    3550
CCC1           3     344      -1
CCC1           3     348      -1
CCC1           1     348      -1
CCC1           1     366      -1
CCC1           2     100      -1
CCC1           2     108      -1
JP     340 .00019                                  0               0
ET     614  614.5     615   615.5     616   616.5     617   617.5     618     619
ET     620    621     622     623     624     625     626     627     628     629
NC     .04    .04    .035
X1     340      5       0     320       0       0       0       0       0
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GR    634        0     617     160     616     185     614     200     633     320
X1    344        0       0       0   21120   21120   21120       0       4
X1    348        5       0     170   21120   21120   21120       0       0
GR    640        0     624      70     622      95     626     120     641     170
X1    348        0       0       0       1       1       1       0       0
SC    348  .000284
X1    366        0       0       0   95040   95040   95040       0      27
SC    366-.000284
X1    100        6       0     190   95041   95041   95041       0       0
KL    100      115     150
GR    640        0     626     115     623     130     622     140     628     150
GR    641      190
SC    100  .000380
X1    108        0       0       0   42240   42240   42240       0      16
EJ
GEOM6          649     656
GEOM6          622     626
GEOM6          638     643
GEOM6          622     626
GEOM6          622     626
GEOM6          618     623
GEOM6          614     618
BOUND            1       1       1       2      -3       3                       1
MR               4       1     348      15     .25
MR               2       2     100       8     .25
MR              -2       3     340      10     .25
END1           999
TITLE
TITLE
TITLE
JOB1
```

```
****************************************************
*  STREAM HYDRAULICS PACKAGE                        *
*  NOVEMBER 1979 UPDATED JANUARY 1982               *
*  ERROR - 01,02                                    *
*                                                   *
*  RUN DATE 15 JAN 85  TIME  12:03:20               *
****************************************************
```

```
**************************************
*  U.S. ARMY CORPS OF ENGINEERS      *
*  THE HYDROLOGIC ENGINEERING CENTER *
*  609 SECOND STREET, SUITE D        *
*  DAVIS, CALIFORNIA 95616           *
*  (916) 440-2105 (FTS) 448-2105     *
**************************************
```

```
 XXXXX  X     X  XXXXXX
X     X X     X  X     X
X       X     X  X     X
 XXXXX  XXXXXXX  XXXXXX
      X X     X  X
X     X X     X  X
 XXXXX  X     X  X
```

FIGURE IX-8

STREAM HYDRAULICS MODULE OUTPUT

```
EXAMPLE PROBLEM 1 - MUSKINGUM ROUTING
FICTITIOUS CALIFORNIA RIVER SYSTEM
CALIFORNIA RIVER BELOW SMITH RESERVOIR INCLUDING SUTTER CREEK

DAYS OF SIMULATION                                       2
FIRST DAY OF SIMULATION                                257 (56/ 9/13 )
FINAL DAY OF SIMULATION                                258 (56/ 9/14 )
NUMBER OF INFLOWS                                        3
NUMBER OF STORM INFLOWS                                  0
NUMBER OF WITHDRAWALS                                    1
DAM BREAK HYDROGRAPH (YES=1/NO=0)                        0
INPUT UNITS SELECTOR (ENGLISH=1/METRIC=0)                1
NON-POINT INFLOWS AND WITHDRAWALS (NO=0/YES=1)           0
PLOT CONTROL (NO=0/PREVIOUS=-1/CURRENT=1)                0
FLOW ROUTING METHOD                                      5
     1 = STAGE FLOW
     2 = BACKWATER
     3 = KINEMATIC WAVE
     4 = ST. VENANT
     5 = MUSKINGUM
     6 = MODIFIED PULS
NUMBER OF RIVER REACHES                                  3
NUMBER OF REACH INTERSECTIONS                            1
NUMBER OF CROSS SECTIONS                                 7
NUMBER OF POINTS DEFINING CROSS SECTIONS                20
X-SECTION WIDTH ADJUSTMENT RATIO                      1.00
CALIBRATION OPTION (CALIBRATE COEFF=1)                   0
NORMAL PRINT INTERVAL,DAYS                               1
COMPUTATIONAL TIME STEP, HOURS                         4.0
OUTPUT FREQUENCY, HOURS                                1.0
UNIFORM INITIAL CONDITIONS (YES=1/NO=0)                  0
READ DOWNSTREAM HEAD CARD (YES=1/NO=0)                   0
PRINT DIAGNOSTIC MESSAGES (YES=1/NO=0)                   0
X-SECTION PRINTOUT (NONE=-1/GEOM4=0/GEDA+GEOM4=1)        0

TAPE OR FILE ASSIGNMENTS

DOWNSTREAM HYDROGRAPH OUTPUT                             0
UPSTREAM HYDROGRAPH NO. 1 INPUT                        -11
UPSTREAM HYDROGRAPH NO. 2 INPUT                          0
```

```
UPSTREAM HYDROGRAPH NO. 3 INPUT                        0
HYDRAULIC OUTPUT FOR QUALITY SIMULATION               14
INITIAL CONDITIONS FOR ST VENANT (READ=-/WRITE=+)      0
PROCESSED HYDROGRAPHS (SCRATCH=+/PERMANENT=-)         16
RAW INFLOW DATA                                        5
CHANNEL GEOMETRY DATA                                  5
RAW STORM INFLOW DATA                                  5
PROCESSED STORM INFLOW DATA                            0
SIMULATION RESULTS FOR CALIBRATION                     0

TRIBUTARY INFLOW AND WITHDRAWAL LOCATIONS

                    REACH NO.    RIVER MILE

INFLO NO.  1            1         366.00
INFLO NO.  2            1         360.40
INFLO NO.  3            2         108.00
WITHDRAWAL NO.  1       1         362.00


FIRST DAY OF INFLOW RECORD     56/ 9/13
FINAL DAY OF INFLOW RECORD     56/ 9/16
TOTAL NUMBER OF DAYS                  4

CREATE PSEUDO INTERFACE UNIT NO. 11 FROM CARD INPUT
     3 CARDS READ FOR  RESERVOIR RELEASES
TIME ( MONTH/DAY/HOUR ) VS. INFLOW OR WITHDRAWAL RATE ( CFS OR CMS )
     TIME      FLOW       TIME      FLOW       TIME      FLOW       TIME      FLOW       TIME      FLOW       TIME      FLOW

   9/12/24    130.0     9/13/ 7    130.0     9/13/ 8    640.0     9/13/21    640.0     9/13/22    120.0     9/14/ 6    120.0
   9/14/ 7    680.0     9/14/14    680.0     9/14/14    880.0     9/14/23    880.0     9/14/23    130.0
     1 CARDS READ FOR  ELK CITY STP
     1 CARDS READ FOR  SUTTER CREEK HEADWATER
     1 CARDS READ FOR  ELK CITY WATER SUPPLY
TIME ( MONTH/DAY/HOUR ) VS. INFLOW OR WITHDRAWAL RATE ( CFS OR CMS )
     TIME      FLOW       TIME      FLOW       TIME      FLOW       TIME      FLOW       TIME      FLOW       TIME      FLOW

   9/12/24     18.0

   9/12/24    120.0

   9/12/24     22.0
```

REACH	NUMBER OF ELEMENTS	ELEMENT LENGTH MILES OR KM
1	8	0.50
	14	1.00
2	8	1.00
3	8	1.00

REACH INTERSECTION DEFINITION
INTERSECTION NO. 1

REACH NO. 1 IS UPSTREAM OF INTERSECTION
REACH NO. 3 IS DOWNSTREAM OF INTERSECTION, SHARE OF TOTAL FLOW IS 0.000
REACH NO. 2 IS UPSTREAM OF INTERSECTION

CROSS SECTION DATA

REACH	RIVER MILE	ELEVATION FT	AREA FT2	R**2/3	WIDTH FT	MANNINGS N	ELEV VS. FLOW CFS	VELOCITY FPS
1	366.00	649.0	0.0	0.04	0.3	0.0350	0.0	0.03
		649.5	2.5	0.40	9.7	0.0350	0.8	0.30
		650.0	9.7	0.63	19.1	0.0350	4.6	0.48
		650.5	21.6	0.83	28.4	0.0350	13.5	0.62
		651.0	38.1	1.00	37.7	0.0350	28.9	0.76
		651.5	58.3	1.22	43.0	0.0350	53.6	0.92
		652.0	81.1	1.40	48.3	0.0350	86.0	1.06
		652.5	106.6	1.57	53.6	0.0350	126.3	1.18
		653.0	134.8	1.72	58.9	0.0350	175.3	1.30
		654.0	197.5	2.05	66.6	0.0350	304.8	1.54
		655.0	267.9	2.33	74.3	0.0350	470.5	1.76
		656.0	346.1	2.58	82.0	0.0350	674.1	1.95
		657.0	432.0	2.82	89.7	0.0350	917.7	2.12
		658.0	525.5	3.04	97.4	0.0350	1203.4	2.29
		659.0	626.8	3.24	105.1	0.0350	1533.4	2.45
		660.0	735.8	3.44	112.8	0.0350	1909.6	2.60
		661.0	852.5	3.63	120.5	0.0350	2334.3	2.74
		662.0	976.9	3.81	128.3	0.0350	2809.4	2.88
		663.0	1109.0	3.99	136.0	0.0350	3337.0	3.01
		664.0	1248.8	4.16	143.7	0.0350	3919.1	3.14

REACH	RIVER MILE	ELEVATION FT	AREA FT2	R**2/3	WIDTH FT	MANNINGS N	ELEV VS. FLOW CFS	VELOCITY FPS
1	348.00	622.0	0.0	0.05	0.5	0.0350	0.0	0.04
		622.5	2.6	0.41	9.9	0.0350	0.8	0.31
		623.0	9.9	0.64	19.2	0.0350	4.7	0.48
		623.5	21.8	0.83	28.6	0.0350	13.7	0.63
		624.0	38.5	1.01	37.8	0.0350	29.2	0.76
		624.5	58.7	1.22	43.1	0.0350	54.1	0.92
		625.0	81.6	1.41	48.4	0.0350	86.6	1.06
		625.5	107.1	1.57	53.7	0.0350	127.1	1.19
		626.0	135.3	1.73	58.9	0.0350	176.3	1.30
		627.0	198.1	2.05	66.7	0.0350	306.1	1.55
		628.0	268.6	2.33	74.4	0.0350	472.0	1.76
		629.0	346.8	2.58	82.1	0.0350	676.0	1.95
		630.0	432.7	2.82	89.8	0.0350	920.0	2.13

		631.0	526.4	3.04	97.5	0.0350	1206.1	2.29
		632.0	627.7	3.24	105.2	0.0350	1536.4	2.45
		633.0	736.8	3.44	112.9	0.0350	1913.1	2.60
		634.0	853.5	3.63	120.6	0.0350	2338.2	2.74
		635.0	978.0	3.81	128.3	0.0350	2813.7	2.88
		636.0	1110.2	3.99	136.0	0.0350	3341.8	3.01
		637.0	1250.1	4.16	143.7	0.0350	3924.4	3.14

REACH	RIVER MILE	ELEVATION FT	AREA FT2	R**2/3	WIDTH FT	MANNINGS N	ELEV VS. FLOW CFS	VELOCITY FPS
2	108.00	638.1	0.0	0.11	0.9	0.0350	0.0	0.10
		638.6	1.9	0.43	6.7	0.0350	0.7	0.36
		639.1	6.7	0.66	12.2	0.0350	3.8	0.56
		639.6	13.7	0.90	15.5	0.0350	10.5	0.77
		640.1	22.3	1.09	18.8	0.0350	20.7	0.93
		640.6	32.5	1.26	22.2	0.0350	34.8	1.07
		641.1	44.4	1.41	25.5	0.0350	53.3	1.20
		641.6	58.0	1.55	28.8	0.0350	76.5	1.32
		642.1	73.3	1.67	32.4	0.0350	104.4	1.42
		643.1	110.7	1.85	42.3	0.0350	174.0	1.57
		644.1	157.9	2.03	52.3	0.0350	273.5	1.73
		645.1	215.8	2.20	63.6	0.0350	405.3	1.88
		646.1	285.1	2.38	74.9	0.0350	578.8	2.03
		647.1	365.6	2.57	86.2	0.0350	798.9	2.19
		648.1	457.4	2.75	97.5	0.0350	1070.1	2.34
		649.1	560.5	2.93	108.8	0.0350	1396.9	2.49
		650.1	674.9	3.10	120.0	0.0350	1783.5	2.64
		651.1	800.6	3.28	131.3	0.0350	2234.0	2.79
		652.1	937.6	3.45	142.6	0.0350	2752.4	2.94
		653.1	1085.9	3.61	153.9	0.0350	3342.6	3.08

REACH	RIVER MILE	ELEVATION FT	AREA FT2	R**2/3	WIDTH FT	MANNINGS N	ELEV VS. FLOW CFS	VELOCITY FPS
2	100.00	622.0	0.0	0.05	0.3	0.0350	0.0	0.05
		622.5	1.6	0.40	6.1	0.0350	0.6	0.34
		623.0	6.1	0.63	11.8	0.0350	3.3	0.54
		623.5	12.9	0.88	15.2	0.0350	9.6	0.75
		624.0	21.3	1.07	18.5	0.0350	19.4	0.91
		624.5	31.4	1.24	21.8	0.0350	33.1	1.06
		625.0	43.1	1.39	25.2	0.0350	51.2	1.19

1/85

		625.5	56.6	1.53	28.5	0.0350	73.9	1.31
		626.0	71.6	1.67	31.9	0.0350	102.0	1.42
		627.0	104.2	2.06	41.8	0.0350	183.2	1.76
		628.0	138.4	2.41	51.7	0.0350	284.0	2.05
		629.0	173.4	2.80	63.0	0.0350	413.5	2.38
		630.0	208.4	3.17	74.3	0.0350	561.8	2.70
		631.0	243.4	3.51	85.6	0.0350	727.7	2.99
		632.0	278.4	3.84	96.9	0.0350	910.3	3.27
		633.0	313.4	4.15	108.2	0.0350	1108.9	3.54
		634.0	348.4	4.46	119.5	0.0350	1322.9	3.80
		635.0	383.4	4.75	130.8	0.0350	1551.8	4.05
		636.0	418.4	5.04	142.0	0.0350	1795.0	4.29
		637.0	453.4	5.31	153.3	0.0350	2052.2	4.53

REACH	RIVER MILE	ELEVATION FT	AREA FT2	R**2/3	WIDTH FT	MANNINGS N	ELEV VS. FLOW CFS	VELOCITY FPS
3	348.00	622.0	0.0	0.05	0.5	0.0350	0.0	0.03
		622.5	2.6	0.41	9.9	0.0350	0.5	0.21
		623.0	9.9	0.64	19.2	0.0350	3.2	0.32
		623.5	21.8	0.83	28.6	0.0350	9.2	0.42
		624.0	38.5	1.01	37.8	0.0350	19.6	0.51
		624.5	58.7	1.22	43.1	0.0350	36.3	0.62
		625.0	81.5	1.41	48.4	0.0350	58.1	0.71
		625.5	107.1	1.57	53.7	0.0350	85.3	0.80
		626.0	135.3	1.73	58.9	0.0350	118.2	0.87
		627.0	198.1	2.05	66.7	0.0350	205.3	1.04
		628.0	268.6	2.33	74.4	0.0350	316.6	1.18
		629.0	346.8	2.58	82.1	0.0350	453.4	1.31
		630.0	432.7	2.82	89.8	0.0350	617.1	1.43
		631.0	526.3	3.04	97.5	0.0350	809.0	1.54
		632.0	627.7	3.24	105.2	0.0350	1030.6	1.64
		633.0	736.7	3.44	112.9	0.0350	1283.3	1.74
		634.0	853.5	3.63	120.6	0.0350	1568.4	1.84
		635.0	978.0	3.81	128.3	0.0350	1887.4	1.93
		636.0	1110.1	3.99	136.0	0.0350	2241.7	2.02
		637.0	1250.0	4.16	143.7	0.0350	2632.5	2.11

REACH	RIVER MILE	ELEVATION FT	AREA FT2	R**2/3	WIDTH FT	MANNINGS N	ELEV VS. FLOW CFS	VELOCITY FPS
3	344.00	618.0	0.0	0.03	0.2	0.0350	0.0	0.02
		618.5	1.8	0.40	7.1	0.0350	0.4	0.20
		619.0	7.1	0.63	14.0	0.0350	2.3	0.32
		619.5	15.8	0.82	20.9	0.0350	6.6	0.42
		620.0	28.0	0.99	28.0	0.0350	14.0	0.50
		620.5	45.9	1.03	43.7	0.0350	23.9	0.52
		621.0	71.7	1.13	59.1	0.0350	41.0	0.57
		621.5	103.2	1.33	67.0	0.0350	69.3	0.67
		622.0	138.7	1.50	74.9	0.0350	105.4	0.76
		623.0	221.4	1.81	90.6	0.0350	202.3	0.91
		624.0	319.9	2.07	106.3	0.0350	335.7	1.05
		625.0	434.1	2.32	122.1	0.0350	509.2	1.17
		626.0	564.0	2.55	137.8	0.0350	726.6	1.29
		627.0	709.7	2.76	153.5	0.0350	991.4	1.40
		628.0	871.0	2.97	169.2	0.0350	1307.1	1.50
		629.0	1048.1	3.16	185.0	0.0350	1677.0	1.60
		630.0	1241.0	3.35	200.7	0.0350	2104.4	1.70
		631.0	1449.5	3.53	216.4	0.0350	2592.5	1.79
		632.0	1673.8	3.71	232.2	0.0350	3144.4	1.88
		633.0	1913.8	3.89	247.9	0.0350	3763.1	1.97

REACH	RIVER MILE	ELEVATION FT	AREA FT2	R**2/3	WIDTH FT	MANNINGS N	ELEV VS. FLOW CFS	VELOCITY FPS
3	340.00	614.0	0.0	0.00	0.0	0.0350	0.0 **	0.00
		614.5	1.7	0.39	6.9	0.0350	2.0 **	1.16
		615.0	6.9	0.63	13.8	0.0350	4.0 **	0.58
		615.5	15.5	0.82	20.7	0.0350	8.0 **	0.51
		616.0	27.6	0.99	27.6	0.0350	20.0 **	0.72
		616.5	45.4	1.03	43.3	0.0350	35.0 **	0.77
		617.0	70.9	1.13	58.9	0.0350	60.0 **	0.85
		617.5	102.4	1.32	66.8	0.0350	90.0 **	0.88
		618.0	137.7	1.50	74.7	0.0350	130.0 **	0.94
		619.0	220.3	1.80	90.4	0.0350	225.0 **	1.02
		620.0	318.5	2.07	106.1	0.0350	380.0 **	1.19
		621.0	432.5	2.32	121.9	0.0350	580.0 **	1.34
		622.0	562.3	2.54	137.6	0.0350	820.0 **	1.46
		623.0	707.7	2.76	153.3	0.0350	1100.0 **	1.55

624.0	868.9	2.96	169.0	0.0350	1400.0 **	1.61
625.0	1045.8	3.16	184.8	0.0350	1725.0 **	1.65
626.0	1238.4	3.35	200.5	0.0350	2100.0 **	1.70
627.0	1446.8	3.53	216.2	0.0350	2530.0 **	1.75
628.0	1670.9	3.71	232.0	0.0350	3000.0 **	1.80
629.0	1910.7	3.88	247.7	0.0350	3550.0 **	1.86

** - ELEVATION VS. FLOW RELATIONSHIP INPUT BY USER

ENERGY GRADE OF BOTTOM ELEVATIONS

REACH	RIVER MILE	ELEVATION FT
1	366.00	649.00
1	348.00	622.00
2	108.00	638.00
2	100.00	622.00
3	348.00	622.00
3	344.00	618.00
3	340.00	614.00

BOUNDARY CONDITION SPECIFICATIONS

FLOW SPECIFIED AT UPSTREAM END OF REACH 1
FLOW SPECIFIED AT UPSTREAM END OF REACH 2
STAGE-FLOW SPECIFIED AT DOWNSTREAM END OF REACH 3

TRIBUTARY INFLOW AND WITHDRAWAL LOCATIONS

	SPECIFIED AT REACH	SPECIFIED AT MILE	ALLOCATED TO MILE
INFLOW NO. 1	1	366.00	366.00
INFLOW NO. 2	1	360.40	360.00
INFLOW NO. 3	2	108.00	108.00
WITHDRAWAL NO. 1	1	362.00	362.00

ROUTING FACTOR TABLES

CONTROL PT	ROUTING STEPS	REACH	RIVER MILE	K(HR)	X
1	4	1	348.000	15.000	0.250
2	2	2	100.000	8.000	0.250
3	2	3	340.000	10.000	0.250

INFLOW HYDROGRAPHS FOR DAY 258

	TIME(HR)	FLOW(*)	TIME(HR)	FLOW(*)	TIME(HR)	FLOW(*)	TIME(HR)	FLOW(*)	TIME(HR)	FLOW(*)
INFLOW 1	0.0	120.0	6.5	120.0	7.0	680.0	14.0	680.0	14.3	880.0
	23.0	880.0	23.3	130.0	24.0	130.0				
INFLOW 2	0.0	18.0	24.0	18.0						
INFLOW 3	0.0	120.0	24.0	120.0						
WITHDRAWAL 1	0.0	22.0	24.0	22.0						

* DEPTH UNITS ARE IN FEET AND FLOW UNITS IN CFS

HYDRAULIC CONDITIONS AT DAY 258, HOUR 4.0

NODE	REACH	RIVER MILE	FLOW	DEPTH	AREA	VELOCITY	ELEVATION	WIDTH
1	1	366.00	120.00	3.42	101.5	1.18	652.43	54.5
2	1	365.50	130.73	3.54	108.1	1.21	651.80	55.7
3	1	365.00	141.47	3.65	114.0	1.24	651.16	56.7
4	1	364.50	152.20	3.76	120.1	1.27	650.52	57.7
5	1	364.00	162.94	3.87	126.3	1.29	649.88	58.7
6	1	363.50	173.67	3.98	132.5	1.31	649.24	59.7
7	1	363.00	184.40	4.07	137.7	1.34	648.58	60.5
8	1	362.50	195.14	4.15	142.7	1.37	647.91	61.2
9	1	362.00	183.87	4.06	137.5	1.34	647.07	60.4
10	1	361.00	194.61	4.15	142.5	1.37	645.66	61.1
11	1	360.00	262.70	4.68	175.4	1.50	644.69	65.4
12	1	359.00	312.79	5.05	200.0	1.56	643.56	68.3
13	1	358.00	362.88	5.35	220.5	1.65	642.37	70.6
14	1	357.00	412.97	5.65	241.8	1.71	641.17	72.9
15	1	356.00	433.15	5.77	250.5	1.73	639.79	73.9
16	1	355.00	453.33	5.89	259.4	1.75	638.41	74.8
17	1	354.00	473.51	6.01	268.2	1.77	637.03	75.7
18	1	353.00	493.69	6.11	275.6	1.79	635.63	76.5
19	1	352.00	513.87	6.21	283.0	1.82	634.23	77.2
20	1	351.00	515.64	6.22	283.7	1.82	632.73	77.3
21	1	350.00	517.41	6.23	284.4	1.82	631.24	77.4
22	1	349.00	519.17	6.23	285.0	1.82	629.75	77.4

23	1	348.00	520.94	6.24	285.7	1.82	628.26	77.5
24	2	108.00	120.00	4.22	80.3	1.49	642.29	36.3
25	2	107.00	120.00	4.22	80.0	1.50	640.28	35.8
26	2	106.00	120.00	4.22	79.7	1.51	638.28	35.3
27	2	105.00	120.00	4.22	79.4	1.51	636.27	34.8
28	2	104.00	120.00	4.22	79.1	1.52	634.27	34.2
29	2	103.00	120.00	4.22	78.8	1.52	632.26	33.7
30	2	102.00	120.00	4.22	78.6	1.53	630.25	33.2
31	2	101.00	120.00	4.22	78.3	1.53	628.25	32.7
32	2	100.00	120.00	4.22	78.0	1.54	626.24	32.2
33	3	348.00	640.94	8.12	442.7	1.45	630.14	92.0
34	3	347.00	620.65	7.86	450.5	1.38	628.88	102.0
35	3	346.00	600.36	7.62	454.9	1.32	627.63	111.2
36	3	345.00	580.06	7.41	458.3	1.27	626.41	119.9
37	3	344.00	559.77	7.22	461.1	1.21	625.23	128.1
38	3	343.00	532.09	7.01	434.6	1.22	624.01	124.7
39	3	342.00	504.42	6.77	404.9	1.25	622.77	120.9
40	3	341.00	476.75	6.54	377.8	1.26	621.53	117.2
41	3	340.00	449.08	6.32	353.1	1.27	620.31	113.8

HYDRAULIC CONDITIONS AT DAY 258, HOUR 8.0

NODE	REACH	RIVER MILE	FLOW	DEPTH	AREA	VELOCITY	ELEVATION	WIDTH
1	1	366.00	680.00	7.03	347.0	1.96	656.03	83.5
2	1	365.50	640.65	6.84	331.7	1.93	655.10	82.0
3	1	365.00	601.29	6.64	316.3	1.90	654.15	80.5
4	1	364.50	561.94	6.45	301.1	1.87	653.21	79.0
5	1	364.00	522.58	6.26	286.3	1.83	652.27	77.6
6	1	363.50	483.23	6.06	271.7	1.78	651.32	76.1
7	1	363.00	443.87	5.84	255.3	1.74	650.35	74.4
8	1	362.50	404.52	5.60	238.2	1.70	649.37	72.5
9	1	362.00	343.16	5.24	212.4	1.62	648.25	69.7
10	1	361.00	303.81	5.00	196.3	1.55	646.51	67.9
11	1	360.00	317.01	5.08	201.7	1.57	645.09	68.5
12	1	359.00	312.22	5.05	199.8	1.56	643.56	68.3
13	1	358.00	307.42	5.02	197.8	1.55	642.03	68.0
14	1	357.00	302.62	4.99	195.7	1.55	640.50	67.8
15	1	356.00	323.17	5.11	204.2	1.58	639.13	68.8

16	1	355.00	343.72	5.24	212.6	1.62	637.75	69.7
17	1	354.00	364.27	5.36	221.1	1.65	636.37	70.7
18	1	353.00	384.82	5.48	229.8	1.67	635.00	71.6
19	1	352.00	405.37	5.60	238.5	1.70	633.62	72.6
20	1	351.00	424.30	5.72	246.7	1.72	632.23	73.4
21	1	350.00	443.23	5.83	254.9	1.74	630.85	74.3
22	1	349.00	462.15	5.94	263.3	1.76	629.46	75.2
23	1	348.00	481.08	6.05	271.0	1.78	628.07	76.0
24	2	108.00	120.00	4.22	80.3	1.49	642.29	36.3
25	2	107.00	120.00	4.22	80.0	1.50	640.28	35.8
26	2	106.00	120.00	4.22	79.7	1.51	638.28	35.3
27	2	105.00	120.00	4.22	79.4	1.51	636.27	34.8
28	2	104.00	120.00	4.22	79.1	1.52	634.27	34.2
29	2	103.00	120.00	4.22	78.8	1.52	632.26	33.7
30	2	102.00	120.00	4.22	78.6	1.53	630.25	33.2
31	2	101.00	120.00	4.22	78.3	1.53	628.25	32.7
32	2	100.00	120.00	4.22	78.0	1.54	626.24	32.2
33	3	348.00	601.08	7.90	422.8	1.42	629.92	90.3
34	3	347.00	601.34	7.75	439.7	1.37	628.77	101.0
35	3	346.00	601.59	7.62	455.6	1.32	627.64	111.3
36	3	345.00	601.85	7.51	470.9	1.28	626.52	121.3
37	3	344.00	602.10	7.41	485.7	1.24	625.42	131.2
38	3	343.00	583.49	7.24	463.1	1.26	624.24	128.4
39	3	342.00	564.88	7.07	442.0	1.28	623.07	125.7
40	3	341.00	546.27	6.90	420.1	1.30	621.89	122.9
41	3	340.00	527.66	6.72	398.2	1.33	620.71	120.0

HYDRAULIC CONDITIONS AT DAY 258, HOUR 12.0

NODE	REACH	RIVER MILE	FLOW	DEPTH	AREA	VELOCITY	ELEVATION	WIDTH
1	1	366.00	680.00	7.03	347.0	1.96	656.03	83.5
2	1	365.50	669.19	6.98	343.1	1.95	655.24	83.1
3	1	365.00	658.37	6.92	338.8	1.94	654.43	82.7
4	1	364.50	647.56	6.87	334.5	1.94	653.63	82.3
5	1	364.00	636.74	6.82	330.2	1.93	652.83	81.9
6	1	363.50	625.93	6.76	325.9	1.92	652.02	81.5
7	1	363.00	615.12	6.71	321.7	1.91	651.22	81.1
8	1	362.50	604.30	6.66	317.4	1.90	650.42	80.6

9	1	362.00	571.49	6.50	304.8	1.88	649.51	79.4
10	1	361.00	560.67	6.44	300.6	1.86	647.95	79.0
11	1	360.00	533.70	6.31	290.4	1.84	646.32	78.0
12	1	359.00	488.72	6.09	273.7	1.79	644.60	76.3
13	1	358.00	443.74	5.84	255.2	1.74	642.85	74.3
14	1	357.00	398.76	5.57	235.7	1.69	641.08	72.3
15	1	356.00	391.34	5.52	232.5	1.68	639.54	71.9
16	1	355.00	383.91	5.48	229.4	1.67	637.99	71.6
17	1	354.00	376.48	5.43	226.2	1.66	636.45	71.3
18	1	353.00	369.06	5.39	223.1	1.65	634.90	70.9
19	1	352.00	361.63	5.34	220.0	1.64	633.36	70.6
20	1	351.00	374.27	5.42	225.3	1.66	631.93	71.2
21	1	350.00	386.90	5.49	230.6	1.68	630.51	71.7
22	1	349.00	399.54	5.57	236.0	1.69	629.09	72.3
23	1	348.00	412.17	5.64	241.4	1.71	627.66	72.9
24	2	108.00	120.00	4.22	80.3	1.49	642.29	36.3
25	2	107.00	120.00	4.22	80.0	1.50	640.28	35.8
26	2	106.00	120.00	4.22	79.7	1.51	638.28	35.3
27	2	105.00	120.00	4.22	79.4	1.51	636.27	34.8
28	2	104.00	120.00	4.22	79.1	1.52	634.27	34.2
29	2	103.00	120.00	4.22	78.8	1.52	632.26	33.7
30	2	102.00	120.00	4.22	78.6	1.53	630.25	33.2
31	2	101.00	120.00	4.22	78.3	1.53	628.25	32.7
32	2	100.00	120.00	4.22	78.0	1.54	626.24	32.2
33	3	348.00	532.17	7.48	386.0	1.38	629.50	87.0
34	3	347.00	545.78	7.44	409.0	1.33	628.45	97.9
35	3	346.00	559.39	7.40	431.8	1.30	627.41	108.7
36	3	345.00	572.99	7.37	454.3	1.26	626.38	119.4
37	3	344.00	586.60	7.34	476.6	1.23	625.35	130.0
38	3	343.00	582.71	7.24	462.6	1.26	624.24	128.3
39	3	342.00	578.81	7.13	449.5	1.29	623.13	126.7
40	3	341.00	574.92	7.04	437.1	1.32	622.03	125.1
41	3	340.00	571.03	6.93	424.1	1.35	620.93	123.4

HYDRAULIC CONDITIONS AT DAY 258, HOUR 16.0

NODE	REACH	RIVER MILE	FLOW	DEPTH	AREA	VELOCITY	ELEVATION	WIDTH
1	1	366.00	880.00	7.84	417.0	2.11	656.85	89.8
2	1	365.50	861.92	7.77	410.5	2.10	656.03	89.2
3	1	365.00	843.84	7.70	404.0	2.09	655.21	88.6
4	1	364.50	825.76	7.62	397.5	2.08	654.38	88.1
5	1	364.00	807.68	7.55	391.1	2.07	653.56	87.5
6	1	363.50	789.60	7.47	384.7	2.05	652.73	86.9
7	1	363.00	771.52	7.40	378.4	2.04	651.91	86.4
8	1	362.50	753.44	7.32	372.1	2.02	651.09	85.8
9	1	362.00	713.36	7.16	358.4	1.99	650.17	84.5
10	1	361.00	695.28	7.09	352.2	1.97	648.60	84.0
11	1	360.00	678.04	7.01	346.4	1.96	647.03	83.4
12	1	359.00	642.80	6.84	332.6	1.93	645.36	82.1
13	1	358.00	607.56	6.67	318.7	1.91	643.68	80.8
14	1	357.00	572.33	6.50	305.1	1.88	642.01	79.4
15	1	356.00	546.68	6.37	295.3	1.85	640.39	78.5
16	1	355.00	521.04	6.25	285.7	1.82	638.76	77.5
17	1	354.00	495.40	6.12	276.2	1.79	637.13	76.5
18	1	353.00	469.76	5.99	266.7	1.76	635.51	75.5
19	1	352.00	444.12	5.84	255.3	1.74	633.85	74.4
20	1	351.00	433.57	5.77	250.7	1.73	632.29	73.9
21	1	350.00	423.02	5.71	246.1	1.72	630.73	73.4
22	1	349.00	412.47	5.65	241.6	1.71	629.16	72.9
23	1	348.00	401.93	5.58	237.0	1.70	627.60	72.4
24	2	108.00	120.00	4.22	80.3	1.49	642.29	36.3
25	2	107.00	120.00	4.22	80.0	1.50	640.28	35.8
26	2	106.00	120.00	4.22	79.7	1.51	638.28	35.3
27	2	105.00	120.00	4.22	79.4	1.51	636.27	34.8
28	2	104.00	120.00	4.22	79.1	1.52	634.27	34.2
29	2	103.00	120.00	4.22	78.8	1.52	632.26	33.7
30	2	102.00	120.00	4.22	78.6	1.53	630.25	33.2
31	2	101.00	120.00	4.22	78.3	1.53	628.25	32.7
32	2	100.00	120.00	4.22	78.0	1.54	626.24	32.2
33	3	348.00	521.93	7.42	380.7	1.37	629.44	86.6
34	3	347.00	529.00	7.34	400.0	1.32	628.36	97.0
35	3	346.00	536.08	7.28	418.8	1.28	627.29	107.3

36	3	345.00	543.16	7.23	437.3	1.24	626.23	117.4
37	3	344.00	550.24	7.18	455.6	1.21	625.18	127.4
38	3	343.00	555.92	7.12	447.7	1.24	624.12	126.4
39	3	342.00	561.60	7.06	440.2	1.28	623.06	125.5
40	3	341.00	567.28	7.00	433.1	1.31	622.00	124.6
41	3	340.00	572.96	6.94	425.2	1.35	620.94	123.5

HYDRAULIC CONDITIONS AT DAY 258, HOUR 20.0

NODE	REACH	RIVER MILE	FLOW	DEPTH	AREA	VELOCITY	ELEVATION	WIDTH
1	1	366.00	880.00	7.84	417.0	2.11	656.85	89.8
2	1	365.50	875.03	7.82	415.2	2.11	656.08	89.6
3	1	365.00	870.06	7.80	413.4	2.10	655.31	89.5
4	1	364.50	865.10	7.78	411.6	2.10	654.54	89.3
5	1	364.00	860.13	7.76	409.8	2.10	653.77	89.2
6	1	363.50	855.16	7.74	408.0	2.10	653.00	89.0
7	1	363.00	850.19	7.72	406.2	2.09	652.23	88.8
8	1	362.50	845.22	7.70	404.5	2.09	651.46	88.7
9	1	362.00	818.25	7.59	394.8	2.07	650.60	87.8
10	1	361.00	813.29	7.57	393.1	2.07	649.08	87.7
11	1	360.00	801.55	7.52	388.9	2.06	647.53	87.3
12	1	359.00	771.80	7.40	378.5	2.04	645.91	86.4
13	1	358.00	742.06	7.28	368.2	2.02	644.29	85.4
14	1	357.00	712.32	7.15	358.0	1.99	642.67	84.5
15	1	356.00	686.24	7.05	349.2	1.97	641.06	83.7
16	1	355.00	660.16	6.93	339.4	1.94	639.44	82.8
17	1	354.00	634.08	6.80	329.1	1.93	637.81	81.8
18	1	353.00	607.99	6.67	318.9	1.91	636.19	80.8
19	1	352.00	581.91	6.54	308.8	1.88	634.56	79.8
20	1	351.00	555.59	6.41	298.7	1.86	632.93	78.8
21	1	350.00	529.27	6.28	288.8	1.83	631.30	77.8
22	1	349.00	502.95	6.15	279.0	1.80	629.67	76.8
23	1	348.00	476.63	6.03	269.3	1.77	628.04	75.8
24	2	108.00	120.00	4.22	80.3	1.49	642.29	36.3
25	2	107.00	120.00	4.22	80.0	1.50	640.28	35.8
26	2	106.00	120.00	4.22	79.7	1.51	638.28	35.3
27	2	105.00	120.00	4.22	79.4	1.51	636.27	34.8
28	2	104.00	120.00	4.22	79.1	1.52	634.27	34.2

29	2	103.00	120.00	4.22	78.8	1.52	632.26	33.7
30	2	102.00	120.00	4.22	78.6	1.53	630.25	33.2
31	2	101.00	120.00	4.22	78.3	1.53	628.25	32.7
32	2	100.00	120.00	4.22	78.0	1.54	626.24	32.2
33	3	348.00	596.63	7.87	420.4	1.42	629.89	90.1
34	3	347.00	584.62	7.66	430.4	1.36	628.67	100.1
35	3	346.00	572.61	7.47	439.2	1.30	627.48	109.5
36	3	345.00	560.60	7.31	447.2	1.25	626.32	118.6
37	3	344.00	548.59	7.17	454.6	1.21	625.17	127.3
38	3	343.00	551.03	7.09	445.0	1.24	624.10	126.1
39	3	342.00	553.47	7.02	435.9	1.27	623.02	124.9
40	3	341.00	555.91	6.95	426.1	1.30	621.94	123.7
41	3	340.00	558.35	6.87	416.4	1.34	620.86	122.4

HYDRAULIC CONDITIONS AT DAY 258, HOUR 24.0

NODE	REACH	RIVER MILE	FLOW	DEPTH	AREA	VELOCITY	ELEVATION	WIDTH
1	1	366.00	130.00	3.54	107.7	1.21	652.55	55.6
2	1	365.50	185.29	4.07	138.1	1.34	652.33	60.5
3	1	365.00	240.58	4.51	164.5	1.46	652.02	64.0
4	1	364.50	295.88	4.94	192.3	1.54	651.70	67.4
5	1	364.00	351.17	5.28	215.7	1.63	651.29	70.1
6	1	363.50	406.46	5.62	239.0	1.70	650.88	72.6
7	1	363.00	461.75	5.95	263.2	1.75	650.46	75.2
8	1	362.50	517.04	6.23	284.2	1.82	649.99	77.3
9	1	362.00	550.34	6.39	296.7	1.85	649.40	78.6
10	1	361.00	605.63	6.66	318.0	1.90	648.17	80.7
11	1	360.00	650.75	6.88	335.7	1.94	646.90	82.4
12	1	359.00	677.88	7.01	346.3	1.96	645.53	83.4
13	1	358.00	705.00	7.12	355.5	1.98	644.14	84.3
14	1	357.00	732.12	7.23	364.8	2.01	642.75	85.1
15	1	356.00	722.26	7.19	361.4	2.00	641.21	84.8
16	1	355.00	712.40	7.15	358.0	1.99	639.67	84.5
17	1	354.00	702.54	7.11	354.7	1.98	638.13	84.2
18	1	353.00	692.68	7.07	351.4	1.97	636.59	83.9
19	1	352.00	682.83	7.03	348.0	1.96	635.05	83.6
20	1	351.00	658.44	6.92	338.7	1.94	633.43	82.7
21	1	350.00	634.06	6.80	329.1	1.93	631.81	81.8

22	1	349.00	609.67	6.68	319.5	1.91	630.19	80.8
23	1	348.00	585.29	6.56	310.1	1.89	628.58	79.9
24	2	108.00	120.00	4.22	80.3	1.49	642.29	36.3
25	2	107.00	120.00	4.22	80.0	1.50	640.28	35.8
26	2	106.00	120.00	4.22	79.7	1.51	638.28	35.3
27	2	105.00	120.00	4.22	79.4	1.51	636.27	34.8
28	2	104.00	120.00	4.22	79.1	1.52	634.27	34.2
29	2	103.00	120.00	4.22	78.8	1.52	632.26	33.7
30	2	102.00	120.00	4.22	78.6	1.53	630.25	33.2
31	2	101.00	120.00	4.22	78.3	1.53	628.25	32.7
32	2	100.00	120.00	4.22	78.0	1.54	626.24	32.2
33	3	348.00	705.29	8.46	473.5	1.49	630.48	94.6
34	3	347.00	679.51	8.16	481.3	1.41	629.18	105.0
35	3	346.00	653.73	7.90	485.9	1.35	627.91	114.5
36	3	345.00	627.95	7.64	486.3	1.29	626.65	123.1
37	3	344.00	602.17	7.42	485.8	1.24	625.42	131.2
38	3	343.00	592.57	7.28	468.2	1.27	624.28	129.0
39	3	342.00	582.97	7.15	451.7	1.29	623.15	126.9
40	3	341.00	573.38	7.03	436.3	1.31	622.03	125.0
41	3	340.00	563.78	6.90	419.7	1.34	620.89	122.8

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FIGURE IX-9

STREAM QUALITY MODULE INPUT DATA

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TITLE     EXAMPLE PROBLEM - STREAM QUALITY
TITLE     FICTITIOUS CALIFORNIA RIVER SYSTEM
TITLE     CALIFORNIA RIVER BELOW SMITH RESERVOIR INCLUDING SUTTER CREEK
JOB1      560913   560914       4       4       1       0
JOB2           1        1       1       1       1       1       1       1       1
JOB2A          1        1       1       1       1       1       1       1       1
JOB2B          1        1       1       0       0       0       0       0
JOB2C          1        1       1       0
JOB3           1        1     500       4       1       1
JOB4      560916
JOB5           1        1       1       3       1       0       3     340
JOB6           1        0       1       0       0     -24       0       0       0
JOB7           0        1       1       5       5       5       1       0       0
PHYS1          1      366     .33
PHYS1          1    360.4
PHYS1          2      108
PHYS1          1      362
PHYS2          1        0       0      41     121       3
COEFF         71      .03     173      .1      -1
SSOL        .001       10   .0012      22   .0014      30    .002       0
INFL1          1        1       1       1       1       1       1       0       1
INFL1A         1        0       0       0       1       1
INFL1B         1        0       0       0       0       0
INFL2     560913   560916
INFL3          0  ELK CITY STP TEMPERATURE
INFL5   56091300       78      -1
INFL3          0  ELK CITY STP DO
INFL5   56091300        6      -1
INFL3          0  ELK CITY STP BOD
INFL5   56091300       -8      -1
INFL3          0  ELK CITY STP COLIFORMS
INFL5   56091300      500      -1
INFL3          0  ELK CITY STP DETRITUS
INFL5   56091300        5      -1
INFL3          0  ELK CITY STP AMMONIA
INFL5   56091300       .5      -1
INFL3          0  ELK CITY STP NITRATE
INFL5   56091300       .5      -1
INFL3          0  ELK CITY STP PHOSPHATE
INFL5   56091300      .25      -1
INFL3          0  ELK CITY STP TDS
INFL5   56091300     1500      -1
```

```
1/85  INFL3           0   ELK CITY STP PH
      INFL5    56091300      7       -1
      INFL3           0   ELK CITY STP ALKALINITY
      INFL5    56091300    100       -1
      INFL3           0   ELK CITY STP SSOL NO 1
      INFL5    56091300     20       -1
      INFL3           4   SUTTER CREEK TEMPERATURE
      INFL4          66     65       68       71       70       68       65       64       67
      INFL4          71     70       67       66       64       67       70       69       68
      INFL4          66     65       68       71       70       68
      INFL3           0   SUTTER CREEK DO
      INFL5    56091300   -.95       -1
      INFL3           0   SUTTER CREEK BOD
      INFL5    56091300     -2       -1
      INFL3           0   SUTTER CREEK COLIFORMS
      INFL5    56091300    100       -1
      INFL3           0   SUTTER CREEK DETRITUS
      INFL5    56091300      1       -1
      INFL3           0   SUTTER CREEK AMMONIA
      INFL5    56091300    .02       -1
      INFL3           0   SUTTER CREEK NITRATE
      INFL5    56091300    .20       -1
      INFL3           0   SUTTER CREEK PHOSPHATE
      INFL5    56091300    .03       -1
      INFL3           0   SUTTER CREEK TDS
      INFL5    56091300    500       -1
      INFL3           0   SUTTER CREEK PH
      INFL5    56091300    7.6       -1
      INFL3           0   SUTTER CREEK ALKALINITY
      INFL5    56091300     60       -1
      INFL3           0   SUTTER CREEK SSOL NO 1
      INFL5    56091300      2       -1
      WEATH1   56091300     .3       70       61       30        3                          -1
      WEATH1   56091304     .3       66       60       30        3                          -1
      WEATH1   56091308     .2       78       62       30        6                          -1
      WEATH1   56091312     .1       92       63       30        6                          -1
      WEATH1   56091316     .1       88       64       30        9                          -1
      WEATH1   56091320     .2       74       62       30        9                          -1
      INIT1           4      0
      INIT2           1    366        1      360       30        5       10
      INIT2           1    360        1      348       20       10       10
      INIT2           2    108        2      100        5       10       10
      INIT2           3    348        3      340       10       20       10
      INIT3           1    366        3      340       68        9        1        2    10000
      INIT4           4    .05      .20      .01      .02      500      200       .1       .1
      INIT5        .001    7.5       50        5        0        0        0        0        0
      INIT6           0    400      500     1000     .001        2        3
      TITLE
      TITLE
      TITLE
      JOB1
```

```
******************************************************
*  WATER QUALITY FOR RIVER-RESERVOIR SYSTEMS         *
*  STREAM QUALITY MODULE                             *
*  DECEMBER 1978 UPDATED SEPTEMBER 1984              *
*  ERROR CORRECTION 009                              *
*  RUN DATE 15 JAN 85  TIME  12:15:43                *
******************************************************
```

```
****************************************
*  U.S. ARMY CORPS OF ENGINEERS        *
*  THE HYDROLOGIC ENGINEERING CENTER   *
*  609 SECOND STREET, SUITE D          *
*  DAVIS, CALIFORNIA 95616             *
*  (916) 440-2105 (FTS) 448-2105       *
****************************************
```

```
X     X    XXX    XXXXXX   XXXXXX    XXXXX     XXX
X     X   X   X   X     X  X     X  X     X   X   X
X     X  X     X  X     X  X     X  X        X     X
X  X  X  X     X  XXXXXX   XXXXXX    XXXXX   X     X
X X X X  X   X X  X   X    X   X          X  X   X X
XX   XX   X   X   X    X   X    X   X     X   X   X
X     X    XXX X  X     X  X     X   XXXXX     XXX X
```

FIGURE IX-10

STREAM QUALITY MODULE OUTPUT

EXAMPLE PROBLEM - STREAM QUALITY
FICTITIOUS CALIFORNIA RIVER SYSTEM
CALIFORNIA RIVER BELOW SMITH RESERVOIR INCLUDING SUTTER CREEK

DAYS OF SIMULATION	2
FIRST DAY OF SIMULATION	257 (56/ 9/13)
FINAL DAY OF SIMULATION	258 (56/ 9/14)
COMPUTATIONAL TIME STEP, HOURS	4
METEOROLOGICAL DATA INTERVAL, HOURS	4
STREAM HYDRAULICS UPDATE INTERVAL, DAYS	1
NON-POINT INFLOWS (NO=0/YES=1)	0

STATUS OF WATER QUALITY CONSTITUENTS

NUMBER	CONSTITUENT	SIMULATE	HOLD CONSTANT	SET TO ZERO
1	TEMPERATUER	****		
2	DISSOLVED OXYGEN	****		
3	CARBONACEOUS BOD	****		
4	COLIFORM BACTERIA	****		
5	ORGANIC DETRITUS	****		
6	AMMONIA AS N	****		
7	NITRATE AS N	****		
8	NITRITE AS N	****		
9	PHOSPHATE AS P	****		
10	TOTAL DISSOLVED SOLIDS	****		
11	PHYTOPLANKTON NO. 1	****		
12	PHYTOPLANKTON NO. 2	****		
13	ZOOPLANKTON	****		
14	TOTAL INORGANIC CARBON	****		
15	ALKALINITY AS CACO3	****		
16	ORGANIC SEDIMENT	****		
17	BENTHIC ANIMALS	****		
18	FISH NO. 1	****		
19	FISH NO. 2	****		
20	FISH NO. 3	****		
21	SUSPENDED SOLIDS NO. 1	****		
22	SUSPENDED SOLIDS NO. 2			****
23	SUSPENDED SOLIDS NO. 3			****
24	SUSPENDED SOLIDS NO. 4			****
25	SUSPENDED SOLIDS NO. 5			****
26	INORGANIC SEDIMENT			****
27	AQUATIC INSECTS	****		
28	BENTHIC ALGAE NO. 1	****		
29	BENTHIC ALGAE NO. 2	****		
30	UNIT TOXICITY			****

PRINTOUT FREQUENCY IN DAYS FOR	
HYDRAULIC CONDITIONS	1
ABBREVIATED STREAM QUALITY	1
COMPREHENSIVE STREAM QUALITY	500
PRINTOUT INTERVAL, HOURS	4
PRINTOUT INTERVAL, ELEMENTS	1
ADDITIONAL PRINTOUT DAYS	260 (56/ 9/16)
POINTS DEFINING INITIAL QUALITY	1
INPUT WATER TEMPERATURE UNITS (F=1/C=0)	1
INPUT UNITS (ENGLISH=1/METRIC=0)	1
NUMBER OF TRIBUTARY INFLOWS	3
NUMBER OF WITHDRAWALS	1
NUMBER OF STORM GENERATED INFLOWS	0
MOST DOWNSTREAM RIVER REACH	3
TAPE OR FILE RELATED DATA	
HYDRAULICS / QUALITY INTERFACE	14
DOWNSTREAM QUALITY INTERFACE	0
INFLOW QUALITY INTERFACE NO. 1	10
DATA INTERVAL, HOURS, INTERFACE NO 1	-24
INFLOW QUALITY INTERFACE NO. 2	0
DATA INTERVAL, HOURS, INTERFACE NO 2	0
INFLOW QUALITY INTERFACE NO. 3	0
DATA INTERVAL, HOURS, INTERFACE NO 3	0
SIMULATION RESULTS FOR HEC PLOT PACKAGE	0
EQUILIBRIUN TEMPERATURE AND EXCHANGE RATES	0
PROCESSED METEOROLOGICAL DATA **	19
PROCESSED INFLOW QUALITY DATA **	18
UNPROCESSED METEOROLOGICAL DATA *	5
UNPROCESSED INFLOW QUALITY DATA *	5
UNPROCESSED STORM GENERATED DATA *	5
SCRATCH FILE NO. 1	15
SCRATCH FILE NO. 2	0
SCRATCH FILE NO. 3	0

* DATA WILL BE READ FROM CARDS IF UNIT = 5

** A NEGATIVE NUMBER INDICATES A PERMANENT RECORD, NO CARD INPUT REQUIRED

INVARIENT METEOROLOGICAL DATA

TYPE OF HEAT EXCHANGE (HEAT BUDGET=0/EQ TEMP=1)	0
TEMPERATURE (DEW POINT=0/WET BULB=1)	1
EVAPORATION CONSTANT A	0.00E+01
EVAPORATION CONSTANT B	0.15E-08
LATITUDE OF STREAM, DEG	41.0
LONGITUDE OF STREAM, DEG	121.0
LONGITUDE (WEST=+1/EAST=-1)	1.
ATMOSPHERIC TURBIDITY	3.0

TRIBUTARY INFLOW OR WITHDRAWAL LOCATIONS

NUMBER	FROM	REACH	RIVER MILE	WITHDRAWAL EL	REAERATION	INPUT FREQUENCY, HOURS
1	TAPE 10	1	366.00	0	0.33	-24
2	CARDS	1	360.40	0		
3	CARDS	2	108.00	0		
4	CARDS	1	362.00	0		

CHEMICAL COMPOSITION

	CARBON	NITROGEN	PHOSPHORUS
ALGAE	0.400	0.080	0.012
ZOOPLANKTON	0.400	0.080	0.012
INSECTS	0.400	0.080	0.012
BENTHOS	0.400	0.080	0.012
FISH	0.400	0.080	0.012
DETR / SED	0.400	0.080	0.012

BIOLOGICAL COEFFICIENTS

	GROWTH 1/DAY	RESPIRATION 1/DAY	MORTALITY NATURAL 1/DAY	MORTALITY TOXICITY 1/DAY/MG/L	HALF SATURATION CONSTANTS LIGHT KCAL/M2/SEC	HALF SATURATION CONSTANTS PO4-P MG/L	HALF SATURATION CONSTANTS NH3+NO3-N MG/L	HALF SATURATION CONSTANTS CO2-C MG/L	SINKING VEL M/SEC	LOSS BY SCOUR 1/DAY/M2/SEC2
PHYTOPLANKTON 1	2.00	0.150		0.000	0.003	0.030	0.060	0.025	0.000	
PHYTOPLANKTON 2	2.50	0.200		0.000	0.004	0.030	0.060	0.025	0.000	
BENTHIC ALGAE 1	1.00	0.070		0.000	0.003	0.030	0.060	0.025		0.020
BENTHIC ALGAE 2	1.20	0.100		0.000	0.004	0.030	0.060	0.025		0.100

	GROWTH 1/DAY	RESPIRATION 1/DAY	MORTALITY NATURAL 1/DAY	MORTALITY TOXICITY 1/DAY/MG/L	HALF SATURATION	GRAZING PREFFERENCE NO 1	GRAZING PREFFERENCE NO 2	GRAZING PREFFERENCE NO 3	ASSIM. EFF	PARTICULATE EXCREATA
ZOOPLANKTON	0.150	0.015	0.010	0.000	0.300	0.50	0.20		0.60	0.60
INSECTS	0.100	0.010	0.005	0.000	1000.000	2.00	0.05		0.60	0.60
BENTHOS	0.030 *	0.008	0.004	0.000	2000.000				0.60	0.60
FISH NO. 1	0.020	0.003	0.002	0.000	0.200	0.005	0.005		0.50	0.60
FISH NO. 2	0.025	0.003	0.002	0.000	0.200	0.005	0.005		0.50	0.60
FISH NO. 3	0.020	0.003	0.002	0.000	500.000	0.001	0.200	0.500	0.50	0.60

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
INSECT EMERGENCE, 1/MONTH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FISH NO. 1 HARVEST, 1/MONTH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FISH NO. 2 HARVEST, 1/MONTH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FISH NO. 3 HARVEST, 1/MONTH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

* INDICATES COEFFICIENT DEFAULT VALUE HAS BEEN OVERRIDDEN BY USER

MISCELLANEOUS COEFFICIENTS

	DECAY RATE, 1/DAY	OXYGEN CONSUMED	CARBON RELEASED
BOD	0.30		0.20
AMMONIA	0.20	3.50	
NITRITE	0.50	1.20	
COLIFORMS	1.00		
DETRITUS	0.020	1.60	
SEDIMENTS	0.005	1.60	
BIOMASS RESPIRATION		1.60	
ALGAL GROWTH		1.60	(PRODUCED)

DETRITUS SETTLING VELOCITY, METERS/DAY 0.000

	ALG 1	ALG 2	ZOO	DETRITUS	SS 1	SS 2	SS 3	SS 4	SS 5
SHADING FACTOR, 1/(MG/L)/M	0.20	0.20	0.02	0.10	0.10 *	0.00	0.00	0.00	0.00

STREAM REAERATION (K 2)

K 2 DETERMINATION OPTION	2	(OCONNER AND DOBBINS)
MINIMUM ALLOWABLE K 2	0.00	
MAXIMUM ALLOWABLE K 2	5.00	
RATIO OF CO2 TO O2 K 2	0.78	
TEMPERATURE COEFFICIENT	1.02	

COEFFICIENT TEMPERATURE ADJUSTMENT PARAMETER

	CALIBRATION MAGNITUDE				CALIBRATION TEMPERATURE			
	K1	K2	K3	K4	T1	T2	T3	T4
ALGAE 1	0.10	0.98	0.98	0.10	5.	22.	25.	34.
ALGAE 2	0.10	0.98	0.98	0.10	10.	28.	30.	40.
ZOOPLANKTON	0.10	0.98	0.98	0.10	5.	28.	30.	38.
INSECTS	0.10	0.98	0.98	0.10	5.	28.	30.	38.
BENTHOS	0.10	0.98	0.98	0.10	5.	22.	25.	38.
FISH 1	0.10	0.98	0.98	0.10	5.	20.	20.	25.
FISH 2	0.10	0.98	0.98	0.10	10.	27.	30.	38.
FISH 3	0.10	0.98	0.98	0.10	5.	22.	30.	36.
BOD	0.10	0.98			4.	30.		
AMMONIA	0.10	0.98			4.	30.		
NITRITE	0.10	0.98			4.	30.		
DETRITUS/SED	0.10	0.98			4.	30.		

Q10 TEMPERATURE ADJUSTMENT FACTORS

COLIFORM DIEOFF	1.040
BOD DECAY	0.000
AMMONIA DECAY	0.000
NITRITE DECAY	0.000
DETRITUS DECAY	0.000
NON GROWTH BIOLOGICAL ACTIVITY	0.000

* INDICATES COEFFICIENT DEFAULT VALUE HAS BEEN OVERRIDDEN BY USER

COEFFICIENT TEMPERATURE ADJUSTMENT

	TEMPERATURE, C																			
	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38
BOD	0.10	0.10	0.10	0.15	0.22	0.31	0.42	0.54	0.65	0.75	0.82	0.88	0.92	0.95	0.97	0.98	0.99	0.99	1.00	1.00
NH3	0.10	0.10	0.10	0.15	0.22	0.31	0.42	0.54	0.65	0.75	0.82	0.88	0.92	0.95	0.97	0.98	0.99	0.99	1.00	1.00
NO2	0.10	0.10	0.10	0.15	0.22	0.31	0.42	0.54	0.65	0.75	0.82	0.88	0.92	0.95	0.97	0.98	0.99	0.99	1.00	1.00
DET	0.10	0.10	0.10	0.15	0.22	0.31	0.42	0.54	0.65	0.75	0.82	0.88	0.92	0.95	0.97	0.98	0.99	0.99	1.00	1.00
COLIF	0.46	0.49	0.53	0.58	0.62	0.68	0.73	0.79	0.85	0.92	1.00	1.08	1.17	1.27	1.37	1.48	1.60	1.73	1.87	2.03
ALG 1, R/M	0.10	0.10	0.10	0.14	0.25	0.40	0.58	0.74	0.85	0.92	0.96	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ALG 2, R/M	0.10	0.10	0.10	0.10	0.10	0.10	0.18	0.30	0.46	0.62	0.77	0.87	0.93	0.96	0.98	0.99	0.99	1.00	1.00	1.00
ALG 1, G	0.10	0.10	0.10	0.14	0.25	0.40	0.58	0.74	0.85	0.92	0.96	0.98	0.98	0.96	0.86	0.62	0.30	0.10	0.00	0.00
ALG 2, G	0.10	0.10	0.10	0.10	0.10	0.10	0.18	0.30	0.46	0.62	0.77	0.87	0.93	0.96	0.97	0.97	0.93	0.81	0.56	0.27
ZOO, R/M	0.10	0.10	0.10	0.13	0.20	0.29	0.41	0.55	0.67	0.78	0.85	0.91	0.94	0.97	0.98	0.99	0.99	1.00	1.00	1.00
ZOO, G	0.10	0.10	0.10	0.13	0.20	0.29	0.41	0.55	0.67	0.78	0.85	0.91	0.94	0.97	0.98	0.97	0.91	0.70	0.34	0.10
BEN, R/M	0.10	0.10	0.10	0.14	0.25	0.40	0.58	0.74	0.85	0.92	0.96	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
BEN, G	0.10	0.10	0.10	0.14	0.25	0.40	0.58	0.74	0.85	0.92	0.96	0.98	0.98	0.96	0.92	0.82	0.65	0.42	0.22	0.10
FISH 1, R/M	0.10	0.10	0.10	0.14	0.27	0.46	0.66	0.81	0.91	0.96	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
FISH 2, R/M	0.10	0.10	0.10	0.10	0.10	0.10	0.19	0.32	0.49	0.66	0.80	0.89	0.94	0.97	0.99	0.99	1.00	1.00	1.00	1.00
FISH 3, R/M	0.10	0.10	0.10	0.14	0.25	0.40	0.58	0.74	0.85	0.92	0.96	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
FISH 1, G	0.10	0.10	0.10	0.14	0.27	0.46	0.66	0.81	0.91	0.95	0.96	0.80	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FISH 2, G	0.10	0.10	0.10	0.10	0.10	0.10	0.19	0.32	0.49	0.66	0.80	0.89	0.94	0.97	0.98	0.97	0.91	0.70	0.34	0.10
FISH 3, G	0.10	0.10	0.10	0.14	0.25	0.40	0.58	0.74	0.85	0.92	0.96	0.98	0.99	0.99	0.99	0.98	0.87	0.46	0.10	0.00
INSECTS, G	0.10	0.10	0.10	0.13	0.20	0.29	0.41	0.55	0.67	0.78	0.85	0.91	0.94	0.97	0.98	0.99	0.99	1.00	1.00	1.00
INSECTS R/M	0.10	0.10	0.10	0.13	0.20	0.29	0.41	0.55	0.67	0.78	0.85	0.91	0.94	0.97	0.98	0.97	0.91	0.70	0.34	0.10

INORGANIC SUSPENDED SOLIDS

NUMBER	FALL VELOCITY, CM/SEC AT THREE TEMPERATURES, C						PARTICLE SIZE, MM	CRIT DEPOSITION VEL. M/SEC	COMPUTATION METHOD
1	0.001	10.	0.001	22.	0.001	30.	0.002	0.00	DEPOSITION ONLY

```
FIRST DAY OF INFLOW QUALITY RECORD    56/ 9/13
FINAL DAY OF INFLOW QUALITY RECORD    56/ 9/16
TOTAL NUMBER OF DAYS                     4

      1 CARDS READ FOR   ELK CITY STP TEMPERATURE            ( TEMP )
      1 CARDS READ FOR   ELK CITY STP DO                     ( OXY  )
      1 CARDS READ FOR   ELK CITY STP BOD                    ( BOD  )
      1 CARDS READ FOR   ELK CITY STP COLIFORMS              ( COL  )
      1 CARDS READ FOR   ELK CITY STP DETRITUS               ( DET  )
      1 CARDS READ FOR   ELK CITY STP AMMONIA                ( NH3  )
      1 CARDS READ FOR   ELK CITY STP NITRATE                ( NO3  )
      1 CARDS READ FOR   ELK CITY STP PHOSPHATE              ( PO4  )
      1 CARDS READ FOR   ELK CITY STP TDS                    ( TDS  )
      1 CARDS READ FOR   ELK CITY STP PH                     ( PH   )
      1 CARDS READ FOR   ELK CITY STP ALKALINITY             ( ALK  )
      1 CARDS READ FOR   ELK CITY STP SSOL NO 1              ( SS 1 )
      3 CARDS READ FOR   SUTTER CREEK TEMPERATURE            ( TEMP )
      1 CARDS READ FOR   SUTTER CREEK DO                     ( OXY  )
      1 CARDS READ FOR   SUTTER CREEK BOD                    ( BOD  )
      1 CARDS READ FOR   SUTTER CREEK COLIFORMS              ( COL  )
      1 CARDS READ FOR   SUTTER CREEK DETRITUS               ( DET  )
      1 CARDS READ FOR   SUTTER CREEK AMMONIA                ( NH3  )
      1 CARDS READ FOR   SUTTER CREEK NITRATE                ( NO3  )
      1 CARDS READ FOR   SUTTER CREEK PHOSPHATE              ( PO4  )
      1 CARDS READ FOR   SUTTER CREEK TDS                    ( TDS  )
      1 CARDS READ FOR   SUTTER CREEK PH                     ( PH   )
      1 CARDS READ FOR   SUTTER CREEK ALKALINITY             ( ALK  )
      1 CARDS READ FOR   SUTTER CREEK SSOL NO 1              ( SS 1 )
TIME ( MONTH/DAY/HOUR ) VS. INFLOW QUALITY ( APPROPRIATE UNITS )
CONSTITUENT  TRIB NO.       TIME      CONC      TIME      CONC      TIME      CONC      TIME      CONC      TIME      CONC

     TEMP         1        9/13/ 0   78.00

     OXY          1        9/13/ 0    6.00

     BOD          1        9/13/ 0   -8.00

     COL          1        9/13/ 0 0.50E+03

     DET          1        9/13/ 0    5.00

     NH3          1        9/13/ 0   0.500

     NO3          1        9/13/ 0   0.500

     PO4          1        9/13/ 0   0.250
```

TDS	1	9/13/ 0	1500.								
PH	1	9/13/ 0	7.0								
ALK	1	9/13/ 0	100.0								
SS 1	1	9/13/ 0	20.0								
TEMP	2	9/13/ 0	66.00	9/13/ 4	65.00	9/13/ 8	68.00	9/14/12	71.00	9/14/16	70.00
TEMP	2	9/14/20	68.00	9/14/ 0	65.00	9/14/ 4	64.00	9/14/ 8	67.00	9/15/12	71.00
TEMP	2	9/15/16	70.00	9/15/20	67.00	9/15/ 0	66.00	9/15/ 4	64.00	9/15/ 8	67.00
TEMP	2	9/16/12	70.00	9/16/16	69.00	9/16/20	68.00	9/16/ 0	66.00	9/16/ 4	65.00
TEMP	2	9/16/ 8	68.00	9/17/12	71.00	9/17/16	70.00	9/17/20	68.00	9/17/ 0	0.00
OXY	2	9/13/ 0	-0.95								
BOD	2	9/13/ 0	-2.00								
COL	2	9/13/ 0	0.10E+03								
DET	2	9/13/ 0	1.00								
NH3	2	9/13/ 0	0.020								
NO3	2	9/13/ 0	0.200								
PO4	2	9/13/ 0	0.030								
TDS	2	9/13/ 0	500.								
PH	2	9/13/ 0	7.6								
ALK	2	9/13/ 0	60.0								
SS 1	2	9/13/ 0	2.0								

METEOROLOGICAL DATA

DATE	TIME	CLOUD COVER	DRY BULB TEMP, F	DEW / WET TEMP, F	PRESSURE IN HG	WIND SPEED MPH
56/ 9/13	0	0.30	70.00	61.00	30.00	3.00
	4	0.30	66.00	60.00	30.00	3.00
	8	0.20	78.00	62.00	30.00	6.00
	12	0.10	92.00	63.00	30.00	6.00
	16	0.10	88.00	64.00	30.00	9.00
	20	0.20	74.00	62.00	30.00	9.00

INITIAL CONDITIONS

COMPREHENSIVE SUMMARY OF INFLOW AND STREAM QUALITY

ELEM	TEMPERATURE WATER C	TEMPERATURE BOTTOM C	OXYGEN MG/L	BOD5 MG/L	COLIF MPN	INORGANIC SUSPENDED SOLIDS NO 1 MG/L	NO 2 MG/L	NO 3 MG/L	NO 4 MG/L	NO 5 MG/L	DETRITUS MG/L	SEDIMENT INORG G/M2	SEDIMENT ORG G/M2	TDS MG/L	ALKA MG/L	PH UNITS	TIC MG/L	CO2 MG/L
1	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
2	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
3	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
4	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
5	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
6	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
7	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
8	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
9	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
10	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
11	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
12	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
13	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
14	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
15	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
16	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
17	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
18	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
19	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
20	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
21	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
22	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
23	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
24	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
25	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
26	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
27	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
28	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
29	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
30	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
31	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
32	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
33	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
34	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
35	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
36	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
37	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821
38	20.0	20.0	9.0	1.00	2.	5.0	0.0	0.0	0.0	0.0	4.0	0.	10.	500.	50.	7.5	12.8	0.821

ELEM	NH3-N MG/L	NO3-N MG/L	PO4-P MG/L	TOXIC MG/L	ALGAE NO 1 MG/L	ALGAE NO 2 MG/L	ZOOPLANK MG/L	BENTHIC ALGAE NO 1 MG/M2	BENTHIC ALGAE NO 2 MG/M2	INSECT MG/M2	BENTHOS MG/M2	FISH NO 1 KG	FISH NO 2 KG	FISH NO 3 KG	FISH GROWTH RATE NO 1 KG/MO	FISH GROWTH RATE NO 2 KG/MO	FISH GROWTH RATE NO 3 KG/MO
1	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
25	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
26	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
27	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
28	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
29	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
30	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
31	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
32	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
33	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
34	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
35	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
36	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
37	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0
38	0.050	0.200	0.020	0.000	0.100	0.100	0.001	500.	1000.	400.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0

MAX VOLUME REPLACEMENT OF 10.5 AT HOUR 20.0, ELEMENT i. TIME STEP IS NOW 0.7 HOURS

SIMULATION RESULTS FOR DAY 258, HOUR 4

METEOROLOGICAL DATA

SHORTWAVE SOLAR RAD, KCAL/M2/SEC	0.0000
LONGWAVE ATMOS RAD, KCAL/M2/SEC	0.0775
WIND SPEED, METERS/SEC	1.3
DRY BULB TEMPERATURE, C	19.1
WET BULB TEMPERATURE, C	15.6
EVAPORATION RATE, METERS/MONTH	0.000
ACCUMULATIVE EVAPORATION, METERS	0.000

STREAM HYDRAULICS

ELEMENT	REACH	MILE	MEAN DEP METERS	SLOPE M/M	AREA K SQ M	VOLUME K CU M	MEAN VEL M/SEC	MEAN FLOW M3/SEC	US FLOW M3/SEC	DS FLOW M3/SEC	INFLOW M3/SEC	OUTFLOW M3/SEC	DVDT M3/SEC	OXY K2 1/DAY
1	1	365.7	1.07	0.00023	9.	8.	0.37	3.58	0.00	3.77	3.40	0.00	-0.37	2.16
2	1	365.2	1.11	0.00024	9.	8.	0.38	3.95	3.77	4.14	0.00	0.00	-0.37	2.07
3	1	364.7	1.15	0.00024	9.	9.	0.39	4.33	4.14	4.51	0.00	0.00	-0.37	1.99
4	1	364.2	1.19	0.00024	10.	10.	0.40	4.70	4.51	4.88	0.00	0.00	-0.37	1.92
5	1	363.7	1.23	0.00024	10.	10.	0.41	5.07	4.88	5.25	0.00	0.00	-0.37	1.85
6	1	363.2	1.26	0.00025	10.	11.	0.41	5.44	5.25	5.62	0.00	0.00	-0.37	1.80
7	1	362.7	1.29	0.00025	10.	11.	0.42	5.81	5.62	5.99	0.00	0.00	-0.37	1.75
8	1	362.2	1.30	0.00031	11.	11.	0.45	6.18	5.99	5.74	0.00	0.62	-0.37	1.80
9	1	361.5	1.30	0.00027	21.	22.	0.43	5.93	5.74	6.11	0.00	0.00	-0.37	1.75
10	1	360.5	1.39	0.00019	24.	25.	0.47	7.30	6.11	7.98	0.51	0.00	-1.36	1.65
11	1	359.5	1.52	0.00022	27.	29.	0.48	8.66	7.98	9.34	0.00	0.00	-1.36	1.45
12	1	358.5	1.62	0.00023	30.	32.	0.50	10.02	9.34	10.70	0.00	0.00	-1.36	1.35
13	1	357.5	1.71	0.00023	32.	35.	0.52	11.38	10.70	12.06	0.00	0.00	-1.36	1.27
14	1	356.5	1.77	0.00026	34.	38.	0.53	12.31	12.06	12.57	0.00	0.00	-0.52	1.22
15	1	355.5	1.80	0.00026	35.	39.	0.53	12.83	12.57	13.09	0.00	0.00	-0.52	1.19
16	1	354.5	1.83	0.00026	36.	40.	0.54	13.35	13.09	13.61	0.00	0.00	-0.52	1.17
17	1	353.5	1.86	0.00027	37.	41.	0.54	13.87	13.61	14.13	0.00	0.00	-0.52	1.15
18	1	352.5	1.89	0.00027	38.	42.	0.55	14.39	14.13	14.65	0.00	0.00	-0.52	1.13
19	1	351.5	1.90	0.00028	39.	43.	0.55	14.65	14.65	14.65	0.00	0.00	0.00	1.12
20	1	350.5	1.91	0.00028	39.	43.	0.55	14.65	14.65	14.65	0.00	0.00	0.00	1.12
21	1	349.5	1.91	0.00028	39.	43.	0.55	14.65	14.65	14.65	0.00	0.00	0.00	1.12
22	1	348.5	1.91	0.00028	39.	43.	0.55	14.65	14.65	14.65	0.00	0.00	0.00	1.12
23	2	107.5	1.31	0.00038	18.	12.	0.46	3.40	0.00	3.40	3.40	0.00	0.00	1.78
24	2	106.5	1.31	0.00038	17.	12.	0.46	3.40	3.40	3.40	0.00	0.00	0.00	1.79
25	2	105.5	1.31	0.00038	17.	12.	0.46	3.40	3.40	3.40	0.00	0.00	0.00	1.80
26	2	104.5	1.30	0.00038	17.	12.	0.46	3.40	3.40	3.40	0.00	0.00	0.00	1.80
27	2	103.5	1.30	0.00038	17.	12.	0.46	3.40	3.40	3.40	0.00	0.00	0.00	1.81
28	2	102.5	1.30	0.00038	16.	12.	0.46	3.40	3.40	3.40	0.00	0.00	0.00	1.82
29	2	101.5	1.30	0.00038	16.	12.	0.47	3.40	3.40	3.40	0.00	0.00	0.00	1.82
30	2	100.5	1.30	0.00038	16.	12.	0.47	3.40	3.40	3.40	0.00	0.00	0.00	1.83

31	3	347.5	2.44	0.00024	49.	66.	0.43	17.75	18.05	17.45	0.00	0.00	0.60	0.68
32	3	346.5	2.36	0.00024	53.	67.	0.41	17.15	17.45	16.84	0.00	0.00	0.60	0.70
33	3	345.5	2.29	0.00023	57.	68.	0.39	16.54	16.84	16.24	0.00	0.00	0.60	0.72
34	3	344.5	2.22	0.00023	61.	68.	0.38	15.94	16.24	15.64	0.00	0.00	0.60	0.73
35	3	343.5	2.16	0.00023	61.	66.	0.37	15.25	15.64	14.86	0.00	0.00	0.78	0.76
36	3	342.5	2.09	0.00024	59.	62.	0.38	14.47	14.86	14.08	0.00	0.00	0.78	0.80
37	3	341.5	2.02	0.00023	56.	58.	0.38	13.68	14.08	13.29	0.00	0.00	0.78	0.85
38	3	340.5	1.95	0.00023	54.	54.	0.38	12.90	13.29	12.51	0.00	0.00	13.29	0.90

INFLOW AND WITHDRAWAL RATES AND QUALITY

ELEMENT	INFLOW CMS	WITHDRAWAL CMS	TEMPERATURE C	OXYGEN MG/L	BOD5 MG/L	COLIFORMS MPN/100ML	INORGANIC SUSPENDED SOLIDS NO 1 MG/L	NO 2 MG/L	NO 3 MG/L	NO 4 MG/L	NO 5 MG/L	DETRITUS MG/L
1	3.40		12.7	6.5	0.0	0.000E+01	0.4	0.0	0.0	0.0	0.0	0.4
8		0.62	12.8	7.7	0.0	0.603E-06	0.4	0.0	0.0	0.0	0.0	0.4
10	0.51		25.6	6.0	8.0	0.500E+03	20.0	0.0	0.0	0.0	0.0	5.0
23	3.40		17.8	9.1	2.0	0.100E+03	2.0	0.0	0.0	0.0	0.0	1.0

ELEMENT	INFLOW CMS	WITHDRAWAL CMS	TDS MG/L	ALKA MG/L	PH UNITS	TIC MG/L	CO2-C MG/L	NH3-N MG/L	NO2-N MG/L	NO3-N MG/L	PO4-P MG/L	TOXIC MG/L	PHYTOPLANKTON NO 1 MG/L	NO 2 MG/L	ZOOPLANK MG/L
1	3.40		302.	48.	7.1	13.5	2.098	0.039	0.015	0.147	0.025	0.00	0.060	0.021	0.001
8		0.62	302.	48.	7.2	13.1	1.661	0.039	0.015	0.147	0.025	0.00	0.060	0.021	0.001
10	0.51		1500.	100.	7.0	28.8	4.907	0.500	0.000	0.500	0.250	0.00	0.000	0.000	0.000
23	3.40		500.	60.	7.6	15.2	0.810	0.020	0.000	0.200	0.030	0.00	0.000	0.000	0.000

ABBREVIATED SUMMARY OF INFLOW AND STREAM QUALITY

ELEM	TEMP C	OXYGEN MG/L	BOD5 MG/L	COLIF MPN	TSS MG/L	TDS MG/L	ALKA MG/L	PH UNITS	TIC-C MG/L	TOT N MG/L	PO4-P MG/L	ALGAE MG/L	B ALGAE MG/M2	ZOO MG/L	INSECTS MG/M2	BENTHOS MG/M2	FISH KG
1	12.7	6.7	0.01	0.	1.	302.	48.	7.2	13.4	0.201	0.025	0.081	1525.	0.001	401.2	200.5	0.0
2	12.7	7.0	0.01	0.	1.	302.	48.	7.2	13.4	0.201	0.025	0.081	1525.	0.001	401.3	200.5	0.0
3	12.8	7.2	0.01	0.	1.	302.	48.	7.2	13.3	0.201	0.025	0.081	1526.	0.001	401.3	200.5	0.0
4	12.8	7.3	0.01	0.	1.	302.	48.	7.2	13.2	0.201	0.025	0.081	1526.	0.001	401.4	200.5	0.0
5	12.8	7.5	0.01	0.	1.	302.	48.	7.2	13.2	0.201	0.025	0.081	1527.	0.001	401.4	200.6	0.0
6	12.8	7.6	0.01	0.	1.	302.	48.	7.2	13.1	0.201	0.025	0.081	1527.	0.001	401.4	200.6	0.0
7	12.8	7.6	0.01	0.	1.	302.	48.	7.2	13.1	0.201	0.025	0.081	1528.	0.001	401.5	200.6	0.0
8	12.8	7.7	0.01	0.	1.	302.	48.	7.2	13.1	0.201	0.025	0.081	1527.	0.001	401.5	200.6	0.0
9	12.9	7.8	0.01	0.	1.	302.	48.	7.3	13.0	0.201	0.025	0.081	1532.	0.001	401.6	200.7	0.0
10	13.7	7.8	0.51	31.	2.	378.	51.	7.2	14.0	0.252	0.039	0.075	1540.	0.001	401.8	200.8	0.0
11	13.6	7.8	0.43	26.	2.	366.	50.	7.3	13.8	0.244	0.037	0.076	1546.	0.001	401.8	200.8	0.0
12	13.6	7.9	0.38	22.	2.	358.	50.	7.3	13.7	0.239	0.036	0.077	1552.	0.001	401.9	200.8	0.0
13	13.6	7.9	0.34	19.	2.	353.	50.	7.3	13.6	0.235	0.035	0.077	1557.	0.001	402.0	200.9	0.0
14	13.6	7.9	0.31	18.	2.	349.	50.	7.3	13.5	0.232	0.034	0.078	1562.	0.001	402.1	200.9	0.0

15	13.7	8.0	0.29	16.	2.	345.	50.	7.3	13.5	0.230	0.033	0.078	1567.	0.001	402.1	200.9	0.0
16	13.8	8.0	0.28	15.	2.	343.	49.	7.3	13.4	0.228	0.033	0.079	1572.	0.001	402.2	201.0	0.0
17	13.9	8.1	0.26	14.	2.	341.	49.	7.3	13.4	0.227	0.032	0.079	1576.	0.001	402.3	201.0	0.0
18	14.1	8.1	0.25	13.	2.	340.	49.	7.3	13.3	0.226	0.032	0.080	1581.	0.001	402.3	201.0	0.0
19	14.3	8.2	0.25	13.	2.	339.	49.	7.3	13.3	0.225	0.032	0.080	1586.	0.001	402.4	201.1	0.0
20	14.5	8.2	0.24	12.	2.	339.	49.	7.3	13.2	0.224	0.032	0.081	1591.	0.001	402.5	201.1	0.0
21	14.8	8.3	0.24	12.	2.	339.	49.	7.3	13.2	0.224	0.032	0.082	1595.	0.001	402.5	201.1	0.0
22	15.1	8.3	0.24	12.	2.	339.	49.	7.3	13.2	0.224	0.032	0.083	1599.	0.001	402.6	201.1	0.0
23	17.9	9.1	1.99	97.	3.	500.	60.	7.6	15.1	0.220	0.030	0.000	1594.	0.000	402.7	201.2	0.0
24	17.9	9.1	1.99	95.	3.	500.	60.	7.6	15.1	0.221	0.030	0.000	1596.	0.000	402.7	201.2	0.0
25	18.0	9.1	1.98	92.	3.	500.	60.	7.7	15.1	0.221	0.030	0.000	1597.	0.000	402.8	201.2	0.0
26	18.2	9.0	1.97	90.	3.	500.	60.	7.7	15.0	0.222	0.030	0.000	1598.	0.000	402.8	201.2	0.0
27	18.3	9.0	1.97	88.	3.	500.	60.	7.7	15.0	0.222	0.030	0.000	1598.	0.000	402.8	201.2	0.0
28	18.5	9.0	1.96	85.	3.	500.	60.	7.7	15.0	0.222	0.030	0.000	1597.	0.000	402.9	201.3	0.0
29	18.7	8.9	1.95	83.	3.	500.	60.	7.7	15.0	0.222	0.030	0.000	1596.	0.000	402.9	201.3	0.0
30	18.9	8.9	1.94	81.	3.	500.	60.	7.7	14.9	0.222	0.030	0.000	1595.	0.000	402.9	201.3	0.0
31	16.2	8.4	0.58	24.	2.	371.	51.	7.4	13.5	0.224	0.031	0.068	1606.	0.001	402.7	201.2	0.0
32	16.6	8.4	0.60	24.	2.	375.	52.	7.4	13.5	0.225	0.032	0.070	1607.	0.001	402.8	201.2	0.0
33	17.1	8.5	0.64	25.	2.	382.	52.	7.4	13.5	0.227	0.032	0.072	1608.	0.001	402.8	201.2	0.0
34	17.6	8.5	0.70	25.	3.	394.	52.	7.4	13.5	0.231	0.033	0.076	1609.	0.001	402.8	201.2	0.0
35	18.1	8.6	0.79	26.	3.	409.	53.	7.5	13.6	0.235	0.033	0.082	1609.	0.001	402.9	201.3	0.0
36	18.6	8.6	0.88	27.	4.	426.	53.	7.5	13.6	0.241	0.034	0.089	1609.	0.001	402.9	201.3	0.0
37	19.1	8.7	0.98	28.	4.	445.	54.	7.6	13.6	0.246	0.034	0.097	1609.	0.001	402.9	201.3	0.0
38	19.5	8.7	1.07	29.	5.	462.	54.	7.6	13.6	0.251	0.034	0.106	1609.	0.001	403.0	201.3	0.0

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APPENDIX A

Mathematical Formulations and Numerical Methods used in the Stream Hydraulics

Appendix A

Mathematical Formulations and Numerical Methods used in the Stream Hydraulics

BACKWATER SOLUTION

For the purposes of backwater analysis, steady state can be assued and the time dependent terms $\frac{\partial q}{\partial t}$ and $\frac{\partial A}{\partial t}$ may be deleted. Because the flow is assumed to be known at all points in the stream section, the principal unknown of equation II-15 is the depth y. Equation II-15 can then be written in terms of $\frac{\partial y}{\partial x}$ as

$$\frac{\partial y}{\partial x} = \frac{\left(- qA^{-2} \frac{\partial q}{\partial x} + q^2 A^{-3} \frac{\partial A}{\partial x} - g \frac{\partial a}{\partial x} - g\, q^2 n^2 A^{-2} R^{-4/3} - M \right)}{g - q^2 A^{-3} \frac{\partial A}{\partial y}} \qquad \text{A-1}$$

Note that in steady state $\frac{\partial q}{\partial x}$ represents the rate of tributary inflow. Thus if it is assumed that $\frac{\partial q}{\partial x} > 0$, there is tributary inflow and its momentum effect may be approximated by

$$M = q\, A^{-2} \frac{\partial q}{\partial x} \qquad \text{A-2}$$

if $\frac{\partial q}{\partial x} < 0$ there is flow withdrawal and no momentum effect. Thus M = 0.

Equation A-1 may thus be rewritten as

$$\frac{\partial y}{\partial x} = \frac{- \frac{Cq}{gA^2} \frac{\partial q}{\partial x} + \frac{q^2}{gA^3} \frac{\partial A}{\partial x} - \frac{\partial a}{\partial x} - q^2 n^2 A^{-2} R^{-4/3}}{\left(1 - \frac{q^2}{gA^3} \frac{\partial A}{\partial y} \right)} \qquad \text{A-3}$$

where

$$C = 1 \quad \text{if } \frac{\partial q}{\partial x} < 0$$

$$C = 2 \quad \text{if } \frac{\partial q}{\partial x} > 0$$

The "trapezoidal method" of integration is used to develop the water surface profile y. In this process the depth y at point 2 is estimated from the depth y at point 1 and the average slope of the water surface between 1 and 2.

Thus $$y_2 = y_1 + \frac{\partial \bar{y}}{\partial x} \Delta x \qquad \text{A-4}$$

where

Δx is the selected integration length along the channel.

Assuming that $$\frac{\partial \bar{y}}{\partial x} = \frac{1}{2} \left[\left(\frac{\partial y}{\partial x}\right)_1 + \left(\frac{\partial y}{\partial x}\right)_2 \right] \qquad \text{A-5}$$

where

points 1 and 2 define the end points of the gradient. The value for y_2 can be estimated by the four steps given below.

1. Compute $\left(\frac{\partial y}{\partial x}\right)_1$ using y_1 which is already known with equation A-3
2. Assume $\left(\frac{\partial y}{\partial x}\right)_2 = \left(\frac{\partial y}{\partial x}\right)_1$
3. Compute y_2 using equation A-4
4. If first iteration, compute new estimate of $\left(\frac{\partial y}{\partial x}\right)_2$. On subsequent iterations check for convergence of y_2 before computing $\left(\frac{\partial y}{\partial x}\right)_2$ and repeating from step 3.

In practice, in order to assure convergence, the integration length Δx is selected to be less or equal to 200 feet.

ST. VENANT METHOD

The finite element method assumes particular approximating functions for each of the unknown variables. Through the solution procedure certain criteria, which are uniquely coupled to the governing differential equations, must be satisfied by these approximating functions. Example constraints on these assumed approximations include the satisfaction of known boundary conditions of the function and continuity of the function and one or more of its derivatives throughout the element and at the element interface. By forcing these types of conditions on the approximating functions within the solution domain, the number of nodes is exactly prescribed for each element. In general, as the order of the approximating functions increase, the greater the number of nodes necessary to force satisfaction of the solution conditions.

For a simple linear approximation of the unknown variables in certain governing equations, the solution conditions may all be satisfied by placing nodes only at the extreme ends of each element. The resulting element form is then restricted to linear variations of the unknowns. The approximating functions are exactly described by finding the solution for the unknown variables at each of the prescribed node points. In choosing higher orders of approximating functions for the unknown variables, additional nodes will be required within each element to insure satisfaction of the solution conditions. By selecting a finite order to the unknown approximating functions, the infinite problem has been reduced to one of finite degree. If the unknown functions are required to be continuous over the element interface as a solution condition, then the number of unknowns exactly equals the number of nodes multiplied by the number of unknown variables.

In its final form, the finite element method coupled with the selection of the best approximation of the unknown functions always leads to a set of simultaneous equations assembled from individual coefficient matrices developed for each element. The essence of the finite element method is the construction of these element coefficient matrices which, when assembled, lead to the solution which is the "best" approximation of the governing differential equation.

For the present problem, a quadratic approximating function has been selected for both of the unknowns (i.e., flow and depth). Thus, a three node element is used with values of the unknowns being defined at either end and at the middle. Figure A-1 defines the element and the location of the principal parameters.

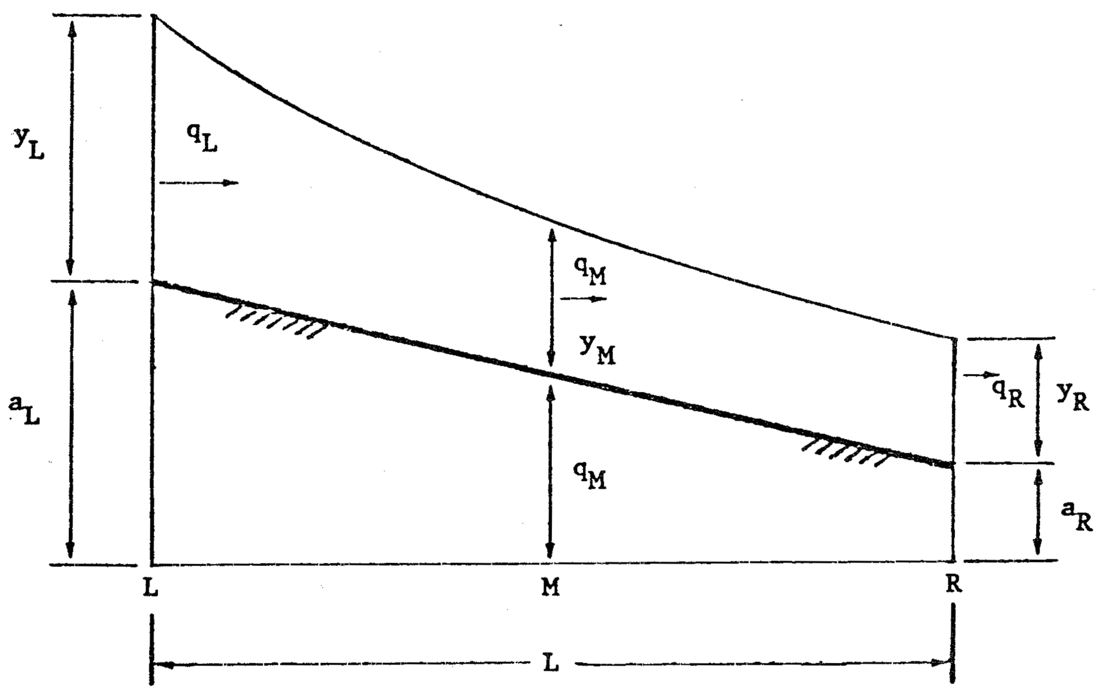


Figure A-1. Definition of Element

The approximation of the unknowns q and y over each element are expressed as geometric functions multiplied by the unknown values of q and y at the node points L, M, N, i.e.,

$$y = [N] \begin{Bmatrix} y_L \\ y_M \\ y_R \end{Bmatrix} \qquad q = [N] \begin{Bmatrix} q_L \\ q_M \\ q_R \end{Bmatrix} \qquad \text{A-6}$$

where N is a row vector describing the quadratic approximation

$$[N] = \left[\frac{1}{L^2} (1-2x)(1-x), \ \frac{4}{L^2} x(1-x), \ \frac{1}{L^2} x(2x-1) \right] \qquad \text{A-7}$$

For one-dimensional equations, the Method of Weighted Residuals is used to express a differential equation, D = 0, as an integral equation.

$$\int_{\text{length}} w \cdot D \, dx = 0 \qquad \text{for all } w \qquad \text{A-8}$$

In particular, if a series of w's are specified which have unit value at one node and are zero everywhere else, a series of equations may be derived, i.e.,

$$\int_{\text{length}} w_i \, D \, dx = 0 \qquad \text{for } i = 1, \text{ number of node points}$$

Thus, each element makes a contribution f to these equations defined as

$$f_e = \int_{\substack{\text{element}\\ \text{length}}} w_i \, D \, dx \qquad \text{A-9}$$

In this case w_i applies twice at each node, because there are two unknowns at each node in the element and f_e has two rows (i.e., flow and depth) for each node. In the Galerkin approach w_i is set equal to the shape functions for each element, and so, separates f into two components, one for flow and one for depth.

$$f_1 = \int_0^L N^T \left[A^2 \frac{\partial q}{\partial t} - Aq \frac{\partial A}{\partial t} + Aq \frac{\partial q}{\partial x} - q^2 \left[\frac{\partial A}{\partial x} + \frac{\partial A}{\partial y} \frac{\partial y}{\partial x} \right] \right.$$

$$\left. + gA^3 \left(\frac{\partial a}{\partial x} + \frac{\partial y}{\partial x} - q|q|/q_F^2 \frac{\partial a_o}{\partial x} \right) \right] dx \qquad \text{A-10}$$

$$f_2 = \int_0^L N^T \left[\frac{\partial q}{\partial x} + \frac{\partial B}{\partial t} - s \right] dx \qquad \text{A-11}$$

where

q_F = equivalent flow based upon Manning's equation

$= \left(- \frac{\partial a_o}{\partial x}\right)^{1/2} \cdot \frac{AR^{2/3}}{n}$

$\frac{\partial a_o}{\partial x}$ = effective bottom slope

B = total channel area including area outside the conveyance limits

Direct formulation of $\int N^T g A^3 \frac{\partial y}{\partial x} dx$ is not always convenient for specification of boundary values and thus it is convenient to apply integration by parts to equation A-10.

Thus,

$$\int_0^L N^T g A^3 \frac{\partial y}{\partial x} dx = N^T g A^3 y \Big|_0^L - \int \left\{ \left(\frac{\partial N}{\partial x} \right)^T g A^3 y \right.$$

$$\left. + N^T g\, 3A^2 \left(\frac{\partial A}{\partial x} + \frac{\partial A}{\partial y} \frac{\partial y}{\partial x} \right) y \right\} dx \qquad \text{A-12}$$

$$\text{and} \quad f_1 = \int_0^L \left[N^T \left(A^2 \frac{\partial q}{\partial t} - Aq \frac{\partial A}{\partial t} + Aq \frac{\partial q}{\partial x} - q^2 \left(\frac{\partial A}{\partial x} + \frac{\partial A}{\partial y} \frac{\partial y}{\partial x} \right) \right. \right.$$

$$gA^3 \frac{\partial a}{\partial x} - gA^3 \frac{\partial a_o}{\partial x} q|q|/q_{f^2} - 3gA^2 \left(\frac{\partial A}{\partial x} + \frac{\partial A}{\partial y} \frac{\partial y}{\partial x} \right) y \Big)$$

$$- \left(\frac{\partial N}{\partial x} \right)^T gA^3 y \Big] dx + N^T g A^3 y \Big|_0^L \qquad \text{A-13}$$

Equations A-10 and A-11 are time dependent and an implicit finite difference scheme has been incorporated to describe the dynamic aspects. In this procedure a time step Δt is used and it is assumed that the values of q and y vary in the following form over this time step:

$$y = y_1 + a\, t + b\, t^{\alpha} \qquad \text{A-14}$$

where subscript $_1$ represents the initial condition, then

$$\frac{\partial y}{\partial t} = a + \alpha\, b\, t^{\alpha-1} \qquad \text{A-15}$$

substituting equation A-14 into A-15 to eliminate b

$$\frac{\partial y}{\partial t} = a + \frac{\alpha}{t} (y - y_1) - \alpha a \qquad \text{A-16}$$

$$\text{and at } t = 0 \quad \frac{\partial y}{\partial t_1} = a \qquad \text{A-17}$$

Then, in particular, y at time Δt, using subscript $_2$

$$\left(\frac{\partial y}{\partial t}\right)_2 = \frac{\alpha}{\Delta t}\,(\,y_2 - y_1\,) + (\,1 - \alpha\,)\left(\frac{\partial y}{\partial t}\right)_1 \qquad \text{A-18}$$

Note that if $\alpha = 1$, this reduces to the conventional linear integration scheme and if $\alpha = 2$, the scheme is identical to the quadratic integration method. In this analysis, $\alpha = 1.5$ has been found stable for large time steps and also to give good accuracy.

The dynamic formulation used in this solution solves for the values of q and y at the end of the time step, thus it is convenient to substitute for $\frac{\partial y}{\partial t}$, and the $\frac{\partial q}{\partial t}$.

For future reference note that

$$\frac{\partial}{\partial y_n}\left(\frac{\partial y}{\partial t}\right) = \frac{\alpha N}{\Delta t} \qquad \text{A-19}$$

where y_n represents the nodal value of y.

Because equation A-13 is nonlinear, the Newton Raphson method has been used to reduce the nonlinear set of simultaneous equations to a purely simultaneous form which are the subject of an iteration technique to reach a converged form. Instead of solving an assemblage of f_1, and f_2, a set of partial differentials with respect to the unknowns q and y at each node must be formed.

Thus, $$\frac{\partial f}{\partial q}\,\Delta q + \frac{\partial f}{\partial y}\,\Delta y + f = 0 \qquad \text{A-20}$$

must be constructed and solved. f now stands for an error function representing the lack of fit of the equations.

The element coefficient matrix for this two degrees of freedom system will then be

$$\begin{bmatrix} \dfrac{\partial f_1}{\partial q_n} & \dfrac{\partial f_1}{\partial y_n} \\[2ex] \dfrac{\partial f_2}{\partial q_n} & \dfrac{\partial f_2}{\partial y_n} \end{bmatrix}$$

and the contribution to the error function will be f_1 and f_2.

$$\frac{\partial}{\partial y_n} A = \frac{\partial A}{\partial y} N \qquad \text{A-21}$$

$$\frac{\partial}{\partial y_n} \left(\frac{\partial y}{\partial x} \right) = \frac{\partial N}{\partial x} \qquad \text{A-22}$$

$$\frac{\partial}{\partial y_n} \left(q_f^{-2} \right) = - 2\, q_f^{-3} \frac{\partial q}{\partial y} N \qquad \text{A-23}$$

Then from equation A-13 and using equation A-19 for time dependence

$$\frac{\partial f_1}{\partial q_n} = \int_0^L N^T \left(A^2 \frac{\alpha N}{\Delta t} - A \frac{\partial A}{\partial t} + Aq \frac{\partial N}{\partial x} + A \frac{\partial q}{\partial x} N - 2q \left(\frac{\partial A}{\partial x} + \frac{\partial A}{\partial y} \frac{\partial y}{\partial x} \right) N \right.$$

$$\left. - 2|q| g A^3 \frac{\partial a}{\partial x} q_f^{-2} N \right) dx \qquad \text{A-24}$$

$$\frac{\partial f_1}{\partial y_n} = \int_0^L [\ N^T \left(\frac{\partial q}{\partial t} \cdot 2A \frac{\partial A}{\partial y} N - Aq \frac{\alpha N}{\Delta t} - q \frac{\partial A}{\partial y} \frac{\partial y}{\partial t} N + q \frac{\partial q}{\partial x} \frac{\partial A}{\partial y} N - q^2 \left(\frac{\partial^2 A}{dxdy} N \right.\right.$$

$$+ \frac{\partial^2 A}{\partial y^2} \frac{\partial y}{\partial x} N + \frac{\partial A}{\partial y} \frac{\partial N}{\partial x} \Big) + \left(\frac{\partial a}{\partial x} - q|q|qf^{-2} \frac{\partial a_o}{\partial x} \right) 3gA^3 \frac{\partial A}{\partial y} N + gA^3 \frac{\partial a_o}{\partial x} q|q|$$

$$.2q_f^{-3} \frac{\partial q_f}{\partial y} N - 3gA^2 \left(\frac{\partial A}{\partial x} + \frac{\partial A}{\partial y} \frac{\partial y}{\partial x} + \frac{\partial^2 A}{\partial x \partial y} y + \frac{\partial^2 A}{\partial y^2} \frac{\partial y}{\partial x} y \right) N$$

$$- 3gA^2 \frac{\partial A}{\partial y} y \frac{\partial N}{\partial x} - 6\ gA \frac{\partial A}{\partial y} \left(\frac{\partial A}{\partial x} + \frac{\partial A}{\partial y} \frac{\partial y}{\partial x} \right) y\ N \Big) - \left(\frac{\partial N}{\partial x} \right)^T$$

$$(gA^3 N + 3gA^2 \frac{\partial A}{\partial y} y\ N\ )\ ]\ dx + N^T gA^3\ N \Big|_0^L + N^T\ gy3A^2 \frac{\partial A}{\partial y} \Big|_0^L \qquad \text{A-25}$$

This function is only evaluated at the downstream end of the system; at all inter-element connections it is assumed to be zero. And from equation A-11

$$\frac{\partial f_2}{\partial q_n} = \int_0^L N^T \frac{\partial N}{\partial x}\, dx \qquad \text{A-26}$$

$$\frac{\partial f_2}{\partial y_n} = \int_0^L N^T \left[\frac{\partial y}{\partial t} \frac{\partial^2 B}{\partial y^2} N + \frac{\partial B}{\partial y} \frac{\alpha N}{\Delta t} \right] dx \qquad \text{A-27}$$

The extreme complexity of these equations makes it impossible to obtain an exact integration; in fact, the functions describing A and q_f are only describable by tabular entries. The integrals are thus formed by numerical integration in which the integrals are evaluated and summed at so-called Gauss points (after the developer of the method), each with a weighting factor.

Then if the subscript g denotes the functions computed at the Gauss points and w_g the weighting factor, equations A-24 and A-27 become

$$\frac{\partial f_1}{\partial q_n} = L_e \sum_{g=1}^{nint} w_g N_g^T \left[A_g^2 \frac{1.5}{\Delta t} N_g - \left(A \frac{\partial A}{\partial y} \frac{\partial y}{\partial t} \right)_g N_g + \left(Aq \right)_g \left(\frac{\partial N}{\partial x} \right)_g \right.$$

$$+ \left(A \frac{\partial q}{\partial x} \right)_g N_g - \left(2q \frac{\partial A}{\partial x} + 2q \frac{\partial A}{\partial y} \frac{\partial y}{\partial x} \right)_g N_g$$

$$- \left(2|q| gA^3 \frac{\partial a}{\partial x} q_f^{-2} \right)_g N_g \qquad \text{A-28}$$

where L_e is the element length. Note the evaluation of the shape function must also take place at the Gauss points.

$$\frac{\partial f}{\partial y_n} = L_e \sum_{g=1}^{nint} w_g N_g^T \left[2 \left(\frac{\partial q}{\partial t} A \frac{\partial A}{\partial y} \right)_g N_g - \left(Aq \frac{1.5}{\Delta t} \right)_g N_g - \left(g \frac{\partial A}{\partial y} \frac{\partial y}{\partial t} \right)_g N_g \right.$$

$$+ \left(q \frac{\partial q}{\partial x} \frac{\partial A}{\partial y} \right)_g N_g - \left(q^2 \left(\frac{\partial^2 A}{\partial x \partial y} + \frac{\partial^2 A}{\partial y^2} \frac{\partial y}{\partial x} \right) \right)_g N_g - \left(q^2 \frac{\partial A}{\partial y} \right)_g \frac{\partial N}{\partial xg}$$

$$+ \left(3gA^2 \frac{\partial A}{\partial y} \left(\frac{\partial a}{\partial x} - q|q| q_f^{-2} \frac{\partial a_o}{\partial x} \right) \right)_g N_g + \left(2gA^3 \frac{\partial a_o}{\partial x} q|q| q_f^{-3} \frac{\partial q}{\partial y} \right)_g N_g$$

$$- \left(3gA^2 \left(\frac{\partial A}{\partial x} + \frac{\partial A}{\partial y} \frac{\partial y}{\partial x} + \frac{\partial^2 A}{\partial x \partial y} y + \frac{\partial^2 A}{\partial y^2} \frac{\partial y}{\partial x} y \right) \right)_g N_g$$

$$- \left(3gA^2 \frac{\partial A}{\partial y} y \right)_g \left(\frac{\partial N}{\partial x}\right)_g - \left(6gA \frac{\partial A}{\partial y} \left(\frac{\partial A}{\partial x} + \frac{\partial A}{\partial y} \frac{\partial y}{\partial x} \right)_g N_g \right]$$

$$- w_g \left(\frac{\partial N^T}{\partial x}\right)_g \left[\left(gA^3 + 3gA^2 \frac{\partial A}{\partial y} y\right) N_g \right] \quad + \text{downstream boundary term.} \qquad \text{A-29}$$

$$\frac{\partial f_2}{\partial q_n} = L_e \sum_{g=1}^{nint} w_g N_g^T \frac{\partial N}{\partial x_g} \qquad \text{A-30}$$

$$\frac{\partial f_2}{\partial y_n} = L_e \sum_{g=1}^{nint} w_g N_g^T \left[\left(\frac{\partial^2 B}{\partial y^2} \frac{\partial y}{\partial t} \right)_g N_g + \frac{\partial B}{\partial y_g} \frac{1.5}{\Delta t} N_g \right] \qquad \text{A-31}$$

(Similar summations may be written for f_1 and f_2 to establish the error functions.)

Note that all the derivatives represented by equations A-28 through A-31 are 3 x 3 submatrices and the final coefficient matrix is thus 6 x 6. As previously indicated, the values A and q_f are represented by tabular values for a series of elevations at each node point. In fact, values of q_f need not be input directly; the program will compute q_f from Mannings equation if no value is given.

Because a consistent representation of gradients with respect to y is essential to smooth convergence of the method, data describing properties must be represented by a polynomial which extends across several table entries and develops a consistent transfer when new table levels are used.

As a demonstration, the curve fitting for q_f will be described. Figure A-2 shows a series of values of q_f at different elevations.

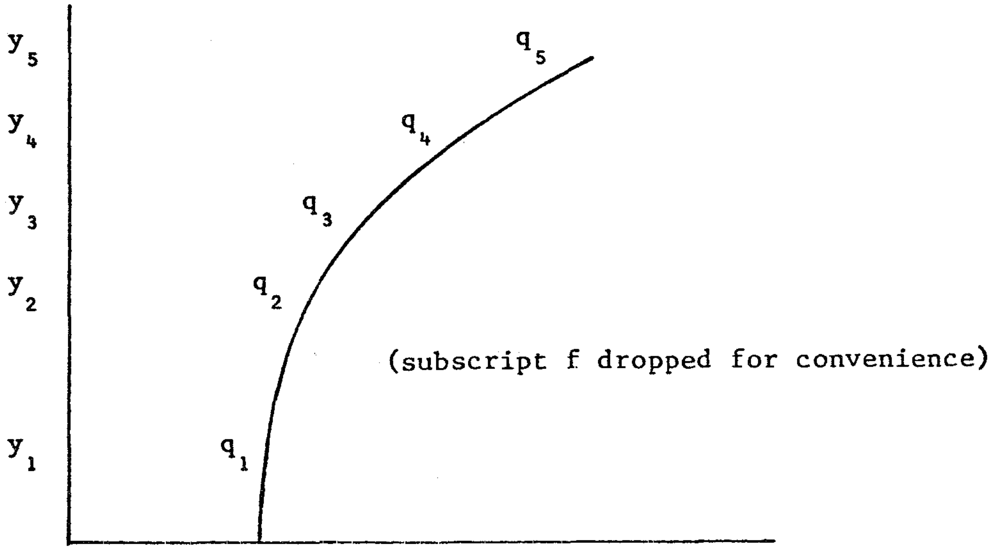


Figure A-2. Tabular Values for q_f

If we select point 3 for development, it is assumed that its polynomial functions fit over the interval from $(y_2 + y_3)/2$ to $(y_3 + y_4)/2$. First using three adjacent values, derivatives are constructed at each mid-point (a finite difference quadratic fit is used), the two values resulting for each mid-point are then averaged and used to construct a quadratic polynomial fit of the derivatives, for example from q_{2m} to q_{4m} (in this fit, values are used at the end points and the table point). This curve is integrated and assumed to apply over the range specified above. The constant of integration assures continuity of curve across ranges.

Kinematic Wave Method

The kinematic wave hydraulic computation method utilizes a quadratic approximating function, a process similar to that used in the St.Venant hydraulic computation method for the solution of the dynamic, nonlinear problem. An error function may be written as

$$f = \int N^T \left(\frac{\partial B}{\partial t} - \frac{\partial q}{\partial x} - s \right) dx \qquad \text{A-32}$$

and the element coefficient matrix

$$\frac{\partial f}{\partial y_n} = \int N^T \left[\frac{\partial B}{\partial y} \frac{\alpha N}{\Delta t} + \frac{\partial y}{\partial t} \frac{\partial^2 B}{\partial y^2} N - \frac{\partial^2 q}{\partial y \partial x} N - \frac{\partial^2 q}{\partial y^2} \frac{\partial y}{\partial x} N \right.$$

$$\left. - \frac{\partial q}{\partial y} \frac{\partial N}{\partial x} \right] dx \qquad \text{A-33}$$

or when numerical integration is used

$$\frac{\partial f}{\partial y_n} = L_e \sum_{g=1}^{nint} w_g N_g^T \left[\left(\frac{\partial B}{\partial y} \frac{1.5}{\Delta t} + \frac{\partial y}{\partial t} \frac{\partial^2 B}{\partial y^2} - \frac{\partial^2 q}{\partial x \partial y} - \frac{\partial^2 q}{\partial y^2} \frac{\partial y}{\partial x} \right)_g N_g \right.$$

$$\left. - \frac{\partial q}{\partial y_g} \frac{\partial N}{\partial x_g} \right] \qquad \text{A-34}$$

where L_e is the element length.

$$\text{or} \qquad f_n = L_e \sum_{g=1}^{nint} w_g N_g^T \left[\frac{\partial B}{\partial t} - \frac{\partial q}{\partial x} - s \right]_g \qquad \text{A-35}$$

The finite element process for the kinematic wave follows the same procedure as the St. Venant solution, the major difference is that only one degree of freedom (i.e., depth) exists at each node point. The element coefficient matrix is thus a 3 x 3 matrix.

In addition, only an upstream boundary condition is necessary to solve the problem; since this condition is usually expressed in terms of flow, it is always necessary to convert this by solving the function of equation II-12 for depth.

APPENDIX B

Source and Sink Equations for Water Quality Constituents

Appendix B

Source and Sink Equations for Water Quality Constituents

TEMPERATURE

Reservoir Model

for surface elements

$$\frac{\partial T}{\partial t} = \frac{1}{\Delta z \rho c} (H_n - I_o) + \frac{\Delta I}{\Delta z \rho c} \qquad \text{B-1.1}$$

and for sub-surface elements

$$\frac{\partial T}{\partial t} = \frac{\Delta I}{\Delta z \rho c} \qquad \text{B-1.2}$$

where

T = water temperature

t = time

z = depth

ρ = water density

c = specific heat of water

H_n = net rate of surface heat transfer

I_o = light energy which penetrates below the surface

I = light energy at depth

Stream Model

$$\frac{\partial T}{\partial t} = \frac{1}{D\rho c}(H_n \pm H_b) \qquad \text{B-1.3}$$

where

D = hydraulic depth

H_b = heat transfer to and from the bottom sediments

COLIFORM BACTERIA

$$\frac{\partial E}{\partial t} = -E \cdot KE \qquad \text{B-2}$$

where

E = concentration of coliform bacteria

KE = rate of coliform bacteria decay

BIOCHEMICAL OXYGEN DEMAND

$$\frac{\partial L}{\partial t} = -L \cdot KL \qquad \text{B-3}$$

where

L = ultimate carbonaceous BOD concentration

KL = BOD decay rate.

ALKALINITY, TOTAL DISSOLVED SOLIDS AND UNIT TOXICITY

$$\frac{\partial C}{\partial t} = 0 \qquad \text{B-4}$$

where

C = concentration of conservative constituent

FISH (Three types)

$$\frac{\partial F}{\partial t} = F(FG - FR - FM - HARVST) \qquad \text{B-5}$$

where

F	=	fish concentration
FG	=	fish growth rate
	=	$FMAX \left(\frac{PREY}{FPR_2 + PREY}\right)$
FMAX	=	maximum fish growth rate
PREY	=	total available food (e.g., benthic animals, aquatic insects, zooplankton, etc.)
	=	$PREY_1 + \Sigma FPREF_n \cdot PREY_n$
$PREY_1$	=	primary prey (e.g., zooplankton)
$FPREF_n$	=	Grazing preference factor relating the secondary prey to primary prey
$PREY_n$	=	secondary prey
FPR_2	=	half saturation constant for fish grazing its primary prey
FR	=	fish respiration rate
FM	=	fish mortality rate
HARVST	=	fish removal rate by fishing and predation

BENTHIC ANTMALS

$$\frac{\partial B}{\partial t} = B(BG - BR - BM) - BPRED \qquad \text{B-6}$$

where

B = equivalent concentration of benthic animals

= BEN · AV

BEN = benthic animal biomass per unit area

AV = ratio of area to volume

BG = benthic animal growth rate

$$= BMAX \left(\frac{SED}{SED_2 + SED}\right)$$

BMAX = maximum benthic animal growth rate

SED = quantity of organic sediment per unit area

SED_2 = half saturation constant for benthic animals grazing organic sediment

BR = benthic animal respiration rate

BM = benthic animal mortality rate

BPRED = quantity of benthic animals removed by predation (e.g., fish)

= FBEN/FEFF

FBEN = fish growth attributed to grazing benthic animals

FEFF = digestive efficiency of fish

AQUATIC INSECTS (Stream Model Only)

$$\frac{\partial AI}{\partial t} = AI(AIG - AIR - AIM - EMERG) - AIPRED \qquad B-7$$

where

AI	=	equivalent concentration of aquatic insects
AIG	=	aquatic insect growth rate
	=	$AIMAX \left(\frac{PREY}{AIPR_2 + PREY}\right)$
AIMAX	=	maximum aquatic insect growth rate
PREY	=	total available food (e.g., benthic algae and organic sediment
$AIPR_2$	=	half saturation constant for aquatic insects grazing its primary prey (i.e., benthic algae type 1)
AIR	=	aquatic insect respiration rate
AIM	=	aquatic insect mortality rate
FMERG	=	aquatic insect emergence rate
AIPRED	=	quantity of aquatic insects grazed by fish

ZOOPLANKTON

$$\frac{\partial Z}{\partial t} = Z(ZG - ZR - ZM) - ZPRED \qquad \text{B-8}$$

where

Z = zooplankton concentration

ZG = zooplankton growth rate

$$= ZMAX \left(\frac{PREY}{ZPR_2 + PREY}\right)$$

ZMAX = maximum zooplankton growth rate

PREY = total available food (e.g., phytoplankton and detritus)

ZPR_2 = half saturation constant for zooplankton grazing its primary prey (i.e., phytoplankton, type 1)

ZR = zooplankton respiration rate

ZM = zooplankton mortality rate

ZPRED = quantity of zooplankton grazed by fish

PHYTOPLANKTON (Two types)

$$\frac{\partial P}{\partial t} = P(PG - PR) + PS\frac{\partial P}{\partial Z} - APRED \qquad \text{B-9}$$

where

P = algae concentration

PG = algae growth rate

$$= PMAX \left| \left(\frac{C}{C_2 + C}\right) \left(\frac{LI}{L_2 + LI}\right) \right|_{min}$$

$PMAX$ = maximum phytoplankton growth rate

C = the critical nutrient concentration (e.g., CO_2,PO_4 or $NH_3 + NO_3$)

C_2 = half saturation constant for algae utilizing the critical nutrient C

LI = available light energy

L_2 = half saturation constant for algae utilizing light energy

PR = algae respiration rate

PS = algae settling velocity

$APRED$ = quantity of algae grazed by zooplankton

BENTHIC ALGAE (Two types) - Stream Model only

$$\frac{\partial BA}{\partial t} = BA(BAG - BAR) - BAPRED - BSCOUR \qquad \text{B-10}$$

where

BA = equivalent, concentration of benthic algae

BAG = benthic algae growth rate

$$= BAMAX \left| \left(\frac{C}{C_2 + C}\right) \left(\frac{LI}{LI_2 + LI}\right) \right|_{min}$$

BAMAX = benthic algae maximum growth rate

BAR = benthic algae respiration rate

BAPRED = quantity of benthic algae grazed by fish and aquatic insects

BSCOUR = benthic algae removed by scour

$$= SK \cdot VEL^2$$

SK = coefficient relating benthic algae loss by scour to velocity

VEL = velocity

DETRITUS

$$\frac{\partial DET}{\partial t} = DS \frac{\partial DET}{\partial z} - KDET \cdot DET + ZDET + Z \cdot ZM - DGRZ + BSCOUR \qquad \text{B-11}$$

where

DET = detritus concentration

DS = detritus settling velocity

KDET = detritus decay rate

ZDET = amount of particulate zooplankton excrement

$= Z \cdot ZG \left(\frac{1}{ZEFF} - 1\right) ZEXC$

Z = zooplankton

ZG = zooplankton growth rate

ZEFF = zooplankton digestive efficiency

ZEXC - particulate fraction of zooplankton excrement

ZM = zooplankton mortality rate

DGRZ = detritus grazed by zooplankton

BSCOUR = benthic algae added to detritus pool by scour

ORGANIC SEDIMENT

$$\frac{\partial S}{\partial t} = - KDET \cdot S + P \cdot PS + DET \cdot DS + \Sigma EXC \cdot EXF$$

$$+ \Sigma PRED \cdot PREDM - SGRZ \qquad \text{B-12}$$

where

KDET	=	detritus decay rate
S	=	equivalent concentration of organic sediment
P	=	algae concentration
PS	=	algae settling rate
DET	=	detritus concentration
DS	=	settling rate of detritus
EXC	=	amount of particulate excrement
	=	$PRED \cdot PREDG \left(\frac{1}{PEFF} - 1\right)$
PRED	=	preditor concentration (e.g., fish, aquatic insects, and benthic animals)
PREDG	=	preditor growth rate
PEFF	=	preditor digestive efficiency
EXF	=	particulate fraction of total excrement
PREDM	=	preditor mortality rate
SGRZ	=	sediment grazed by fish, benthic animals and aquatic insects

INORGANIC SUSPENDED SOLIDS

$$\frac{\partial SS}{\partial t} = SETL \frac{\partial SS}{\partial Z} \qquad \text{B-13}$$

where

SS = inorganic suspended solids concentration

SETL = settling rate

INORGANIC SEDIMENTS

$$\frac{\partial SSOL}{\partial t} = SETL \cdot SS \qquad \text{B-14}$$

where

SSOL = equivalent concentration of inorganic sediment

PHOSPHATES PHOSPHORUS

$$\frac{\partial PO_4}{\partial t} = KDET(DET + S)DP + \Sigma BIO \cdot BIOP\ [BIOR + BIOG(\frac{1}{BIEFF} - 1)(1 - EXF)] - \Sigma A \cdot AP(AG - AR) \qquad \text{B-15}$$

where

PO_4	=	phosphate concentration as phosphorus
KDET	=	detritus decay rate
DET	=	detritus concentration
S	=	equivalent concentration of organic sediment
DP	=	phosphorus fraction of detritus
BIO	=	biota concentration excluding algae
BIOP	=	phosphorus fraction of biota
BIOR	=	biota respiration rate
BIOG	=	biota growth rate
BIEFF	=	biota digestive efficiency
EXF	=	particulate fraction of total excrement
A	=	algal concentration (i.e., phytoplankton and benthic algae)
AP	=	phosphorus fraction of algae
AG	=	algal growth rate
AR	=	algal respiration rate

CARBON

$$\frac{\partial C}{\partial t} = K_o(CO_2^* - CO_2) + KDET(DET + S)DC + KL \cdot L \cdot LC$$

$$+ \Sigma BIO \cdot BIOC \left[BIOR + BIOG \left(\frac{1}{BIEFF} - 1\right) (1 - EXF)\right]$$

$$- \Sigma A \cdot AC(AG - AR) \qquad \text{B-16}$$

where

C	=	concentration of total inorganic carbon
K_o	=	surface exchange coefficient for carbon dioxide
CO_2^*	=	concentration of carbon dioxide as carbon at saturation
CO_2	=	concentration of dissolved carbon dioxide as carbon
KDET	=	detritus decay rate
DET	=	detritus concentration
S	=	equivalent concentration of organic sediment
DC	=	carbon fraction of detritus
KL	=	rate of BOD removal by oxygen uptake
L	=	concentration of ultimate BOD
LC	=	carbon produced with BOD decay
BIO	=	biota concentration excluding algae
BIOC	=	carbon fraction of biota
BIOR	=	biota respiration rate
BIOG	=	biota growth rate
BIEFF	=	biota digestive efficiency
EXF	=	particulate fraction at total excrement
A	=	algae concentration (i.e., phytoplankton and benthic algae)
AC	=	carbon fraction of algae
AG	=	algal growth rate
AR	=	algal respiration rate

AMMONIA NITROGEN

$$\frac{\partial NH_3}{\partial t} = - KNH_3 \cdot NH_3 + KDET(DET + S)DN + \Sigma BIO \cdot BION\ [BIOR + BIOG(\frac{1}{BIEFF} - 1)(1 - EXF)] - \Sigma A \cdot AP(AG \cdot FNN - AR) \tag{B-17}$$

where

NH_3	=	ammonia concentration as nitrogen
KNH_3	=	ammonia decay rate
KDET	=	detritus decay rate
DET	=	detritus concentration
S	=	equivalent concentration of organic sediment
DN	=	detritus fraction of detritus
BIO	=	biota concentration excluding algae
BION	=	nitrogen fraction of biota
BIOR	=	biota respiration rate
BIOG	=	biota growth rate
BIOEFF	=	biota digestive efficiency
EXF	=	particulate fraction of total excrement
A	=	algae concentration (i.e., phytoplankton and benthic algae)
AN	=	nitrogen fraction of algae
AG	=	algal growth rate
AR	=	algal respiration rate
FNN	=	ammonia fraction of available nitrogen

NITRITE NITROGEN

$$\frac{\partial NO_2}{\partial t} = KNH_3 \cdot NH_3 - KNO_2 \cdot NO_2 \qquad \text{B-18}$$

where

NO_2 = concentration of nitrite nitrogen

KNH_3 = ammonia decay rate

NH_3 = ammonia concentration as nitrogen

KNO_2 = nitrite decay rate

NITRATE NITROGEN

$$\frac{\partial NO_3}{\partial t} = KNO_2 \cdot NO_2 - \Sigma A \cdot AN \cdot AG(1 - FNN) \qquad \text{B-19}$$

where

NO_3 = nitrate concentration as nitrogen

KNO_2 = nitrite decay rate

NO_2 = nitrite concentration as nitrogen

A = algae concentration (i.e., phytoplankton and benthic algae)

AN = nitrogen fraction of algae

AG = algae growth rate

FNN = ammonia fraction of available nitrogen

DISSOLVED OXYGEN

$$\frac{\partial O_2}{\partial t} = K_o(O_2^* - O_2) - KL \cdot L - KNH_3 \cdot NH_3 \cdot O_2NH_3 - KNO_2 \cdot NO_2 \cdot O_2NO_2 - KDET \cdot (DET + S) \cdot O_2DET - \Sigma BIO \cdot O_2R\ [BIOR + BIOG(\frac{1}{BIEFF} - 1)(1 - EXF)] + \Sigma A(O_2P \cdot AG - O_2R \cdot AR) \qquad \text{B-20}$$

where

O_2	=	concentration of dissolved oxygen
K_o	=	surface exchange coefficient for dissolved oxygen
O_2^*	=	concentration of dissolved oxygen at saturation
KL	=	rate of BOD removal by oxygen uptake
L	=	concentration of ultimate BOD
KNH_3	=	ammonia decay rate
NH_3	=	ammonia concentration as nitrogen
O_2NH_3	=	stoichiometric equivalence between oxygen and ammonia
KNO_2	=	nitrite decay rate
NO_2	=	nitrite concentration as nitrogen
O_2NO_2	=	stoichiometric equivalence between oxygen and nitrite
KDET	=	detritus decay rate
DET	=	detritus concentration
S	=	concentration equivalent of organic sediment
O_2DET	=	stoichiometric equivalence between oxygen and detritus decay
BIO	=	biota concentration excluding algae
O_2R	=	stoichiometric equivalence between oxygen and biomass respiration
BIOR	=	biota respiration rate
BIOG	=	biota growth rate

BIEFF = biota digestive efficiency

EXF = particulate fraction of total excrement

A = algal concentration (i.e., phytoplankton and benthic algae)

O_2P = oxygenation factor for algal photosynthesis

AG = algal growth rate

AR = algal respiration rate

APPENDIX C

Definition of Selected FORTRAN Variables used in the Stream Hydraulics Module

Appendix C

Definition of Selected FORTRAN Variables used in the Stream Hydraulics Module

Variable	Definition
A	Cross sectional area table
AMAN	Manning coefficient table
ASC	Cross sectional area during computation
ASEC	Cross sectional area at node points at any time in the simulation
ASECG	Cross sectional area at Gauss point during numerical integration for each element
AVAM	Average value of change of flow and depth during one iteration
A2	Parameters describing cubic curve fit of cross sectional area for each node point and each table elevation
BASE	Table identifying nearest table entry for elevation implied by subscript number times minimum step interval of table (STINT)
CFAF	Conversion factor for storage values in acre-ft to cu ft when English units are used
CORD	Length coordinate of each node point
CPL	Control point location measured upstream for printing
CPMT	Control point location as read on data cards
CPOF	Table containing outflow values at control points for equivalent storage values (CPSI)
CPOX	Outflow values for a control point as read on data cards
CPSI	Table containing storage levels at control points for equivalent outflow values (CPOF)
CPSX	Storage levels for a control point as read on data cards

Variable	Definition
CROUT	Array containing Muskingum routing coefficients C1, C2, C3 for each control point
C1 C2 C3	Routing coefficients as defined in description of Muskingum method
DADX	Rate of change of bottom elevation for each element
DADXG	$\partial A/\partial x$ at a Gauss point
DADY	$\partial A/\partial y$ at specified point
DADYG	$\partial A/\partial y$ at a Gauss point
DAXY	$D^2 A/\partial x\partial y$ at specified point
DAY	Function describing $\partial A/\partial y$ at any elevation or location
DELT	Time step for solution
DELX	Subelement length for solution of backwater equation
DFLY	Required accuracy for changes in depth during computation of backwater solution
DHEAD	Downstream head
DHF	Derivatives of each shape function in local coordinates for each Gauss point
DISTF	Non-point inflow and withdrawal rate
DNX	Derivatives of each shape function in global coordinates for a Gauss point
DQDT	$\partial Q/\partial t$ at each node point at end of time step
DQDTG	$\partial Q/\partial t$ at a Gauss point for an element at end of time step
DQDTO	$\partial Q/\partial t$ at each node point at beginning of time step
DQDX	$\partial Q/\partial x$ at each node point or a Gauss point of an element
DQDY	$\partial Q/\partial y$ for each elevation at the downstream node point
DWDYG	$\partial Q/\partial y$ at a Gauss point for an element
DRDXG	$\partial Q/\partial x$ at a Gauss point of an element

Variable	Definition
DRDY	$\partial Q/\partial y$ at upstream node during iterations to determine upstream depth
DRDYG	$\partial Q/\partial y$ based on normal flow-depth relationship at a Gauss point of an element
DRXYG	$\partial^2 Q/\partial x \partial y$ at a Gauss point of an element
DRY	Function describing $\partial Q/\partial y$ based on normal flow-depth tables
DSAVE	Array containing backsubstitution parameters to develop midelement flows and depths as appropriate
DWDXG	$\partial^2 A/\partial x \partial y$ at a Gauss point of an element
DYDT	$\partial y/\partial t$ at each node at end of time step
DYDTG	$\partial y/\partial t$ at a Gauss point for an element at end of a time step
DYDTO	$\partial y/\partial t$ at each node at beginning of each time step
DYDX	$\partial y/\partial x$ at a Gauss point for an element
D2A	Function for computing $\partial^2 A/\partial y^2$ at any elevation or node
D2AY	Bottom slope at node point
D2AYG	$\partial^2 A/\partial y^2$ at a Gauss point for an element
D2R	Function for computing $\partial^2 A/\partial y^2$ at any elevation or node
D2RYG	$\partial^2 Q/\partial y^2$ at a Gauss point for an element
ELEV	Cross section elevation table
ESTIFM	Coefficient matrix formed for each element
F	Error vector for each element
G	Acceleration due to gravity
HF	Shape function at each Gauss point
HOUR	Time
HRAD	Instantaneous flow at each node
HRADG	Instantaneous flow at a Gauss point
HRD	Instantaneous flow at an integration point

Variable	Definition
IALL	Indicator that all intermediate time steps should be printed
ICM	Indicator for identifying input units
ICND	Indicator for identifying initial conditions
IDAY	First day of simulation
IDCP	Segment number of each control point
IDST	Identifies where downstream condition is specified head or head flow table
IHYD	Logical number for file containing record of flows and depths at all nodes
IHYDRO	Indicator which identifies which method of routing has been selected
IIDAY	Temporary storage of day number of hydrograph
ILVL	Array containing location in data tables of this depth of water times the step interval (STINT)
ISEG	Node location of tributary flow
ITRLIM	Maximum number of iterations during nonlinear solution
JJMAX	Maximum column location during elimination process
JMAX	Maximum column location of simultaneous equations
JMIN	Location of diagonal term of simultaneous equations
KEY	Indicator to separate kinematic wave and settlement solutions
KMAX	Maximum row location during an individual elimination step
KMIN	Minimum row location during an individual elimination step
KTAPE	Logical number of file on which downstream value of flow is written
LDAY	Last day of simulation
LI	Logical number of card reader
LP	Logical number of line printer

Variable	Definition
LTAPE	Logical numbers of upstream input files
MK	Value of K in Muskingum routing for each control point
MX	Value of X in Muskingum routing for each control point
NBC	Array containing equation number for each node and degree of freedom
NBPP	Number of cross sections of input data
ND	Counter on number of days
NDAYS	Maximum day of simulation
NDF	Number of degrees of freedom per node in simultaneous equations
NE	Number of elements used in the simulation
NELEV	Number of levels in input cross section data
NEQS	Number of equations in system
NFREQ	Frequency of printing of simulation results
NL	Number of locations with tributary input
NOP	Matrix containing node connections for each element
NP	Number of nodes in the system to be simulated
NRB	Row locator when forming global matrix
NREM	Number of withdrawals
NROW	Equation number when forming global right hand vector
NROWB	Equation number for specified node and degree of freedom
NS	Number of segments in system
NSLOAD	Number of storm inflows
NSTEP	Number of time steps per day of simulation
NSZF	Number of equations in global system
QA	Flow at each node

Variable	Definition
QADD	Tributary flow between control points
QAX	Flow at a subelement during computation of depth by backwater method
QG	Instantaneous flow at a Gauss point of an element
QIN	Tributary inflow
QONE	Flow at control point at start of time step
QREM	Withdrawal rate
QST	Table of input specified flows for each elevation and cross section
QSTAGE	Table of specified flows developed for each elevation step and each node point
QT	Sum by node of all tributary inflows
QTCP	Sum of all tributary inflows and outflows by control point
QTCPO	Sum of all tributary inflows and outflows by control point for previous time step
QTWO	Computed flows at control points at end of time step
QW	Sum by node of tributary outflows
RAD	Normal or friction flow at each node for each elevation of the table
RADY	Rate of change of normal or friction flow with elevation at each node for each elevation of the table
RCK	Muskingum routing coefficient K for a control point
RCX	Muskingum routing coefficient X for a control point
R1	Right hand side vector for simultaneous equations and correction vector after solution
R2	Curve fit parameters for normal or function flow for each node and elevation
R23	Hydraulic radius to the 2/3 power
R3	Curve fit parameters for normal or friction flow for each node and elevation

Variable	Definition
SCALE	Parameter used for interpolation of cross section data to nodal points
SE	Friction slope used in computation of backwater solution
SEC	Cross sectional area for each node and elevation
SECY	Derivative of cross sectional area with respect to elevation for each node and elevation
SFLOW	Net rate of inflow per unit length for each element
SK	Global matrix of simultaneous equations, stored in rectangular form
SLOPE	Mean effective channel slope at a convection data point
SO	Effective channel slope at each node
STEP	Distance between actual depth and table elevation for use in interpolation function
STINT	Basic step interval (lowest common multiplier) of interval in elevation of cross section data
TIME	Incremental time in hours during day of simulation
VEL	Latest value in simulation for flow and depth at a node
VOLD	Value at end of previous time step for flow and depth
WAIT	Waiting function used in numerical integration
WD	Surface width as entered in cross section tables
X	Location of cross section data
XINC	Increment between each elevation in geometric data table
XL	Length of each finite element distance between control points
XM	Coordinates of nodal points
XMT	Location of tributary
XN	Values of each shape function of each Gauss point
XOVER	Distance between actual depth from nearest table elevation

Variable	Definition
Y	Depth at each node or Gauss point
YC	Specified downstream depth
YN	Normal flow depth
ZB	Bottom elevation at each node

APPENDIX D

Definition of Selected FORTRAN Variables used in the Quality Modules

Definition of Selected FORTRAN Variables
used in the Quality Modules

Variable	Definition
AH	Element surface area
ALGAC	Carbon fraction of algae
ALGADT	Rate of change in algae (i.e., $\partial P/\partial t$)
ALGAE	Algae (i.e., phytoplankton and benthic algae) concentration
ALGAN	Carbon fraction of algae
ALGAP	Phosphorus fraction of algae
ALKA	Alkalinity concentration
ALKADT	Rate of change in alkalinity
AMU	Algal growth rate
AREA	Element surface area
ART	Algal respiration rate
ASEC	Channel cross section area
ATOP	Lake surface area
ATOV	Element bottom area to volume ratio
BDET	Benthos (i.e., Benthic animals) excreta
BDETR	Particulate fraction of benthos excreta
BEFFIC	Assimilative efficiency of benthos
BEN	Benthos density
BENC	Carbon fraction of benthos
BENDT	Rate of change in benthos
BENN	Nitrogen fraction of benthos
BENP	Phosphorus fraction of benthos
BFLUX	Heat flux between water and sediment

Variable	Definition
BMAX	Benthos maximum growth rate
BMORTA	Benthos natural mortality coefficient
BMORTB	Benthos toxicity induced mortality coefficient
BMT	Benthos mortality rate
BMU	Benthos growth rate
BOD	BOD (i.e., ultimate carbonaceous BOD) concentration
BODDK	Maximum BOD decay rate
BODDT	Rate of change in BOD
BOD5	Five day BOD
BRESP	Maximum benthos respiration rate
BRT	Benthos respiration rate
BS2SED	Half saturation constant for benthos grazing organic sediment
CARBDT	Rate of change in TIC (i.e., total inorganic carbon)
CARBON	TIC concentration
CBALGA	Equivalent concentration of benthic algae
CBEN	Equivalent concentration of benthos
CMUD	Bottom sediment thermal conductance coefficience
CNH3	Ammonia nitrogen concentration
CNH3DK	Maximum ammonia decay rate
CNH3DT	Rate of change in ammonia nitrogen
CNO2	Nitrite nitrogen concentration
CNO2DK	Nitrite decay rate
CNO2DT	Rate of change in nitrite nitrogen
CNO3	Nitrate nitrogen concentration
CNO3DT	Rate of change in nitrate nitrogen
CNSECT	Equivalent concentration of aquatic insects

Variable	Definition
COLIDK	Coliform decay rate at 20°C
COLIDT	Rate of change in coliforms
COLIF	Coliform density
CO2	Carbon dioxide carbon concentration
CO2BOD	Carbon dioxide produced with BOD decay
CO2STR	Function for computing carbon dioxide concentration at saturation
CSED	Equivalent concentration of organic sediment
CSTAR	Function for computing dissolved oxygen concentration at saturation
DC	Effective diffusion coefficient
DEEP	Stream element mean depth
DELT	Computation time step increment
DENS	Water density
DETRC	Carbon fraction of detritus
DETRN	Nitrogen fraction of detritus
DETRP	Phosphorus fraction of detritus
DETUDK	Maximum detritus decay rate
DETUDT	Rate of change in detritus
DETUS	Detritus concentration
DFALG	Temperature correction for algal growth
DFALG1	Temperature correction for algal respiration and mortality
DFBEN	Temperature correction for benthos growth
DFBEN1	Temperature correction for benthos respiration and mortality
DFBT	Temperature correction for BOD decay
DFCOL	Temperature correction for coliform dieoff

Variable	Definition
DFDT	Temperature correction for detritus decay
DFFSH	Temperature correction for fish growth
DFFSH1	Temperature correction for fish respiration and mortality
DFINS	Temperature correction for aquatic insect growth
DFINS1	Temperature correction for aquatic insect respiration and mortality
DFNH3T	Temperature correction for ammonia decay
DFNO2T	Temperature correction for nitrite decay
DFSED	Temperature correction for organic sediment decay
DFZOO	Temperature correction for zooplankton growth
DFZOO1	Temperature correction for zooplankton respiration and mortality
DISTF	Non-point inflow rate
DISTQ	Non-point inflow quality
DMUD	Bottom sediment thickness
DSED	Inorganic sediment accumulation rate
DSETL	Detritus settling rate
DTBY2	One half the computational time step increment
DTH	Time step increment
DVDT	Rate of changes in element volume
DVOL	Element volume
ELTC	Elevation of thermocline
EMERGE	Aquatic insect emergence rate
EX	Light extinction coefficient
EXT	Light extinction coefficient
EXCO	Light extinction coefficient without the effects of modeled particulate materials
EXTINP	Self shading coefficients

Variable	Definition
FALGA	Algae consumed by zooplankton
FBALGA	Benthic algae consumed by fish and aquatic insects
FBEN	Benthos consumed by fish
FC	Sources and sinks of TIC
FDET	Sources and sinks of detritus
FDETR	Particulate fraction of fish excreta
FEE	External sources of heat
FEFFIC	Assimilative efficiency of fish
FG	Fish growth rate
FGROW	Fish growth rate
FISH	Fish density
FISHC	Carbon fraction of fish
FISHDT	Rate of change in fish
FISHN	Nitrogen fraction of fish
FISHP	Phosphorus fraction of fish
FISHT	Fish density
FMA	Function for integrating the effects of light energy on algal growth over depth
FMAX	Maximum fish growth rate
FMORTA	Fish natural mortality coefficient
FMORTB	Fish toxicity induced mortality coefficient
FMT	Fish mortality rate
FRT	Fish respiration rate
FN	Sources and sinks of nitrogen
FNSECT	Aquatic insects consumed by fish
FONE	Surface heat exchange coefficient

Variable	Definition
FOOD	Total available fish prey
FOXY	Sources and sinks of dissolved oxygen
FP	Sources and sinks of phosphorus
FPREF	Grazing preference factor for fish
FRACT	Fraction of reservoir element in contact with the bottom
FRES	Fish respiration rate
FRESP	Maximum fish respiration rate
FRT	Fish respiration rate
FSEDMT	Sources and sinks of organic sediment
FTWO	Surface heat exchange coefficient
FZOO	Zooplankton consumed by fish
F2FOOD	Fish growth half saturation constant
HARVST	Fish harvest rate
IDAY	First day of simulation
ISEG	Segment receiving tributary inflow
ITEST	Water quality constituent computation modification switch
ITIME	Number of points defining inflow hydrograph
JFZONE	Limits of fish zones
LD	Days since beginning the simulation
LDAY	Final day of simulation
MAXE	Maximum number of elements
NEQ	Number of equation representing changes in a water quality constituent
NFZONE	Number of fish zones
NS	Number of elements
NUME	Number of elements

Variable	Definition
OSAT	Dissolved oxygen concentration at saturation
OXY	Dissolved oxygen concentration
OXYDT	Rate of change in dissolved oxygen
O2DET	Oxygen consumed with detritus decay
O2FACT	Oxygen produced with algal growth
O2NH3	Oxygen consumed with ammonia decay
O2NO2	Oxygen consumed with nitrite decay
O2RESP	Oxygen consumed with biota respiration
P	Source and sink term
PALGAE	External sources of phytoplankton
PALK	External sources of alkalinity
PBOD	External sources of BOD
PCAR	External sources of TIC
PCOLIF	External sources of coliforms
PDET	External sources of detritus
PMAX	Maximum algal growth rate
PMORT	Benthic algae toxicity induced mortality coefficient
PNH3	External sources of ammonia nitrogen
PNO2	External sources of nitrite nitrogen
PNO3	External sources of nitrate nitrogen
POXY	External sources of dissolved oxygen
PO4	Phosphate phosphorus concentration
PO4DT	Rate of change in phosphate phosphorus
PPO4	External sources of phosphate phosphorus
PREF	Preference factor for zooplankton grazing phytoplankton
PRESP	Maximum algal respiration rate

Variable	Definition
PSED	External sources of inorganic sediment
PSOL	External sources of inorganic suspended solids
PS2CO2	Half saturation constant for algae utilizing TIC
PS2L	Half saturation constant for algae utilizing light energy
PS2N	Half saturation constant for algae utilizing nitrogen
PS2PO4	Half saturation constant for algae utilizing phosphorus
PTDS	External sources of TDS
PTOX	External sources of unit toxicity
PZOO	External sources of zooplankton
QA	Stream interelement flow rate
QHI	Reservoir element inflow rate
QHO	Reservoir element outflow rate
QIN	Inflow rate
QM	Mean stream element flow rate
QREM	Withdrawal rate
QTEN	Temperature correction for reaeration of oxygen
QVUP	Reservoir interelement flow rate
QVDN	Reservoir interelement flow rate
QW	Stream element withdrawal rate
RATE	Function for interpolating rate coefficient temperature adjustment factors
RO	Function for calculating water density as a function of temperature and dissolved and particulate solids
ROX	Oxygen reaeration coefficient
ROXY	Oxygen reaeration coefficient
RO2CO2	Ratio between the reaeration coefficients of carbon dioxide and oxygen

Variable	Definition
SDZ	Element thickness
SEDDK	Organic sediment decay rate
SEDDT	Rate of change in organic sediment
SEDMT	Organic sediment
SETL	Phytoplankton settling rate and benthic algae scour rate
SIZE	Inorganic suspended solids partical size
SO	stream channel slope
SORS	Variant portion of coefficient matrix representing the rates of change in a quality constituent
SSCAP	Inorganic suspended solids carrying capacity of the stream
SSED	Inorganic sediment
SSEDDT	Rate of change in inorganic sediment
SSETL	Settling velocity of inorganic suspended solids
SSLIM	Stream velocity below which inorganic suspended solids may settle
SSOL	Inorganic suspended solids concentration
SSOLDT	Rate of change in inorganic suspended solids
SWS	Short wave solar radiation at depth
TBENT	Total available benthic animal food
TDS	TDS (i.e., total dissolved solids) concentration
TDSDT	Rate of change in TDS
TEMP	Water temperature
TEMPDT	Rate of change in water temperature
TFG	Total fish growth
TFOOD	Total available fish prey
TINSEC	Total available aquatic insect food
TMUD	Temperature of bottom sediment

Variable	Definition
TMUDDT	Rate of change in bottom sediment temperature
TOX	Unit toxicity concentration
TOXDT	Rate of change in unit toxicity
TOXI	Unit toxicity adjusted to the dissolved oxygen concentration
VEL	Velocity in stream channel
VOL	Reservoir volume
XIN	Inflow concentrations of all advected constituents
XLEN	Stream element length
XQNS	Short wave solar radiation
XWIND	Wind speed
XX	Invariant portion of coefficient matrix
YBAR	Mean channel depth
YDETR	Particulate fraction of aquatic insect excreta
YEFFIC	Assimilative efficiency of aquatic insects
YG	Aquatic insect growth rate
YMAX	Aquatic insect maximum growth rate
YMORTA	Aquatic insect natural mortality coefficient
YMORTB	Aquatic insect toxicity induced mortality coefficient
YNSECT	Aquatic insects
YNSEDT	Rate of change in aquatic insects
YPREF	Grazing preference factors for aquatic insects
YRESPA	Aquatic insect maximum respiration rate
YSECC	Carbon fraction of aquatic insects
YSECN	Nitrogen fraction of aquatic insects
YSECP	Phosphorus fraction of aquatic insects
YYP	Available food for benthos, aquatic insects and fish by elements
YZFOOD	Aquatic insect growth half saturation constant

Variable	Definition
YDETR	Particulate fraction of aquatic insect excreta
Z	Reservoir element elevation
ZDET	Zooplankton excreta
ZEFFIC	Assimilative efficiency of zooplankton
ZMAX	Maximum zooplankton growth rate
ZMORTA	Zooplankton natural mortality coefficient
ZMORTB	Zooplankton toxicity induced mortality coefficient
ZMT	Zooplankton mortality rate
ZMU	Zooplankton growth rate
ZOO	Zooplankton concentration
ZOOC	Carbon fraction of zooplankton
ZOODT	Rate of change in zooplankton
ZOON	Nitrogen fraction of zooplankton
ZOOP	Phosphorus fraction of zooplankton
ZRESP	Zooplankton maximum respiration rate
ZRT	Zooplankton respiration rate
ZS2P	Zooplankton growth half saturation constant

APPENDIX E

Conversion Tables

APPENDIX E

TEMPERATURE CONVERSION

Absolute Temperatures

°Kelvin = °C + 273
°Rankine = °F + 460

Conversion Factors

$$°F - 32 = \frac{°C \times 9}{5}$$

$$°C = \frac{(°F - 32) \times 5}{9}$$

Interpolation Figures

°F		°C	°F		°C
1.8	**1**	0.6	10.8	**6**	3.3
3.6	**2**	1.1	12.6	**7**	3.9
5.4	**3**	1.7	14.4	**8**	4.4
7.2	**4**	2.2	16.2	**9**	5.0
9.0	**5**	2.8	18.0	**10**	5.6

The bold figures are the temperature readings in °C or °F, which can be converted to °F or °C, respectively

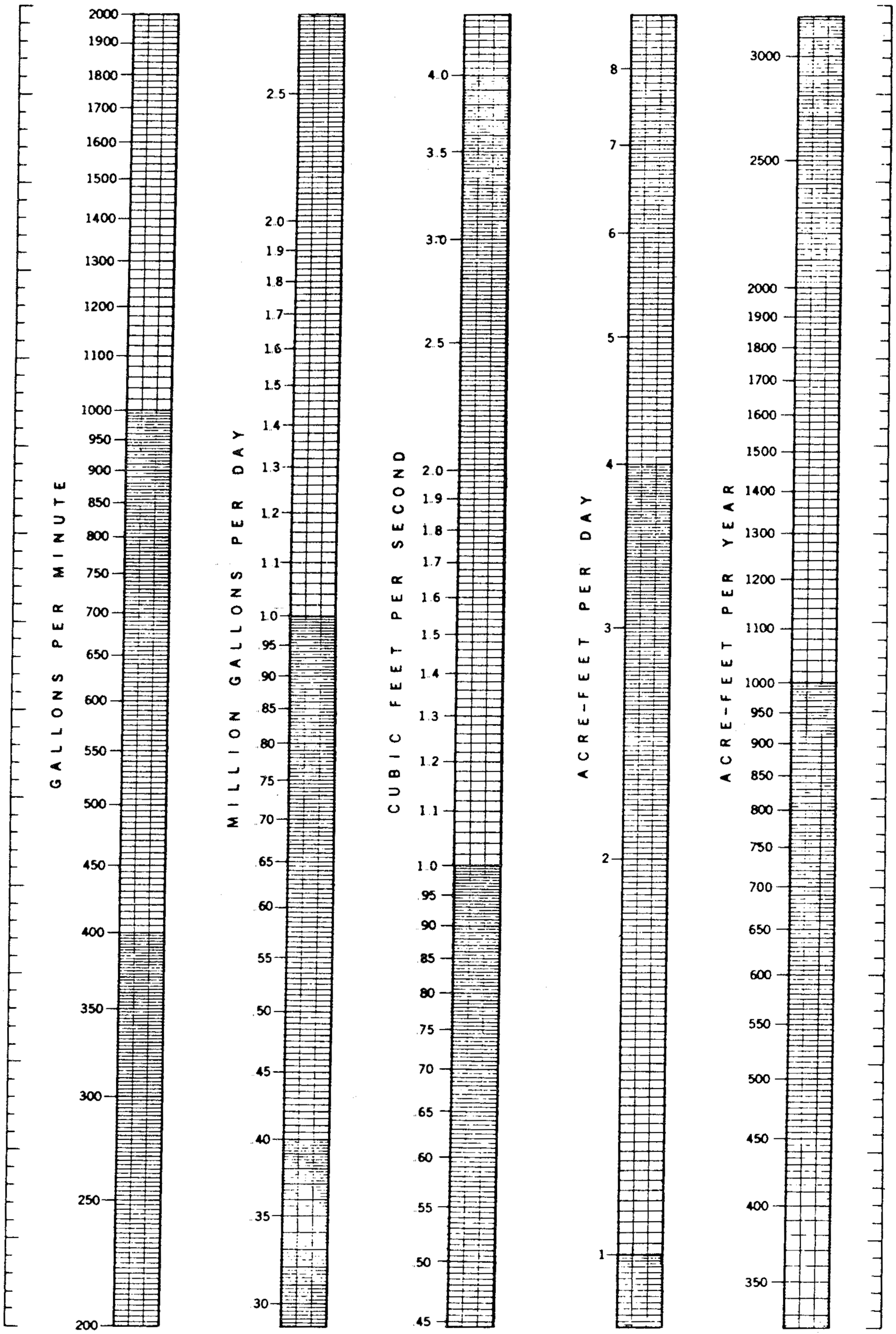
14°F	**-10**	-23.3°C	104°F	**40**	4.44°C	194°F	**90**	32.2°C	770°F	**410**	210°C
15.8	**- 9**	-22.8	106	**41**	5.00	196	**91**	32.8	788	**420**	216
17.6	**- 8**	-22.2	108	**42**	5.56	198	**92**	33.3	806	**430**	221
19.4	**- 7**	-21.7	109	**43**	6.11	199	**93**	33.9	824	**440**	227
21.2	**- 6**	-21.1	111	**44**	6.67	201	**94**	34.4	842	**450**	232
23.0	**- 5**	-20.6	113	**45**	7.22	203	**95**	35.0	860	**460**	238
24.8	**- 4**	-20	115	**46**	7.78	205	**96**	35.6	878	**470**	243
26.6	**- 3**	-19.4	117	**47**	8.33	207	**97**	36.1	896	**480**	249
28.4	**- 2**	-18.9	118	**48**	8.89	208	**98**	36.7	914	**490**	254
30.2	**- 1**	-18.3	120	**49**	9.44	210	**99**	37.2	932	**500**	260
32.0	**0**	-17.8	122	**50**	10.0	212	**100**	37.8	950	**510**	266
33.8	**1**	-17.2	124	**51**	10.6	214	**101**	38.3	968	**520**	271
35.6	**2**	-16.7	126	**52**	11.1	216	**102**	38.9	986	**530**	277
37.4	**3**	-16.1	127	**53**	11.7	217	**103**	39.4	1004	**540**	282
39.2	**4**	-15.6	129	**54**	12.2	219	**104**	40.0	1022	**550**	288
41.0	**5**	-15.0	131	**55**	12.8	221	**105**	40.6	1040	**560**	293
42.8	**6**	-14.4	133	**56**	13.3	223	**106**	41.1	1058	**570**	299
44.6	**7**	-13.9	135	**57**	13.9	225	**107**	41.7	1076	**580**	304
46.4	**8**	-13.3	136	**58**	14.4	226	**108**	42.2	1094	**590**	310
48.2	**9**	-12.8	138	**59**	15.0	228	**109**	42.8	1112	**600**	316
50.0	**10**	-12.2	140	**60**	15.6	230	**110**	43.3	1130	**610**	321
51.8	**11**	-11.7	142	**61**	16.1	248	**120**	48.9	1148	**620**	327
53.6	**12**	-11.1	144	**62**	16.7	266	**130**	54.4	1166	**630**	332
55.4	**13**	-10.6	145	**63**	17.2	284	**140**	60.0	1184	**640**	338
57.2	**14**	-10.0	147	**64**	17.8	302	**150**	65.6	1202	**650**	343
59.0	**15**	- 9.44	149	**65**	18.3	320	**160**	71.1	1220	**660**	349
60.8	**16**	- 8.89	151	**66**	18.9	338	**170**	76.7	1238	**670**	354
62.6	**17**	- 8.33	153	**67**	19.4	356	**180**	82.2	1256	**680**	360
64.4	**18**	- 7.78	154	**68**	20.0	374	**190**	87.8	1274	**690**	366
66.2	**19**	- 7.22	156	**69**	20.6	392	**200**	93.3	1292	**700**	371
68.0	**20**	- 6.67	158	**70**	21.1	410	**210**	98.9	1310	**710**	377
69.8	**21**	- 6.11	160	**71**	21.7	428	**220**	104	1328	**220**	382
71.6	**22**	- 5.56	162	**72**	22.2	446	**230**	110	1346	**730**	388
73.4	**23**	- 5.00	163	**73**	22.8	464	**240**	116	1364	**740**	393
75.2	**24**	- 4.44	165	**74**	23.3	482	**250**	121	1382	**750**	399
77.0	**25**	- 3.89	167	**75**	23.9	500	**260**	127	1400	**760**	404
78.8	**26**	- 3.33	169	**76**	24.4	518	**270**	132	1418	**770**	410
80.6	**27**	- 2.78	171	**77**	25.0	536	**280**	138	1436	**780**	416
82.4	**28**	- 2.22	172	**78**	25.6	554	**290**	143	1454	**790**	421
84.2	**29**	- 1.67	174	**79**	26.1	572	**300**	149	1472	**800**	427
86.0	**30**	- 1.11	176	**80**	26.7	590	**310**	154	1490	**810**	432
87.8	**31**	- 0.56	178	**81**	27.2	608	**320**	160	1508	**820**	438
89.6	**32**	0	180	**82**	27.8	626	**330**	166	1526	**830**	443
91.4	**33**	0.56	181	**83**	28.3	644	**340**	171	1544	**840**	449
93.2	**34**	1.11	183	**84**	28.9	662	**350**	177	1562	**850**	454
95.0	**35**	1.67	185	**85**	29.4	680	**360**	182	1580	**860**	460
96.8	**36**	2.22	187	**86**	30.0	698	**370**	188	1598	**870**	466
98.6	**37**	2.78	189	**87**	30.6	716	**380**	193	1616	**880**	471
100.4	**38**	3.33	190	**88**	31.1	734	**390**	199	1634	**890**	477
102.2	**39**	3.89	192	**89**	31.7	752	**400**	204	1652	**900**	482

DEPTH CONVERSION-FEET TO METERS

Feet	0	1	2	3	4	5	6	7	8	9
0	0.0	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7
10	3.0	3.4	3.7	4.0	4.3	4.6	4.9	5.2	5.5	5.8
20	6.1	6.4	6.7	7.0	7.3	7.6	7.9	8.2	8.5	8.8
30	9.1	9.4	9.8	10.1	10.4	10.7	11.0	11.3	11.6	11.9
40	12.2	12.5	12.8	13.1	13.4	13.7	14.0	14.3	14.6	14.9
50	15.2	15.5	15.8	16.1	16.5	16.8	17.1	17.4	17.7	18.0
60	18.3	18.6	18.9	19.2	19.5	19.8	20.1	20.4	20.7	21.0
70	21.3	21.6	21.9	22.3	22.6	22.9	23.2	23.5	23.8	24.1
80	24.4	24.7	25.0	25.3	25.6	25.9	26.2	26.5	26.8	27.1
90	27.4	27.7	28.0	28.3	28.7	29.0	29.3	29.6	29.9	30.2
100	30.5	30.8	31.1	31.4	31.7	32.0	32.3	32.6	32.9	33.2
110	33.5	33.8	34.1	34.4	34.7	35.1	35.4	35.7	36.0	36.3
120	36.6	36.9	37.2	37.5	37.8	38.1	38.4	38.7	39.0	39.3
130	39.6	39.9	40.2	40.5	40.8	41.1	41.5	41.8	42.1	42.4
140	42.7	43.0	43.3	43.6	43.9	44.2	44.5	44.8	45.1	45.4
150	45.7	46.0	46.3	46.6	46.9	47.2	47.5	47.9	48.2	48.5
160	48.8	49.1	49.4	49.7	50.0	50.3	50.6	50.9	51.2	51.5
170	51.8	52.1	52.4	52.7	53.0	53.3	53.6	53.9	54.3	54.6
180	54.9	55.2	55.5	55.8	56.1	56.4	56.7	57.0	57.3	57.6
190	57.9	58.2	58.5	58.8	59.1	59.4	59.7	60.0	60.4	60.7
200	61.0	61.3	61.6	61.9	62.2	62.5	62.8	63.1	63.4	63.7
210	64.0	64.3	64.6	64.9	65.2	65.5	65.8	66.1	66.4	66.8
220	67.1	67.4	67.7	68.0	68.3	68.6	68.9	69.2	69.5	69.8
230	70.1	70.4	70.7	71.0	71.3	71.6	71.9	72.2	72.5	72.8
240	73.2	73.5	73.8	74.1	74.4	74.7	75.0	75.3	75.6	75.9
250	76.2	76.5	76.8	77.1	77.4	77.7	78.0	78.3	78.6	78.9
260	79.2	79.6	79.9	80.2	80.5	80.8	81.1	81.4	81.7	82.0
270	82.3	82.6	82.9	83.2	83.5	83.8	84.1	84.4	84.7	85.0
280	85.3	85.6	86.0	86.3	86.6	86.9	87.2	87.5	87.8	88.1
290	88.4	88.7	89.0	89.3	89.6	89.9	90.2	90.5	90.8	91.1

Feet	00	10	20	30	40	50	60	70	80	90
300	91.4	94.5	97.5	100.6	103.6	106.7	109.7	112.8	115.8	118.9
400	121.9	125.0	128.0	131.1	134.1	137.2	140.2	143.3	146.3	149.4
500	152.4	155.4	158.5	161.5	164.6	167.6	170.7	173.7	176.8	179.8
600	182.9	185.9	189.0	192.0	195.1	198.1	201.2	204.2	207.3	210.3
700	213.4	216.4	219.5	222.5	225.6	228.6	231.6	234.7	237.7	240.8
800	243.8	246.9	249.9	253.0	256.0	259.1	262.1	265.2	268.2	271.3
900	274.3	277.4	280.4	283.5	286.5	289.6	292.6	295.7	298.7	301.8

Feet	000	100	200	300	400	500	600	700	800	900
1,000	305	335	366	396	427	457	488	518	549	579
2,000	610	640	671	701	732	762	792	823	853	884
3,000	914	945	975	1,006	1,036	1,067	1,097	1,128	1,158	1,189
4,000	1,219	1,250	1,280	1,311	1,341	1,372	1,402	1,433	1,463	1,494
5,000	1,524	1,554	1,585	1,615	1,646	1,676	1,707	1,737	1,768	1,798
6,000	1,829	1,859	1,890	1,920	1,951	1,981	2,012	2,042	2,073	2,103
7,000	2,134	2,164	2,195	2,225	2,256	2,286	2,316	2,347	2,377	2,408
8,000	2,438	2,469	2,499	2,530	2,560	2,591	2,621	2,652	2,682	2,713
9,000	2,743	2,774	2,804	2,835	2,065	2,896	2,926	2,957	2,987	3,018



Nomograph for converting water-measurement units (by William Back).

Copied from "Water Facts and Figures for Planners and Managers," U.S. Geological Survey Circular 601-1, 1973.

APPENDIX F

Julian Date Calendar

JULIAN DATE CALENDAR

(PERPETUAL)

Day	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Day
1	001	032	060	091	121	152	182	213	244	274	305	335	1
2	002	033	061	092	122	153	183	214	245	275	306	336	2
3	003	034	062	093	123	154	184	215	246	276	307	337	3
4	004	035	063	094	124	155	185	216	247	277	308	338	4
5	005	036	064	095	125	156	186	217	248	278	309	339	5
6	006	037	065	096	126	157	187	218	249	279	310	340	6
7	007	038	066	097	127	158	188	219	250	280	311	341	7
8	008	039	067	098	128	159	189	220	251	281	312	342	8
9	009	040	068	099	129	160	190	221	252	282	313	343	9
10	010	041	069	100	130	161	191	222	253	283	314	344	10
11	011	042	070	101	131	162	192	223	254	284	315	345	11
12	012	043	071	102	132	163	193	224	255	285	316	346	12
13	013	044	072	103	133	164	194	225	256	286	317	347	13
14	014	045	073	104	134	165	195	226	257	287	318	348	14
15	015	046	074	105	135	166	196	227	258	288	319	349	15
16	016	047	075	106	136	167	197	228	259	289	320	350	16
17	017	048	076	107	137	168	198	229	260	290	321	351	17
18	018	049	077	108	138	169	199	230	261	291	322	352	18
19	019	050	078	109	139	170	200	231	262	292	323	353	19
20	020	051	079	110	140	171	201	232	263	293	324	354	20
21	021	052	080	111	141	172	202	233	264	294	325	355	21
22	022	053	081	112	142	173	203	234	265	295	326	356	22
23	023	054	082	113	143	174	204	235	266	296	327	357	23
24	024	055	083	114	144	175	205	236	267	297	328	358	24
25	025	056	084	115	145	176	206	237	268	298	329	359	25
26	026	057	085	116	146	177	207	238	269	299	330	360	26
27	027	058	086	117	147	178	208	239	270	300	331	361	27
28	028	059	087	118	148	179	209	240	271	301	332	362	28
29	029		088	119	149	180	210	241	272	302	333	363	29
30	030		089	120	150	181	211	242	273	303	334	364	30
31	031		090		151		212	243		304		365	31

FOR LEAP YEAR USE REVERSE SIDE

JULIAN DATE CALENDAR

FOR LEAP YEARS ONLY

Day	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Day
1	001	032	061	092	122	153	183	214	245	275	306	336	1
2	002	033	062	093	123	154	184	215	246	276	307	337	2
3	003	034	063	094	124	155	185	216	247	277	308	338	3
4	004	035	064	095	125	156	186	217	248	278	309	339	4
5	005	036	065	096	126	157	187	218	249	279	310	340	5
6	006	037	066	097	127	158	188	219	250	280	311	341	6
7	007	038	067	098	128	159	189	220	251	281	312	342	7
8	008	039	068	099	129	160	190	221	252	282	313	343	8
9	009	040	069	100	130	161	191	222	253	283	314	344	9
10	010	041	070	101	131	162	192	223	254	284	315	345	10
11	011	042	071	102	132	163	193	224	255	285	316	346	11
12	012	043	072	103	133	164	194	225	256	286	317	347	12
13	013	044	073	104	134	165	195	226	257	287	318	348	13
14	014	045	074	105	135	166	196	227	258	288	319	349	14
15	015	046	075	106	136	167	197	228	259	289	320	350	15
16	016	047	076	107	137	168	198	229	260	290	321	351	16
17	017	048	077	108	138	169	199	230	261	291	322	352	17
18	018	049	078	109	139	170	200	231	262	292	323	353	18
19	019	050	079	110	140	171	201	232	263	293	324	354	19
20	020	051	080	111	141	172	202	233	264	294	325	355	20
21	021	052	081	112	142	173	203	234	265	295	326	356	21
22	022	053	082	113	143	174	204	235	266	296	327	357	22
23	023	054	083	114	144	175	205	236	267	297	328	358	23
24	024	055	084	115	145	176	206	237	268	298	329	359	24
25	025	056	085	116	146	177	207	238	269	299	330	360	25
26	026	057	086	117	147	178	208	239	270	300	331	361	26
27	027	058	087	118	148	179	209	240	271	301	332	362	27
28	028	059	088	119	149	180	210	241	272	302	333	363	28
29	029	060	089	120	150	181	211	242	273	303	334	364	29
30	030		090	121	151	182	212	243	274	304	335	365	30
31	031		091		152		213	244		305		366	31

(USE IN 1964, 1968, 1972, etc.)

GPO : 1964 O—722-[illegible]